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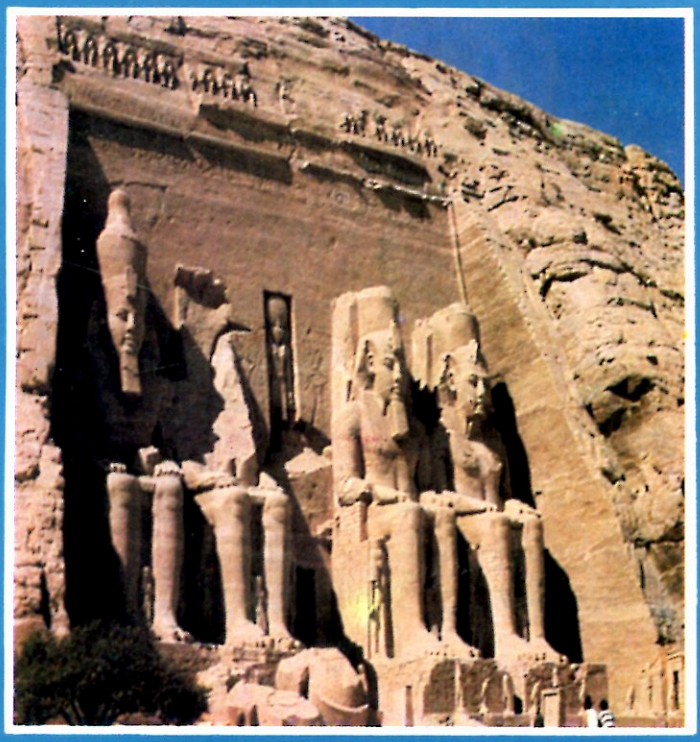
CAIRO EGYPT

18th INTERNATIONAL CONFERENCE

on

NUCLEAR TRACKS IN SOLIDS



BOOK OF ABSTRACTS

CAIRO, EGYPT, 1 - 5 SEPTEMBER 1996

18th INTERNATIONAL CONFERENCE

NUCLEAR TRACKS IN SOLIDS

CAIRO, EGYPT, 1 - 5 SEPTEMBER 1996

Organized by

Ain Shams University, Cairo
National Institute for Standards, Cairo
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International Nuclear Track Society

BOOK OF ABSTRACTS

CAIRO 1996

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18th International Conference on Nuclear Tracks in Solids
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Preliminary Program

	Sunday, 1 September	Monday, 2 September	Tuesday, 3 September	Wednesday, 4 Sept.	Thursday, 5 September
8:30 - 10:00	9.00 **Welcome Address** (& Photo)	**Track Formation III, Methodology & Detectors I**	**Nuclear Physics & Space Res. I**	Sight-seeing	**Dosimetry & Life Science II, Radon IV**
10:00 - 10:30	Coffee	Coffee	Coffee		Coffee
10:30 - 12:30 Parallel Session „A"	**Opening Lectures**	**Methodology & Detectors II**	**Radon II**		**Dosimetry & Life Science III**
10:30 - 12:30 Parallel Session „B"		**Geoscience I**	**Nuclear Physics & Space Res. II**		**Nuclear Physics & Space Res. III**
12:30 - 14:00	Lunch	Lunch	Lunch		Lunch
14:00 - 15:30	**Track Formation I**	**Filters & Other Applications I**	**Geoscience II & Radon III**		**Environment & Radiography II**
15:30 - 16:30	Coffee & Posters	Coffee & Posters	Coffee & Posters		Coffee
16:30 - 18:30 Parallel Session „A"	**Track Formation II**	**Track Formation IV**	**Methodology & Detectors III**		16:30 - 18:00 **Track Observation and Meas.**
16:30 - 18:30 Parallel Session „B"	**Radon I**	**Environment & Radiography I**	**Dosimetry & Life Science I**		16:30 - 18:00 **Filters & Other Applications II**
	19:30 Reception		19:30 Meeting INTS	19.30 Banquet on the Nil	18:00 **Concluding Remarks**

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Oral Presentations (Program and Abstracts)

Posters (Abstracts)

ORAL PRESENTATIONS

Sunday, 1 September

9.00 Welcome Address

10:30 - 12:30 Opening Lectures
(Hall A, Chair: M.A. Kenawy)

R.L. Fleischer
Tracks to innovation - interplay between science and technology
M.A. El-Fiki
N.N.

14.00 - 15:30 **Track Formation I**
(Plenary, Hall A, Chair: L.T. Chadderton)

A. Dunlop
Formation of latent tracks under energetic atomic and cluster ions irradiations

T.A. Tombrello
Getting off the track

C.T. Reimann
Learning about swift-heavy-atomic-ion-induced surface defects and sputtering of organic solids by scanning probe microscopy

15:30 - 16:30 **Posters**

16:30 - 18:30 **Track Formation II**
(Parallel, Hall A, Chair: T.A. Tombrello)

S.P. Kostenko
α-particle tracks in solids as triggers of the self-formation mechanism for structures with the predetermined behavior

D.D.N.B. Daya, C.T. Reimann, A. Hallén, Å. Petersson, A.P. Quist, P. Håkansson, B.U.R. Sundqvist, A. Brunelle, S. Della-Negra and Y. Le Beyec
A scanning force microscopy study of surface and sub-surface tracks on mica due to fast ^{127}I atomic and C_{60} cluster ions

S. Ghosh and K.K. Dwivedi
Angular dependence of heavy ion range (ADHIR) of energetic ^{209}Bi in mica and polycarbonate

M. Fujii, R. Yokota, T. Kobayashi and H. Hasegawa
Effect of vacuum, oxygen and carbon dioxide on the track registration in SR-90 and CR-39

K. Oda, K. Yoshida, T. Yamauchi, T. Ikeda, Y. Honda and S. Tagawa
Effects of low-LET radiations on CR-39 track detctor

K. Kimura
Fast dynamics of core and self-trapped excitons formed at high density in ion tracks in BaF2 and CsCl single crystals

16:30 - 18:30 **Radon I**
(Parallel, Hall B, Chair: G. Jönsson)

A.F. Maged and E. Borham
A study of the radon emitted from various building materials using alpha track detectors

I. Hunyadi, I. Csige, Z. Dezsö, J. Hakl, L. Lénárt, I. Mócsy, Z. Németh, Z. Papp, J. Somlai and A. Vásárhelyi
Comparative study of indoor radon concentrations in four radon prone areas in Central Europe

S.A. Durrani, A.H. Khayrat, M.A. Oliver and I. Badr
Estimating soil radon concentration by Kriging in the Biggin area of Derbyshire (UK)

F. Abu-Jarad
Indoor cigarette smoking: uranium contents and carrier of indoor radon products

T.A. Pavlenko, I.P. Los, N.V. Aksenov and O.B. Yudin
Irradiation doses from indoor radon on the Ukraine and basic directions of their decrease

J.C. Hadler N., P.J. Iunes, S.R. Paulo, and A.R. Zuñiga G.
Measurement of radon daughter deposition rates by using CR-39 as an α-spectrometer

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TRACKS TO INNOVATION - INTERPLAY BETWEEN SCIENCE AND TECHNOLOGY

ROBERT L. FLEISCHER
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The uses of particle tracks-- the main themes and many of the specific examples-- were initiated in an industrial environment at the General Electric Research Laboratory by a group whose original principal actors were P. Buford Price, Robert M. Walker, and the author. Science in industrial environments is neglected in the United States today, yet the area of nuclear tracks gives us a good many examples of practical applications of science-- applications that would have been unlikely to have emerged promptly from science done outside of industry (where the obligation to seek practical outcomes is absent). This talk will review how track uses developed. The discussion will cover discrete fields of use, both scientific and applied, with emphasis on the interplay of science and technology. Three of the subjects are role engineering-- from filters to counters, radon-- a hazard and a help, and tracks of time-- oil and geochronology.

The mix of science and technology in the various advances will be reviewed briefly. The unique opportunities for science in industry that existed in the 1960's and 70's is noted to have enabled the rapid ballooning of the field of nuclear track etching. A conclusion is that the fabric of science and technology has intermingled threads. Occasionally a clearly scientific fiber led to a particular technological advance, and sometimes the case is reversed. Distinctions often are not readily decipherable. Typically the most direct highway to practical uses of tracks crosses the boundaries of science and technology more than once.

N. N
M. A. EL-Fiki

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FORMATION OF LATENT TRACKS UNDER ENERGETIC ATOMIC AND CLUSTER IONS IRRADIATIONS.

A. DUNLOP

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It is shown that electronic excitation and ionization arising from the slowing-down of swift heavy (GeV oxygen to uranium) ions and cluster (a few 10 MeV Au_4 ,C_{20} or C_{60}) projectiles can lead to a great variety of structural modifications in the vicinity of the projectile wake. According to nature (insulating or metallic material) of the target and to the deposited energy density, isolated point defects, highly damaged crystalline matter, new crystalline phases or amorphous tracks can be formed.

The talk will emphasize the specific aspects occuring when energetic aggregate projectiles are used. The specificity of such projectiles comes from the fact that high rates of energy deposition in electronic processes ($(dE/dx)_e \approx 10$ to 100 keV/nm), similar to those usually obtained with GeV uranium, are now accessible with slow projectiles. The main result is a tremendous increase of the deposited energy density which can reach values as high as ≈ 100 eV/atom. The relaxation of such a high energy density induces spectacular structural modifications in all kinds of targets. A wide selection of very recent experimental results will be presented.

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Getting off the Track*

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The production of MeV/amu heavy-ion beams has allowed continuous damage tracks to be made in a wide variety of materials. Using simple phenomenological models of the track-formation process one can estimate in advance the morphology of the tracks that will result from a particular set of irradiation parameters, i.e., target material, ion type and energy. In this talk I shall discuss the use of these models and how they are applied in a specific example: the pinning of quantized magnetic-flux vortices in high-temperature superconductors. For this application one must also employ models for the interaction of the vortex and the column of damage. On the basis of such simulations it is found that although damage tracks are extremely useful for increasing the flux pinning, and hence the critical current, it would be even better if one could control the track positions and radii over a wider range of values. A new development in nanotechnology will be discussed that may, indeed, allow this to be accomplished.

*Supported in part by the National Science Foundation [grant DMR93-18931].

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α-PARTICLE TRACKS IN SOLIDS AS TRIGGERS OF THE SELF-FORMATION MECHANISM FOR STRUCTURES WITH THE PREDETERMINED BEHAVIOR

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Tel: (0482)33-07-84, fax: (0482)26-97-37

The tracks in solids are generally accepted to be the bearers of information indispensable in fission reactions' studies, elemental analysis, in applied biology, geology, etc. The tracks, by definition are meant to reflect the history of the events in solid state under high-energy particle irradiation I suggest to recur to the starting point, when penetrating particles have just left behind them the ionized local volumes of substance It is those ionized local volumes that trigger the self-formation mechanism of novel structures with the unique properties.

The track patterns, their behaviors are known to be the function not solely of the ionizing particles' sorts but of the radiated object attributes: elemental composition of substance, its initial structure The tracks may be further grouped into two classes those in the whole bulk of the irradiated substance, and surface tracks composed of the material that has been physically expelled from the matrix upper layers Our results show unambiguously that relaxation of the excited track volumes entails self-formation of novel structures

The samples were attacked by α-particles from ^{239}Pu sources were utilized with fission product emission excluded except for 5 MeV α-particles flux Various materials have been studied, semiconducting chips included An example of p-n transition in the silicon pressure microsensor is shown in Figs 1-6.

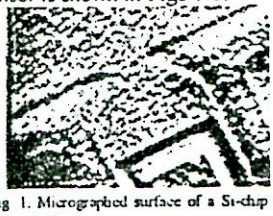

Fig 1. Micrographed surface of a Si-chip after 25 min α-irradiation

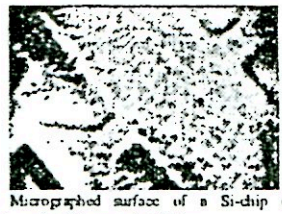

Fig 2 Micrographed surface of a Si-chip of another composition after 25 min α-irradiation

Fig 3-5 present cross-sections of the chip from Fig 1 α-irradiated during Fig 3 -25 min.; Fig 4 -45 min ; Fig 5 -120 min.; Fig 6 displays the cross-section of the chip from Fig. 2 α-irradiated for 25 min

Fig. 3

Fig. 4

Fig. 5

Fig. 6

In this manner, Figs 1, 3-5 illustrate α-dosage dependence of structural transformations both of the investigated tracks and volumes between them. Figs 1,2,6 demonstrate the finite structure being a function of the elemental composition of the investigated substance. The report exemplifies other materials, introduces self-formation mechanisms in the local volumes. Gaining an insight into the nature of the above mechanisms will help controlling these processes and creating the desired properties for different purposes, e g in microelectronics, nanotechnology, biotechnology, etc.

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A Scanning Force Microscopy Study of Surface and Sub-Surface Tracks on Mica due to Fast ^{127}I Atomic and C_{60} Cluster Ions

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*Department of Physics, University of Colombo, Colombo 3, Sri Lanka; **Division of Ion Physics, Department of Radiation Sciences, Uppsala University, Box 535, S-751 21, Uppsala, Sweden; and §Institut de Physique Nucléaire, 91406 Orsay, France.

A summary is presented of the work performed to date in Uppsala on MeV ion-induced radiation damage on mica. It has been shown for the first time that fast heavy ions (78.2-MeV ^{127}I atomic ions from the Uppsala EN tandem accelerator and 23-MeV C_{60} cluster ions from the Orsay MP tandem accelerator) impinging on muscovite mica at normal incidence induce conically-shaped topological hillocks as probed by tapping-mode scanning force microscopy (TM-SFM). The height of the hillocks is ~0.5 nm and the width is ~20 nm for normally incident ^{127}I ions. The corresponding hillocks due to normally incident C_{60} ions are about 7 times taller and 2 times broader; this enhancement may be attributed to a greater energy density deposition by MeV C_{60} cluster ions. Mica samples irradiated at grazing incidence using ^{127}I ions also display hillocks, but they are accompanied by raised tails in the ion penetration direction, indicating the occurrence of a radial expansion around the ion track as predicted by theoretical models. The latent (sub-surface) ion tracks due to ^{127}I ions incident at a grazing angle are also found to be hillocks accompanied with raised tails on *both* surfaces exposed by cleaving the mica *after* irradiation. The complementary orientation of the raised tails associated with the hillocks found on the exposed surfaces gives clear evidence for a symmetric radial expansion occuring due to the passage of the fast ion through the layer-gap structure of mica.

It has also been observed for the first time that mica samples irradiated at grazing incidence using 20.4-MeV C_{60} ions display gigantic tailed hillocks each with a cave-shaped crater on the top of the hillock at the intersection of the ion track with the surface. These hillocks are ~50 nm wide, ~85 nm long, and ~9 nm tall. The presence of much taller hillocks than those induced by normally incident C_{60} ions in the same energy range indicates further the occurrence of a radial expansion around the ion track. The tail lengths of these huge hillocks are significantly shorter than those obtained with the ^{127}I ions incident at a similar grazing angle, indicating that the C_{60} cluster ions are dissociated into fragments when they strike the mica surface. Hence the penetration depth of C_{60} cluster ions is shorter compared to ^{127}I atomic ions. The presence of a crater on these hillocks is evidence for the large energy density deposition by the MeV C_{60} ions.

Acknowledgements: Funding is provided by the Swedish Natural Sciences Council (NFR), the Swedish Technical Research Council (TFR), the Swedish National Board for Industrial and Technical Development (NUTEK), the Knut and Alice Wallenberg Foundation, the International Science Programs (ISP) of Uppsala University, and the Department of International Relations at CNRS of France.

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ANGULAR DEPENDENCE OF HEAVY ION RANGE (ADHIR) OF ENERGETIC ^{209}Bi IN MICA AND POLYCARBONATE

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In an effort to understand the effect of the crystal structure on the path of a highly energetic charged particle we had earlier bombarded muscovite mica at three different angles with a beam of 1.65 GeV ^{132}Xe ions. Mica being an anisotropic material exhibits such phenomenon as channelling, quasi-channelling and blocking. It has been observed through optical microscope during our experiment that the ranges vary systematically with the angle of incidence. These anomalous ranges have been ascribed to repeated and curved refracted orbits in the molecular layers. The detailed angular influence on these orbits in turn produced a strong "non-linear" effect on the stopping-power. This has introduced new concept of "ridging" and "bridging" of particle trajectories.

In the present work we have further extended the earlier investigation on muscovite mica by bombarding it at five different angles from 15° to 75° with ^{209}Bi ions at an energy of 2.72 GeV. An isotropic dielectric detector Bayer polycarbonate was also irradiated at the same angles with ions of the same energy. The variation of range with the angle of incidence gives an indication of the amount of "ridging" or "bridging" that is involved.

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EFFECT OF VACUUM, OXYGEN AND CARBON DIOXIDE ON THE TRACK REGISTRATION IN SR-90 AND CR-39

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The molecular structures of SR-90 and CR-39 are very similar except that the average length of carbonate linkages in SR-90 is longer than in CR-39. However, the effect of vacuum on the track registration on these two detectors is very different. It is well known that the sensitivity of CR-39 becomes very low in a vacuum. On the contrary we have found that the sensitivity of SR-90 does not go down to zero even after storage in a vacuum for a long time.

We have other findings: 1)The sensitivity of SR-90 decreases in a vacuum but the original sensitivity can be recovered by storing it in carbon dioxide. 2)The setting of latent tracks by oxygen is effective only at the time of irradiation but the sensitization in carbon dioxide is effective even after irradiation.

The mechanism of the track formation in polymer will be discussed with reference to above findings.

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Effects of Low–LET Radiations on CR–39 Track Detector

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Several authors have already pointed out that the etching characteristics of plastic track detectectors were influenced by iradiation of intense γ–rays. It is, from a viewpoint of track formation mechanism, very interesting to compare the track etch along the trajectory locally damaged by a heavy charged particle with the bulk etch in the detector where the same amount of the energy is almost uniformly deposited by low–LET (Linear Energy Transfer) radiations such as photons and electrons.

In this experiment, we measured the change in both etching and optical properties of CR–39 plastic detector exposed to ^{60}Co γ–rays and 28–MeV electrons. It was found that the bulk etch rate (V) increased exponentially with the absorbed dose (D) under a constant dose rate. Namely,

$$V = V_0 \cdot \exp[kD] \ ,$$

where V_0 is the bulk etch rate of unirradiated samples. The parameter (k) was also evaluated to be 3.0×10^{-5} Gy^{-1} for γ–ray irradiation with a dose rate of 6.0 $kGy\cdot h^{-1}$, and 1.2×10^{-5} Gy^{-1} for accelerated electrons with a much higher dose rate of 160 ± 10 $kGy\cdot h^{-1}$. This notable difference implies that certain chemical or radical reactions, dependent sensitively on the dose rate, take part in the track formation process.

Further experiments about irradiation in vacuum and correlation with the optital density are now in progress.

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FAST DYNAMICS OF CORE AND SELF-TRAPPED EXCITONS FORMED AT HIGH DENSITY IN ION TRACKS IN BaF2 AND CsCl SINGLE CRYSTALS

Kazuie KIMURA

RIKEN, Hirosawa Wako Saitama JAPAN, 81 048 461 4668

Electronic excited states followed by the primary collisions by projectile ions are key states to result in atomic displacement and chemical reactions as radiation effects. Excited states are formed by ion irradiation at high density. Such the states are studied by means of decay measurements on luminescence from ion irradiated BaF2 and CsCl crystals, using the fast decay measurement system developed by us, named SISP with 100 ps resolution: A single ion hitting (single track) and single photon counting. Recently, above crystals have been interested in their showing the Auger free luminescence (AFL) based on the outermost core excitons when they are irradiated with VUV-light. Ion irradiation makes the decay fast compared with the case of light irradiation (lifetime of 800 ps) according to an increase of LET of the ion. The luminescence efficiency per LET was decreased with increasing LET but showed the minimum at N ion among He, N, Ar, Kr, Xe ions used. On the other hand, the self-trapped excitons (STE) showed much more drastic differences compared with the photo- irradiation. Both rise up and decay of luminescence were much faster than those in the photo-irradiation In addition, lifetime of STE were shortened with decreasing temperature, which is contrary to the case of photo-irradiation. These phenomena can be explained by high density excitation charasteristic in ion irradiation. Fast dynamics of excitons in the ion track is described by the its simulation using the decay equation.

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A study of the radon emitted from various building materials using alpha track detectors

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Abstract

Solid state alpha track detectors using CR-39 plastic detectors were used to measu radon concentration and the radon exhalation rates from building materials used in Egypt radon flux emitted from the surface of the building material was measured by placing detector within the chamber. Tracks due to alpha particles from radon that migrate fr building materials into the air space in the chamber were registered on the CR-39 detecto detectors were etched in 6M NaOH solution at 70 'C. An image analyzer system was u record the tracks appearing on the CR-39 detector. Infiltration and ventilation effect excluded in this work. This technique can be used to establish the database for average exhalation rates from all available building materials and walls or floors.

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Comparative study of indoor radon concentrations in four radon prone areas in Central Europe

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Abstract

The distribution of indoor radon activity concentration and its link with different environmental parameters was studied using integrating etched track and time resolving continuous techniques in four different radon prone areas in Central Europe. The studied areas were in Western Hungary Ajka and its region (provincial town with 34000 inhabitants, Bakony Mountains); in the North Hungarian Central Range Mátraderecske (village with 3000 inhabitants situated on the volcanic andesite of the Mátra Mountain) and Miskolc (big industrial town with 210000 inhabitants situated on the Eastern feet of Bükk Mountains); and finally in the Transylvanian Basin Cluj Napoca (second largest town in Romania with 350000 inhabitants situated on the riverside of Somes). From the study the complex interplay of natural environmental parameters (as geology and field setting) and applied building materials and techniques can be identified. From continuous multiparameter measurements assessments were made to identify the main parameters influencing the indoor radon accumulation as well as to estimate the dependence of radon entry rates on atmospheric parameters.

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ESTIMATING SOIL RADON CONCENTRATION BY KRIGING IN THE BIGGIN AREA OF DERBYSHIRE (UK)

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ABSTRACT

A survey of soil radon gas was carried out in an area around the village of Biggin in Derbyshire, England, on a single geological formation. The location lies in what is considered to be a 'radon affected area' by the UK National Radiological Protection Board (NRPB). The aim of this survey was to investigate the spatial variation of radon within a single lithological unit based on the result of an earlier 'nested survey',which had shown spatial correlation between radon levels in the field and the local geology. An irregular sampling scheme, with the sample interval varying from 50 to 250 m, was used. Ninety-three dosimeters were placed at a depth of 50 cm over an area of 4 km^2, to measure the soil radon concentration levels. These levels varied in the surveyed area from 3 to 35 kBq m^{-3}, the mean value being 13.03 ± 7.6 $kBqm^{-3}$. The conventional *variogram* was computed, and soil radon concentration was estimated efficiently using *kriging*. The variogram suggests that there is spatial autocorrelation in the radon levels over the surveyed area but that there is also a large *nugget variance* indicating that much of the variation is occurring over distances of less than 80 m. The kriged map of radon shows that there is a strong pattern in its variation, which may be linked to some of the physical feature of the area studied.

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INDOOR CIGARETTE SMOKING: URANIUM CONTENTS AND CARRIER OF INDOOR RADON PRODUCTS

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ABSTRACT

The role of cigarette smoking inside a room has been studied experimentally. As a result of indoor smoking, the number of aerosol particles has increased inside a room from 10000 particles per cm^{-3} up to ten times more. Injecting a radon source inside a room which contains cigarettes smoke showed a reduction of diffusion of radon daughters particles to the surfaces and walls of the room. This happens mainly because the radon daughter particles stick to cigarette smoke particles floating in the room. These particles will then be inhaled by every body in the room regardless if he is smoking or not. Further more an attempt to measure the uranium concentration was performed in fresh tobacco and tobacco ash samples. In addition, another attempt to measure the uranium concentration in air of a room was also performed in two different conditions: when the room was clean and after lighting 6 cigarettes. In the two conditions the same amount of air with and without smoke was sucked through filter papers. The fresh tobacco and tobacco ash samples were prepared as pellets. Each sample of filter paper and pellet is sandwiched between two plastic Lexan polycarbonate detectors. The plastic detectors were used in a high flux of thermal neutrons in order to detect the uranium content of the sample through the uranium fission fragments after irradiation. The whole assembly was exposed to a thermal neutron flux of $\sim 10^{15}$ $n.cm^{-2}.s^{-1}$ in the Herald reactor at Aldermaston in U.K. The uranium distribution on the surfaces of the detectors attached to the pellets related to fresh, tobacco ash and filter paper used to collect smoke shows non-uniform distribution of fission fragment as track clusters and mostly as sunburst shape. Estimate of uranium content through those sunburst was difficult. Even after using an electron microscope to magnify those sunbursts, it was difficult to count the tracks and thus it was impossible to estimate the uranium concentration. But those dense track cluster is an evidence of uranium content of the tobacco and cigarette smoke.

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INTS

IRRADIATION DOSES FROM INDOOR RADON ON THE UKRAINE AND BASIC DIRECTIONS OF THEIR DECREASE.

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Results of 8500 measurements that showed the average indoor ^{222}Rn concentrations in premises in different regions of the Ukraine where a preliminary stage of the studies launched for determination of the population effective doses delivered to the Ukrainian population.

As the same time, equipment, methodological and metrological bases of the system for the control of radon were established.

Computer-linked automatic spark counter was designed on the base of the method of passive track dosimetry. Software, including formats of databases and information input for analyzing results of measurements, were developed.

The metrological support was provided by radon atmosphere created in RCRM and certified by State Metrology Committee (*Gosstandart*) as the basic measurement device.

The comparison run program started for the organizations that monitor radon concentrations.

Radon monitoring should be carried out by radiation control services on the basis of existing bodies of the Ministry of health. This will allow to reveal houses with high radon levels and decrease the dose received by inhabitants.

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INTS

MEASUREMENT OF RADON DAUGHTER DEPOSITION RATES BY USING CR-39 AS AN α-SPECTROMETER

J.C.Hadler N.[1], P.J.Iunes[1] and S.R.Paulo[2] and A.R.Zúñiga G.[1,3]

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In this work, indoor mean deposition rates of the radon daughters Po-218 and Po-214 are estimated by measuring the α-activity plated-out on the surface of bare CR-39 sheets. By means of the track size distribution measured after two different etching times, it was possible to obtain the plated-out activity of Po-218 and Po-214 separately, under the criteria of considering only the tracks whose ratio between the major and the minor diameters is lesser or equal to 1.1. The same procedure was repeated for CR-39 sheets exposed in closed and ventilated rooms and the results were compared. All the track analysis was made by using an automated system, constituted by a CCD camera coupled to a microscope and to a microcomputer working with an adequate software. Based on the obtained data, the reliability of the measurement of indoor radon daughters deposition rates by using CR-39 as an α-spectrometer is discussed.

Monday, 2 September

8.30 - 10.00 Track Formation III, Methodology & Detectors I
(Plenary, Hall A, Chair: R.L. Fleischer)

E. Gamaly and L T. Chadderton
GeV heavy ion induced phase transitions in solids: energy thresholds, kinetic stage, and break of symmetry

A. Chambaudet, D. Klein, R. Barillon and M. Voytchev
Study of the response of silicon detectors for alpha particles

V.A. Ditlov, E A Silaev, A.U. Gatchegov, W. Enge, F. Petersen, M. Danziger, A. Schultz and V. Trofimov
The radial etching velocity for tracks in polymer film

10:30 - 12:30 Methodology & Detectors II
(Parallel, Hall A, Chair: M. Fujii)

J.-U. Schott, M.M. Meier and K. Strauch
A detector telescope with charge coupled devices (CCDs) for single particle dosimetry in space

M. Sadowski, J. Baranowski, E. Skladnik-Sadowska, A. Szydlowski, H. Kelly, G. Lascalea, A. Lepone and A. Marquez
Calibration of CN and CR-39 track detectors for measurements of fast deuterons and nitrogen ions

T. Yamauchi, K Oda, S. Tanabe, H. Matsumoto and H Miyake
Calibration study on triton response of CR-39 track detector

M. Yamamoto, N. Yasuda, T. Kanai, N. Ishigure, A. Furukawa, M. Kurano, Y. Kaizuka and K. Ogura
CR-39 sensitivity analysis on heavy ion beam with atomic force microscope

M. Novák, K Turek, J. Jakeš and J. Voigt
Directly heated etching stand for electrochemical treatment of track detectors

Matiullah, N. Ahmad and A.J.A.H. Khatibeh
Effect of gamma energy, temperature and shelf life on the response of gamma and BD-100R neutron bubble detectors

10:30 - 12:30 Geoscience I
(Parallel, Hall B, Chair: A. Chambaudet)

F. Villa, M. Grivet, M. Rebetez, C. Dubois and A. Chambaudet
Calibration and simulation of apatite fission track etching: influence of diffusion and crystal symmetry

A. Mironov, N. Zhatnuev and M. Epelbaum
Experimental study of water behavior in melt and melt-rock interaction using tritium autoradiography

N.M. Fahmi, M. Rossy, M. Rebetez, A. Chambaudet and A.A. Abou El Kheir
Fission track dating and thermal history of some volcanic and plutonic rocks from Turkey and France

L.L. Kashkarov, L.M. Bulgakova and G.V. Kalinina
Fossil tracks in olivine crystals separated from Zagami meteorite as indicator of its complex radiation-thermal history

A. Enulescu, C. Ciortea, V. Zoran, B. Bucur, A. Danis, M. Ciubotariu and L. Marinescu
The contribution of the (α + Al, Si) interactions to the fossil tracks in muscovite mineral track detectors

J.C. Miellou, H. Igli, A. Chambaudet, M. Rebetez and M. Grivet
Convection methods and functional equations to solve inverse thermochronology problems

14.00 - 15:30 **Filters & Other Applications I**
(Plenary, Hall A, Chair: P. Vater)

J. Vetter and D.D. Dobrev
Etched heavy ion track membranes as templates for metallic microstructures
V.V. Shirkova and S.P. Tretyakova
Physical and chemical basis for the manufacturing of fluoropolymer track membranes
M. Yoshida, M. Asano, A. Safranj, H. Omichi, R. Spohr and R. Katakai
Substrate-specific functional membranes based on etched ion tracks

15.30 - 16:30 **Posters**

16:30 - 18.30 **Track Formation IV**
(Parallel, Hall A, Chair: A. Dunlop)

P.Yu. Apel, A.Yu. Didyk, L.I. Kravets, V.G. Nesterov, L.I. Samoilova, B.I. Fursov and G.S. Zhdanov
Registration temperature effect in polymers: Physico-chemical aspects
G.U. Bacmeister and W. Enge
Some relations of the diffusion constant of latent tracks in polymers and the ion energy loss
K. Havancsák, L.P. Biró, J. Gyulai and A.Yu. Didyk
STM and AFM observations of damage produced by swift Ne and Kr ions in graphite
D. Fink, R. Klett, G.Schiwietz, L.T. Chadderton
The influence of deposited energy density on characteristic ion track parameters in polymers
A. Schulz, M. Danziger, V.V. Trofimov and K. Prokert
The pore opening process of etching polymer films irradiated by single and multiple heavy ions
J. Henry
Tracks in MoS_2 irradiated with 20 MeV fullerenes

16:30 - 18:30 **Environmental Sciences & Radiography I**
(Parallel, Hall B, Chair: R. Ilić)

A.F. Hafez, M.A. Kotb, A.M. Heriba and Y. Selim
Assessment of alpha emitters in some biological samples using nuclear track detection method
M. Balcázar, L. Tavera, M.E. Camacho and A. Chávez
CR-39 detector for checking up a decontamination process
A.F. Malenchenko, N.N. Bazanova, N.V. Kanash, I.V. Zhuk, E.M. Lomonosova, M.K. Kievets and S.F. Boulyga
Fissile radionuclides in thyroid of the inhabitants of the Gomel region in Belarus. Peculiarities of their distribution
T. Güzel, T. Akyüz, P. Saritepe, Yu.Ts. Oganessian, S.P. Tretyakova
Fissionable elements investigations of the Turkish fluorites using dielectric track detectors
L. Enkhjin and V.P. Perelygin
Th and U content determination using double gamma-irradiation
V.D. Rusov, T.N. Zelentseva and L.M. Zemskov
Utilization of nuclear track biodetectors in Chernobyl's experiments

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INTS

GEV HEAVY ION INDUCED PHASE TRANSITIONS IN SOLIDS: ENERGY THRESHOLDS, KINETIC STAGE,AND BREAK OF SYMMETRY

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Heavy ions with GeV energies, on entering a solid target, create extremely high local energy densities which lead - in the primary transient core - to total destruction of the basic structure. The physical processes involved are closely akin to those taking place in studies of heavy energetic ion-induced fusion. We shall show that GeV ion energy deposition, ionisation, recombination, and energy transfer processes in space and time are followed, self consistently, by the formation of a secondary outer track zone where general conditions for genesis of a new phase (state) may be achieved. These remarkably simple conditions are the background to the fundamental kinetic formation stage of the new phase, and can be described in terms of certain "selection rules" which delineate the swiftest reaction routes which are themselves closely associated with the symmetry properties of the clusters created. The process is similar to that of a phase transition in solid state physics: the initial high symmetry of "primeval soup" is broken at certain transition temperature by formation of a cluster having the lower symmetry (axial symmetry of high order).

The approach is quite general - different phase transitions - different materials. For carbonaceous targets (graphite, polymers etc) large and beautiful three-dimensional carbon clusters (eg the 'family' of fullerenes) are created by a process of accretion from a hot dense "primeval soup" of single carbon atoms through repeated stochastic, "sticky" collisions. The incident ion energy threshold is seen as arising from a balance in the competition between the rate of primary energy deposition and the rate of system cooling. Rate equations for the basic clustering process permit calculation of the time-dependent number densities for the specific different carbon clusters produced. An important consequence of the theory applied to carbon is that the region for the specific phase transition from graphite to fullerene lies in the same pressure regime on the phase diagram as does the corresponding transition for graphite to diamond.

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INTS

Study of the Response of Silicon Detectors for Alpha Particles

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Numerous radon measurements are carried out by using silicon detectors directly in the environment. This new kind of alpha radiation measurement has been developed because the reduced cost makes it possible to replace the usual plastic track detectors.

At our Laboratory, an alpha particle detector has been designed from a commercial silicon photodiode.

This type of detector can determine the device response perfectly in any kind of environment. Different spectrum analysis has been conducted in laboratory and in fieldwork to define the exact origin of counted alpha particles. We studied the response for different radon and thoron concentration levels and observed the energy of the detected alpha particles. We carried out some of these experiments with gas flux, and some without, to show the effects of the surface's interactions to obtain thermodynamic equilibrium in the detection chamber. The experimental results, compared with a mathematical model, showed the influences of depositions on the surface of the detector and on the wall of the cells used as the detection chamber.

In conclusion, the silicon diodes, that we tested, measure the alpha particles of the decay products (polonium) from the radon and the thoron, but very weakly of the gases themselves. Thus, it is possible to make mistakes when measuring the radon if a counting of alpha particles is performed without spectrum analysis. One reason for this is that the decay progenies of the radon are solid radioelements with thermodynamical proprieties different from gases.

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INTS

THE RADIAL ETCHING VELOCITY FOR TRACKS IN POLYMER FILM

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Here was studied large set of questions arising from etchable track consideration. The experiments included tracks of Au and Xe in Makrofole KG etched in 6n NaOH in two temperatures, the theoretical part based on many-hit model of local response.

At first it was studied dependence V/V_b on restricted energy losses REL. Two ways of their calculation are compared. We used approximation formula

$$V_t / V_b = 1 + a \cdot REL^B \qquad (1)$$

and probability of local response of many-hit model in approximation REL:

$$V_t / V_b = c \cdot P_\nu^* (\xi_b + \xi_\infty) \qquad (2)$$

were the probability of local response was used with

$$\xi_\infty = \frac{REL}{REL_o} \qquad (3)$$

coefficients a, B, c, ν, ξ_b and characteristic parameter $RELo$ were found from fitting of expressions (1) and (2) to experimental data.

Then the different activation energies of etching process and of local responses were studied.

With help of registration parameters c, ν, ξ_b and $RELo$ there were studied radial distribution of local responses and radial etch rate over cross-section of ion tracks in nanometer regions. The many-hit model was used in two kinds. The first one was in approximation of R.Katz approach /1/ with

$$\xi_\infty(\rho) = \frac{D(\rho)}{D_{37}}, \qquad (4)$$

where we calculated the radial distribution of dissipated energy using exact solution of the theory of multiple electron scattering /2/. The second version of many-hit model was used on the base of our theoretical approach /3/. The results of both calculations are compared with experimental data for radial etching rate, received by electrochemical method.

At the end of the work there is a demonstration of application of many-hit model for calculation of radial distributions of local responses over cross-section for several quick ions , where the chemical attacks of etchant molecules were calculated with help of Monte-Carlo method.

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INTS

A detector telescope with charge coupled devices (CCDs) for single particle dosimetry in space

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Radiobiological investigations with single heavy ions require to detect and to correlate particle traversals to extinguished sites of the biological object of concern. For experiments in space an adequate detector system with local resolution and on-line information for single particles has been established. It consists of a telescopic array of charge coupled devices (CCDs), operated in coincidence. As part of the dosimetric experiment "Radiation Health During Prolonged Spaceflight (DOM)" performed during the EUROMIR mission in 1995, it measured protons and heavier particle fluxes inside the MIR station under different orbital parameters. The response of the CCDs against particles and the spatial response of the telescope are discussed.

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INTS

CALIBRATION OF CN- AND CR39-TRACK-DETECTORS FOR MEASUREMENTS OF FAST DEUTERONS AND NITROGEN IONS

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Soltan Institutte for Nuclear Studies, 05-400 Świerk n. Warsaw, Poland
and
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Abstract

High-current pulsed discharges of the pinch type are widely investigated in many laboratories all over the world to study properties of dense magnetized plasmas [1] or to optimize Z-pinch and Plasma-Focus (PF) facilities for technological applications [2]. In order to measure fluxes of charged particles emitted form such facilities there are often applied Solid-State Nuclear Track Detectors (SSNTDs). Recently, SSNTDs of the CN- and CR39-type have became very popular [3-4], although their accurate characteristics have not been known for a long time. In fact, many authors used such detectors basing only on approximate calibration diagrams [5-6] which presented a dependance of track diameters on energy of selected particles for given etching conditions .

Hence, the main aim of this paper has been to collect new calibration data from corpuscular measurements carried out in different PF facilities at SINS in Świerk, Poland, and at INFIP in Buenos Aires, Argentina. Those measurements were performed by means of Thomson-type mass-spectrometers equipped with Kodak CN foils and Pershore CR39 plastic-plates.

The compared SSNTDs were irradiated with fast deuterons and different nitrogen ions emitted from the PF facilities operated with the deuterium and nitrogen fillings, respectively. The irradiated samples were etched under controlled conditions (the CN foils - in 2.25-N water solution of NaOH, at a temeprature of 60°C, and the CR39 plastics - in 6.25-N water solution of NaOH, at a temperature of 70°C). The etching procedure was stopped every two hours and ion tracks distributed along Thomson-parabolas (corresponding to deuterons and different nitrogen ions) were measured with an optical microscope. Basing on the known calibration constants of the applied mass-spectrometers, there were determined track diameters as a function of ion energy for different etching times.

The paper presents the detailed calibration diagrams for the CN- and CR39-detectors which may be compared with other calibration data [7] and applied for studies of fast deuterons e.g. in fusion-oriented experiments, and fast nitrogen ions, e.g. in various plasma devices used for technological applications.

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Calibration Study on Triton Response of CR-39 Track Detector

Tomoya YAMAUCHI, Keiji ODA, Sunao TANABE,
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Triton response of CR-39 track detector has been evaluated as a function of the residual range using three different methods. Tritons with an energy of 2.7 MeV were generated in a thermal neutron field through $^{6}Li(n,t)^{4}He$ reactions, guided to a collimator and then hit on both top and polished side surface of CR-39 samples using two neutron-to-triton converters.

In the first method, growth curves of etch-pit radius were obtained by multi-step etching technique, from which the etch rate ratio was derived. Fine result was obtained at large residual ranges over 10μm but the response at near the track end-point could not obtained owing to missing track effect [1].

Secondly, we tried to assess the response from growth curves of etch-pit length. This method didn't suffer from the missing track effect, but there was another difficulty in measuring the etch-pit length precisely, particular in the determination of the side surface position by an ordinary optical microscope.

Fine results for near the track end-point were obtained from the shape analysis of etch-pit profile. In this analysis, track end-point was decided from rounded region at the top of etched track just transferred from the conical phase to the transition phase. The response obtained showed good correlation to LET_{200} in the region corresponding to residual ranges more than about 3μm where the response had the maximum value of S=2.6.

[1] T.YAMAUCHI *et al.* (1995) :"Missing Track Segment on the Growth Curve of Etch-Pit Radius", Radiation Measurements, Vol.24, pp.101-104.

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INTS

CR-39 Sensitivity Analysis on Heavy Ion Beam with Atomic Force Microscope

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The recent observations of latent tracks of heavy ions in solids were demostrated with high resolution electron microscopy, with scanning tunneling microscopy and atomic force microcopy. But quantitative analysis in the region of nano meter was limited in this field.

This is a feasibility experimental study to apply an atomic force microscope (AFM) to observe and analyze quantitatively minute etch pits on CR-39 plastic nuclear track detectors. This method makes it possible to observe more than $10^7/cm^2$ etch pit density produced by 135 MeV/n carbon ions. It is applicable to the flux, LET and dose measurements for carbon ion cancer treatments, because the order of the ion particle density is $10^6/cm^2$. It is impossible to do this kind of measurements with ordinary optical microscope (OPT) observation, because almost all etch pits overlap.

CR-39 were exposed by carbon ion beams at NIRS HIMAC with a density of $\sim 10^7$ particles/cm^2 and were etched in 80° NaOH 27% solution for several minute. The 3D image of CR-39 ($10 \times 10\mu m$) is shown in Figure 1. We will report that the comparison of the sensitivity as a fuction of $LET_{200\ keV}$ between OPT method and AFM method. It is observed that the etch rate ratio of carbon ions is significantly small. This difference in track formation sensitivity is probably due to a surface effect of the detector material itself.

Amount of bulk etch (B) on the CR-39 was measured by the AFM.We examined two traditinal methods for measuring B; 1) the change in the detector thickness, 2) the diameter of high-LET particle tracks (fission fragment of ^{252}Cf). As same as under the OPT measurement,the fission fragment method can be applyed to the measurement of the B in the nano meter region.

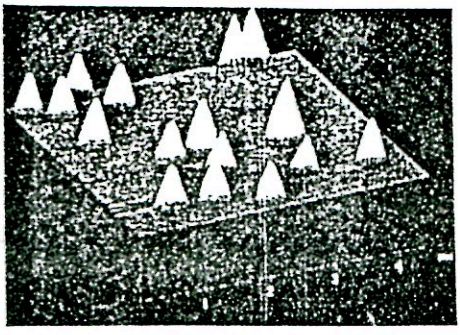

Figure 1

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INTS

DIRECTLY HEATED ETCHING STAND FOR ELECTROCHEMICAL TREATMENT OF TRACK DETECTORS

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ABSTRACT

The directly electrically heated etching stand has been developed for the electrochemical treatment of track detectors to avoid the time consuming overnight pre-heating and to simplify the procedure. The large plate electrode containing several heating elements on its rare side creates the main part of the etching stand. The temperature of the electrode connected to the control unit is variable within 30-70°C. Two types of etching stands were tested. The uniformity of the temperature distribution on the electrode surface, heating rate and stability of temperature were studied as the main parameters and the results are presented. The technical solution allows to construct smaller (even portable) devices for the electrochemical etching.

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Effect of Gamma Energy, Temperature and Shelf Life on the Response of Gamma and BD-100R Neutron Bubble Detectors

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2 - Nuclear Energy Department, MEMR, Amman, Jordan.

Abstract

The use of commercially available bubble detectors for gamma and neutron detection has been reported by several groups. We have carried out systematic investigations to study the response of gamma bubble detector as a function of energy, the effect of waiting time on sensitivity of BD-100R neutron detector and the effect of shelf life on both types of the detectors. Our results show that the response of the gamma bubble detector is energy dependent. Waiting time of up to 260 hours for BD-100R neutron detector has no significant effect. Both the detectors have a limited shelf life. These factors must be taken into account while using these detectors.

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CALIBRATION AND SIMULATION OF APATITE FISSION TRACK ETCHING : INFLUENCE OF DIFFUSION AND CRYSTAL SYMMETRY

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To understand recent developments in geochronology, a thorough knowledge of etching mechanisms is necessary. An earlier study, which we presented at the 17th International Conference on Nuclear Tracks in Solids, was aimed at demonstrating how the segmentation of latent fission tracks in apatite governs etching track profiles. It also highlighted the influence of crystallography and reagent diffusion on the morphology of etched tracks. The aim of this paper is to simulate track etching phenomena (first of all in non-segmented tracks) taking crystallographic and diffusional aspects into account. To this end, we have developed a software program which allows a three-dimensional representation of the etching figures obtained.

During simulation, we accounted for the influence of crystallography on the etching process by allowing for an etching rate dependent on the parameters of the crystal lattice. Thus, in the case of apatite with a symmetry of $P6_{3/m}$, we applied the concept of hexagonal etching prisms. For the diffusion model of the etchant in the tracks, however, we applied Fick's laws by associating the etching-rate vectors with two geometric parameters that vary with time.

We subjected Durango apatites to irradiation by swift heavy ions in the GANIL accelerator. This was done perpendicularly to the prismatic or basal planes. They were then etched by acids of varying concentration. The morphological parameters of the etched tracks were observed using electron microscopy on the different irradiated planes. By measuring the diameters and aperture angles, we were able to adjust simulation parameters. We are at present conducting other experiments in order to include segmentation parameters in this model.

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EXPERIMENTAL STUDY OF WATER BEHAVIOR IN MELT AND MELT–ROCK INTERACTION USING TRITIUM AUTORADIOGRAPHY

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New possibilities of the natural systems modelling are discovered by using a radioisotope tracers method. Partially, the water solubility in basaltic and granitic melts and it behavior under water–bearing melt–rock interaction have been studied with use of tritium autoradiography (tritiumbearing water). The tritium was used as a tracer in the water ($^3HHO+H_2O$) with quantitative 10–15 MBc/g. The experiment conditions: T=900–1000°C, P=2 kbar, duration – 3–5 hours. The glass samples radio activity was measured by the autoradiographical method on the nuclear emulsion plate (MR) with the resolution about 10–20 micron and exposition – 5–20 days. The beforehand melting glasses with known water concentration were used: granite glass – 2,8–4,5 mass.%, basalt glass – 3,9 mass.%.

The autoradiographic data obtained have shown that water solubility at the pressure 2 kbar in basalt melt is higher than in obsidian and the temperature dependence has different trend: in basalt melt solubility increases with temperature whereas in obsidian – decreases. It was found that the water solubility is more higher in mixing zone of granite and basalt melts and water–bearing melt–rock interaction zone. The edgings of basalt glass (10–20 micron) around the parcial melting plagioclase crystals are very enriched with water while the contact of the pyroxen crystals and water–bearing basalt glass did not reveal such kind of edging.

The H_2O–saturated melt–glass interaction was carried out in experiments under T=825°C, P=2100–2300 bar with tritium beta radiography. The velocity of the water diffusion from granite H_2O–saturated melt into the host glass of the granite and basalt composition was investigated. The effective water diffusion coefficients for granite glass ($3,1x10^{-8}$ cm^2/s) and for basalt glass ($1,5x10^{-9}$ cm^2/s) were found. The reaction zone on the melt–glass interaction contact is observed.

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Fission Track Dating and Thermal History of Some Volcanic and Plutonic Rocks from Turkey and France

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Two sets of natural samples of known ages and different geological history were analysed using the fission track dating method: (1) apatite was extracted in three lavas belonging to the Tertiary Bodrum volcanic complex in Turkey; (2) apatite and sphene were separated in a single sample of an Hercynian granite from the Vosges massif in France. In both cases, these rocks had already been dated either by the K/Ar conventional method or by the $^{40}Ar/^{39}Ar$ method on biotite, K-feldspars or amphibole (Robert and Cantagrel, 1977; Montigny and Robert, 1991; Boutin et al., 1995).

Method

Apatite and sphene are dated by the external detector method (EDM), in which a calibration constant (Zeta factor) for these minerals is determined using different age standards recommended by IUGS.

Individual fission track ages (FT) are determined for each sample and a radial plot is designed to evaluate their homogeneity. For each radial plot, a central age is defined. Then an χ^2-test is applied to detect the presence of such expected undesired uncertainties and to define a suitable FT age for each sample.

The measured FT ages represents the period of fission track accumulation in a sample. Thus, the analysis of FT track age and the track length distribution is used to retrace the thermal history of the analysed rocks.

Results

In the case of Turkish volcanic rocks, apatite fission track (AFT) dating of the three samples gave Miocene ages which were in reasonable concurrence with that yielded by K/Ar and $^{40}Ar/^{39}Ar$ methods and with the relative chronology of the three samples deduced from the latter data and from field relationships. From the analysis of track length distribution, these AFT ages are interpreted as emplacement ages due to rapid cooling with no trace of a reheating episode.

The granite sample from the southern Vosges in France has a more complex history. The emplacement age of the pluton is given by K/Ar dating on amphibole (closure temperature ≈ 500 ± 50°C) at 335 ± 13 Myr. Sphene and apatite gave respective FT ages around 297 and 100 Myr. The considerable discrepancy between these FT ages and the results of the analysis of track length distribution indicates that an annealing episode can be predicted. A thermal history computer model, in which known geological constraints are introduced, is used to retrace the time-temperature (t,T) path. The model suggests a moderate reheating episode after the lower Triassic probably due to a burial evolution and a long stay within the partial annealing temperature interval for apatite.

Finally this work emphasizes the importance of analysing both FT ages, on different minerals (i.e. apatite and sphene) when they are available, and track length distribution to retrace the thermal history of complex samples.

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Robert U and Cantagrel JM (1977) Proc. of the VIth Colloquium on the Geology of the Aegean Region, III, 961-967, Athens. Montigny R and Robert U (1991) Terra abstracts, 3, 500, EUG VI, Strasbourg.
Boutin R et al. (1995) Géologie de la France, I, 3-25.

Fossil tracks in olivine crystals separated from Zagami meteorite as indicator of its complex radiation-thermal history.

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The different track sources and high sensitivity of the track parameters to thermal conditions make possible to search a meteorite radiation-thermal history.

In this report the results of the fossil track in olivine crystals of the Zagami meteorite are presented. For this meteorite is assumed as Martian origin [1,2] we can consider at least two main stages in radiation history of its matter: 1) on the planetary near-surface layer, 2) during flying in space up to fall on the Earth. If it is so, then tracks that can be observed in the silicate crystals with extremely low uranium concentration (e.g. olivine) can be due to VH-nuclei of the galactic cosmic ray (GCR) and fragments of the nuclear-active particle induced the fissions of the heavy elements.

Ten large (200-800 mm in size) olivine grains were investigated. Track parameters: track density (r), track length, volume and angular distributions were measured by the optical microscope after chemical etching in the boiling WN- solution for 36 hours. The total interval of r-values $(0,9\text{-}5,0)*10^6$ cm $^{-2}$ was measured.

According to cosmogenic age of Zagami meteorite 2 MY [3]. and to the observed isotropic angle distributions of the tracks single olivine grains, the shielding depth of olivine grains can not be more than 3 cm from the preatmospheric surface of meteorite. Can be considered that the main source of the observed tracks is the fragments of ^{235}U neutron- induced fission. In this case for the olivine uranium concentration $C_u \sim 1$ ppb for production of $r \sim 10^6$ cm $^{-2}$ the total thermal neutrons flux would be equal $\sim 10^{15}$ n/cm ^{2}.

This flux value is at least by three orders of magnitude much more than those which can be formed by the secondary neutrons from nuclear interaction of solar and galaxy cosmic rays protons in the upper layer of the Martian regolith.

In the thin upper (<10 mm) layer of some olivine grains very high r-values (up to $\sim 10^8$ cm $^{-2}$) were observed. These tracks can be due to uranium nuclei neutron-induced fission in the neighbouring uranium rich minerals. For the quantitative estimation of this possibility the uranium microdistribution in the bulk meteorite sample (grains 20-50 mm in size) was investigated by neutron-induced fission track method. The average uranium concentration C u = (130±20) ppb was obtained. Uranium-rich mineral (ilmenite, magnetite etc.) [4] grains have C u = (500-600)ppb. The measured olivine surface track densities in this case can be storage for the integral thermal neutron flux not smaller $\sim 10^{15}$n/cm ^{2}.

Comparison of the natural and ^{252}Cf fission fragments track length distributions in some olivine grains indicate the thermal annealing effect corresponding to 300-400 °C, 1 hour. Thin (20-50 mm) near-surface zones with $r < 10^4$ cm^{-2} in several olivine grains were observed. Probably, this can be due to the local effective heating (up to 1000 °C, 10s) during the impact process which is indicated by the crush traces. The same is observed in the other olivine grains.

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THE CONTRIBUTION OF THE (α + Al, Si) INTERACTIONS TO THE FOSSIL TRACKS IN MUSCOVITE MINERAL TRACK DETECTORS

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The study of natural heavy ion radioactivity using the fossil tracks registered during geological time in the muscovite detector, required to evaluate the contribution of 8.8 MeV alpha particle interactions with Al and Si nuclei in muscovite to the total fossil tracks. Alpha particles are emitted by ^{212}Po from Th radioactive series which is presented in muscovite mineral as an impurity. In this paper two experiments for the identification of the tracks of these interactions are described aiming to eliminate them during counting the tracks of interest. These experiments are:

1) irradiations of the muscovite detectors with 6 MeV, 9 MeV and 12 MeV alpha particles using an HV-FN Van de Graaff tandem accelerator and, after a chemical etching of detectors, the identification of the recoiling Al and Si nuclei tracks, by track patterns;

2) exposures of the muscovite detectors to 8.8 MeV alpha particles emitted by ^{212}Po from a Th chemical compound (under radioactive equilibrium). The Th compound was sandwiched between two muscovite track detectors, each of them having a 8 - 10 cm^2 area and being pre-etched for fossil tracks. After different exposure times, ranging from 3 months up to 30 months, the muscovite detectors were chemically etched in the same etching conditions and then they were studied by optical microscopy in order to identify the tracks of the Al and Si nuclei that had interacted with 8.8 MeV alpha particles.

Both experiments led us to conclude that, in muscovite detectors, the tracks of Al and Si nuclei which interacted with 8.8 MeV alpha particles can be put into evidence by their particular track patterns which are different from those presented by heavy ions or fission fragments. Also, some quantitative conclusions have been drawn.

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Convection Methods and Functional Equations to solve Inverse Thermochronology Problems

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Our aim is to give a complete account of convection methods which allow:

1) numerical simulations of both the simultaneous phenomenons of the population of the nuclear tracks production and of the thermal annealing of these tracks, giving rise, at the final state, to numerical histograms. These histograms are similar to the ones found today by etching technics applied to a sample of apatite and tracks length measurements.

2) solutions to the corresponding inverse problem in which we have to go back from a given (computed or measured) histogram to a) the length and production time relation and b) to the thermal history, which is the main unknown of this kind of inverse problem.

In fact, we deal with densities of probabilities of presence of tracks lying in given length intervals, which explain the use of models of functional equations both for the direct and inverse problem, and consider two convection approachs:

i) to write the equation of the move of functions related to density probabilities which is valid for the mono and multiexponential cases and for the situation of a continuum of activation energies.

ii) to write an equation of convection for the part of the whole population of tracks produced until a given time. The corresponding method is valid for nearly all known fission track annealing laws.

These two approachs are nevertheless complementary to one another in the sense that they lead to the same functional equations (integral equations of the volterra kind) in order to solve the inverse thermochronology problems for both the simpler and the most involved mathematical encountered situations corresponding respectively to the monoexponential case and the others quoted (i) just above. As a result, they give rise to excellent possibilities of the assesment of the entire convection approach of this kind of inverse problems, which are in connection with numerical simulation experiments.

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ETCHED HEAVY ION TRACK MEMBRANES AS TEMPLATES FOR METALLIC MICROSTRUCTURES

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PHYSICAL AND CHEMICAL BASIS FOR THE MANUFACTURING OF FLUOROPOLYMER TRACK MEMBRANES

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Experimental results of heavy ion (1.0-5.6 Mev/amu) radiolysis investigations of polyvinylidenefluoride and some copolymers of vinylidenefluoride have been presented. The formation of conjugated C=C double bonds, the growing of number of these bonds' with the increasing REL have been confirmed by the UV- and IR-spectroscopy methods. It has been found that along with the formation of conjugated double and the triple alkine bonds in copolymers of vinylidenefluoride with hexafluoropropylene and trifluorochloroethylene arise, but their quantities are low. The ratio between destruction and crosslinking processes as a function of heavy ions REL value has been evaluated by means of viscosimetry and gel-fraction method.

The composition of the etching solution for technological process of track membranes manufacturing according to the obtained data has been proposed. The using of the etching solution with concentrations of $KMnO_4$ – 5-20% and $NaOH$ – 10-15% at 85 – 105°C decreases the etching time to 10-20 hours. Selectivity of the etching process did not change for this regime. It is possible to create different shapes of pores by varying REL . Track sensibilization by different methods did not give good results.

This technology allows one to manufacture fluoropolymer track membranes with pore sizes from 0.1 to some micrometers, different shapes and narrow pore size distribution. Such membranes have different selective properties.

The results of these membranes testing for aggressive chemical solutions and gases have been presented. High adsorption on the surface of these membranes allows one to use them in biotechnology and medicine.

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SUBSTRATE-SPECIFIC FUNCTIONAL MEMBRANES BASED ON ETCHED ION TRACKS

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Diethyleneglycol-bis-allylcarbonate is a polymerizable monomer leading to an ion track recorder with narrow pore size distribution. The range of application of the resulting "rigid pore ion track filters" can be further enhanced using intelligent hydrogels.

First, multi-responsive membranes can be obtained by grafting intelligent hydrogels onto the ion track pores. These membranes are based on amino acids and their oligomers such as acryloyl-L-proline methyl ester and methacryloyl-L-asparaginyl-L-alanyl-L-asparaginyl-L-proline methyl ester. They respond to changes in temperature, pH, and solute.

Second, highly substrate-specific membranes can be obtained by modifying grafted hydrogels additionally via immobilized enzymes. These membranes have the ability to recognize e.g. antigens for malaria antibodies.

The contribution will — based on scanning electron and atomic force microscopy — demonstrate the realization of multi-responsive and highly substrate-specific membranes. Details of the used procedures will be discussed, specifically the creation of intelligent functions based on pendant amino acid groups.

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Some Relations of the Diffusion Constant of Latent Tracks in Polymers and the Ion Energy Loss

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Measurements of the diffusion constant of ion irradiated Makrofol KG (PC) sheets have been done with Argon as diffusion gas. The polymers were irradiated at the "Gesellschaft für Schwerionenforschung" (Germany) with Uran and Gold ions at different energies of about 10 MeV/nuc. The fluence varies from $3*10^9$ to $2*10^{12}$.
For the irradiation the material was put together in stacks of 25 layers of 8 µm Makrofol KG for each layer. This allows to relate a definite amount of energy loss to each layer and examine the dependence of the diffusion constant on it.
The diffusion constant was calculated by a numerical mathematical optimisation from the measurement data. For comparison also the "time lag method" is used.
The relations of the diffusion constant with the ion energy loss and with the track core radius are discussed.

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STM and AFM observations of damage produced by swift Ne and Kr ions in graphite

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Radiation damage of highly oriented pyrolitic graphite (HOPG) samples have been investigated following irradiation with 215 MeV Ne and 209 MeV Kr ions, available at U-400 cyclotron, Dubna. Freshly cleaved HOPG surface was irradiated perpendicular to the sample surface (c-plane) on some samples and nearly parallel to that, on other samples. Low ion irradiation doses were used (10^{10}-10^{12} ions/cm^2) in order to avoid damage overlap.

Scanning tunnelling microscopy (STM) and atomic force microscopy (AFM) are useful methods allowing direct observation of surface defects. Our observations were made after irradiation without any further sample preparation. Atomic scale resolution is achieved when necessary.

The experimental observations are compared to computer simulations (TRIM code) and primary knocked-on atomic spectrum calculations (LET code). Clear distinction can be made between surface features attributed to nuclear stopping effects and defects owing to electronic stopping mechanisms of knocked-on C atoms. There is no evidence of features produced directly by the high-energy projectile. On the other hand, there are several experimental evidences of irradiation induced carbon tube formation on the sample surface.

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The Influence of Deposited Energy Density on Characteristic Ion Track Parameters in Polymers

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The spatial distribution of the transferred electronic energy density of energetic ions impinging into a polymer is inhomogeneous after single ion track formation, but becomes isotropic at elevated ion fluences when multiple ion track overlapping occurs. This justifies the attempt to correlate the properties of polymers irradiated with ions at higher fluence with the average transferred electronic energy density D_E = particle fluence Φ x electronic stopping power S_e, as an universal scaling.

The various material's properties are small for pristine and low-fluence irradiated polymers, but start growing dramatically above well-defined energy density thresholds $D_{E,thr}$. With increasing energy density, the thresholds for the following radiation effects are reached subsequently: permanent chemical changes, mass loss and density change of the irradiated polymers, changes in the optical refraction index, formation of free volume along tracks, formation of stable radicals, formation of carbonaceous clusters, and finally the onset of intrinsic material's conductivity. This sequence reflects the evolution of ion track effects.

Above these thresholds, the various effects increase proportionally with $(D_E-D_{E,thr})^n$. For a yet unknown reason the exponent n is different for the different effects. For example, it is small for chemical changes, but assumes a value as high as n=9 for the intrinsic conductivity.

There have been examined more complicated scalings of the form $D_E S_e^k$ $(0<k<2)$, where k assumes specific values for each of the considered material's properties. The additional term S_e^k is introduced to describe the effect of the spatial inhomogeneity of the energy transfer along the tracks of the impinging ions onto the various effects. Though it appears that this type of scaling partly leads to better descriptions of specific effects in individual systems, it has the great disadvantage of loss in universality.

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THE PORE OPENING PROCESS OF ETCHING POLYMER FILMS IRRADIATED BY SINGLE AND MULTIPLE HEAVY IONS

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The technique of the electrochemical etching of irradiated polymer films is an useful method to investigate structures of the track cores. The transversal etching rate as a function of the radius, derived from the time-dependence of the radius of the etching pore, can be interpreted as a corresponding magnitude of the degree of the damage within the track core.

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Tracks in MoS_2 irradiated with 20 MeV Fullerenes

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Molybdenite crystals (MoS_2), cleaved along the (0001) plane, were irradiated (using the tandem accelerator at IPN, Orsay) with 20 MeV C_{60}^{+} fullerenes up to fluences ranging from about 3 10^9 cm^{-2} up to 4 10^{11} cm^{-2}. The tracks formed along the paths of the fullerenes, which deposit a very high energy density, present very remarquable features never reported before in irradiated MoS_2. Their nature was thoroughly investigated using Transmission Electron Microscopy.

When imaged with the electron beam parallel to the aggregate beam direction, the tracks appear circular, many of them with a pair of "ears" (small, roughly semi-circular contrast features which protrude out of the circular contrast). When the sample is tilted in the microscope, the tracks appear continuous. High resolution imaging shows that except a very narrow cylinder of amorphous matter situated at the core of the tracks, these retain their crystalline nature (though the crystal inside the tracks is somewhat distorted). No ring could be detected on the diffraction patterns of the sample irradiated up to a high fluence, which confirms that the volume fraction of amorphous matter is low.

Using phase contrast imaging, stereo-pairs imaging and topographic contrast, it could be shown that craters are created at the surface of the sample : the aggregates produce intense sputtering when they enter and leave the sample. Some of the sputtered matter "condenses" on the surface, which is the origin of the "ears" of the tracks. In the case of the sample irradiated to the highest fluence, the sample surface, imaged under topographic contrast conditions, has a striking "lunar" aspect due to the multiplicity of partially overlapping craters. Furthermore, high resolution imaging shows that " condensed" matter on the surface forms small crystalline domains, with a crystalline orientation different from that of the underlying matrix. At some points of the edges of the sample, we could even detect small nested fullerene-like crystals.

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ASSESSMENT OF ALPHA EMITTERS IN SOME BIOLOGICAL SAMPLES USING NUCLEAR TRACK DETECTION METHOD

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ABSTRACT

CR-39 polymeric nuclear track detector was used in close contact α- autoradiography with dry ash of soft tissues of fish, liver and kidney of cows collected from the local market in Alexandria. The sensitivity function, V(R), of the detector was determined using both the α-particles and the fission fragments of Cf-252 source as well as the response envelope method. This function was used to identify the internal α- particle emitters exist in the biological materials. The can-technique was also used to estimate the thorium to uranium ratio in the dry ash samples.

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CR-39 DETECTOR FOR CHEKING UP A DECONTAMINATION PROCESS

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In the event of accidental release of fission fragment products by a nuclear power plant, it is necessary to apply a standard decontamination procedure to the surfaces of the primary container, where most of the fission products will be kept.

In addition to the standard detection method, CR-39 was used to evaluate the amount of α and fission fragments emitters from contaminated surfaces, during the experiments to establish the decontamination procedure.

The advantage of this alternative method is discussed in the paper.

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FISSILE RADIONUCLIDES IN THYROID OF THE INHABITANTS OF THE GOMEL REGION IN BELARUS. PECULIARITIES OF THEIR DISTRIBUTION.

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The number of events of thyroid cancer in children in the regions of Belarus under the impact of the Chernobyl NPP accident has exceeded all forecasts. This is connected to the influence of radioactive iodine on the thyroid. The long latent period and tissue development after disintegration of the radioactive iodine, however, gives evidence about the presence of other factor promoters of the cancerogenesis. Taking into account experimental and epidemiological observations, this role can be played by the destroyed block of the reactor. Taking into account the high functional asynchronicities of thyroid diseases in endemic goitre regions, non-uniform damage to thyroid tissue by radioactive iodine was supposed.

Severe radiation damages with the following sclerosis right up to calcinosis are the effect of high doses in microsections of the thyroid. Calcium, stroncium and uranium deposited into these sections with the increased amount in comparison with a normal tissue of the thyroid.

An estimation of the microdistribution of fissile radionuclides was carried out using the method of fragmental radiography. Histology cuts prepared from thyroid tissue were stuck on a solid state nuclear track detector (polycarbonat). Irradiation of the sample with a detector was carried out in a neutron fluence of 10^{16} n/cm^2 (Reactor TRIGA, Institute for Nuclear Chemistry, Mainz), with consequent etching in 6.25N NaOH. The analysis of tracks done visually using a microscope magnification of 300 revealed the local accumulation of fission fragments up to 10^3 mm^{-2}. That fact confirms the correctness of our supposition and is associated with initial radionuclide dose at places of accumulated fissile radionuclides, but does not exclude their possible promoter role in thyroid cancerogenesis.

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INTS

Th and U Content Determination Using Double Gamma-Irradiation

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Abstract

A new technique of determination of Th and U content in samples was proposed. The ratio of U and Th fission reaction yields for "infinite thick" layers was measured in the γ-ray energy range from 7 + 23.5 MeV - metallic layers of U and Th in contact with polyethyleneterephtalate track detectors were irradiated at the Microtron MT-25. The method bases on the fact that the ratio N_U/N_{Th} differs sufficiently depending on the γ-ray energy - from 1.7 to 3.2. Irradiating an Uranium ethalon and samples with γ-rays of 20-23 MeV (N_U/N_{Th} = 2.2) and 15-17 MeV (N_U/N_{Th} = 3.2) one can determine simultaneously both U and Th content in samples.

The comparison of the results of determination of U and Th content in different samples obtained by the proposed and other methods is presented.

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INTS

UTILIZATION OF NUCLEAR TRACK BIODETECTORS IN CHERNOBYL'S EXPERIMENTS

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Presented are results of using of biodetectors (the living organism cells) in nuclear track detectors for determination of received irradiation dose.

Ionizing and neutron radiation effect upon cells is known to be a spectrum of various types of aberrations (tracks) depending upon quality of radiation and cell types (biodetectors). We used the cascade stochastic model of charged particles detection in biosubstance [1, 2] as basis for obtaining a type of resulting probabilistic distribution of tracks (chromosom aberrations) in cells which describes the statistics of detecting charged particles in the sensitive layer of a biodetector, where physical parameteres of the particle that are essential elements of the distribution enable one to identify and to quantitatively analyse the charged particles.

In the paper the results of study the chromosome aberration distribution in leicocityes and lymphocites of the human blood by the radiation of neutrons and X-ray (for getting information about irradiation dose got by the mans after Chernobyl accident) and in the plant cells exposed to X-ray, alpha-, beta-particles and neutrons (for dosimetrical diagnostics and the control of the radioecological situation in the regions of radioactive pollution) are presented.

Discussed are biophysical experiments in field of fundamental studies of radiobiological effects upon various organization levels (for example, the small doses problem) and other practical applications.

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2. Rusov V. D., Zelentsova T. N., Petrosiants M. E. Proc. of 17th Intern. Conference "Nuclear Tracks in Solids", Dubna, Russia, August 24-28, 1994, p. 294.

Tuesday, 3 September

8:30 - 10.00 Nuclear Physics & Space Research I
(Plenary, Hall A, Chair: W. Heinrich)

M. El-Nadi, A. Abdelsalam, A. Hussein, E.A. Shaat, N. Ali Mousa, Z. Abou Mousa, S. Kamel, Kh. Abdel-Waged, E. El Falaky and M. Fayed
Fragmentation of ^{32}S nuclei in photoemulsion at 3.7 AGeV

I.G. Abdullaev, I. Adam, V. Bradnova, V.S. Butsev, M.I. Krivopustov, B.A. Kulakov, V.P. Perelygin, V.S. Pronskich, A.N. Sosnin, V.I. Stegailov, J.C. Adloff, M. Debeauvais, R. Brandt, M. Bognitzki, M. Ochs, E.-J. Langrock, Th. Schmidt, R. Sudowe, P. Vater, J.S. Wan, M. Zamani, K.K. Dwivedi, S.-L. Guo, R. Odoj, G. Modolo and I.G. Bersina
SSNTD and radiochemical studies on the transmutation of nuclei using relativistic ions

A.J. Keane, D. O'Sullivan, A. Thompson, L.O'C. Drury and K.-P. Wenzel
The charge spectrum of ultra heavy nuclei, including actinides, in the cosmic radiation

10:30 - 12:30 Radon II
(Parallel, Hall A, Chair: S.A. Durrani)

J. Hakl, I. Hunyadi, I. Csige, G. Géczy, L. Lénárt and A. Várhegyi
Radon in caves

N. Segovia, E. Tamez, M. Mena, P. Peña, J.L. Seidel and M.M. Monnin
Radon in soil, behaviour and volcanic activity

A. Bassignani, G. Giacomelli, B.B. Bam, R. Fresca Fantoni, G. Colombo, C. Sartorio, M. Mascoli, V. Fracchetta and L. Patrizii
Successfully reduction of the radon concentration in MACRO experiment at the LNGS

M. Buzinny and I. Los
The methodical approaches to measurements of radon, thoron and their daughters in air

R. Shweikani, B. Al-Bataina and S.A. Durrani
Thoron and radon diffusion through different types of filter

R. Barillon, M. Fromm, A. Chambaudet, H. Marah and A. Sabir
Track etch velocity study in a radon detector (LR 115, cellulose nitrate)

10:30 - 12:30 Nuclear Physics & Space Research II
(Parallel, Hall B, Chair: R. Brandt)

Yu.A. Batusov
Experimental study of the annihilation of antiprotons at rest in nuclear photoemulsion

T. Streibel, S.E. Hirzebruch, G. Hüntrup, H. Röcher and W. Heinrich
Fragmentation cross sections of ^{197}Au at 10 A GeV and ^{207}Pb at 158 A GeV

J.C. Adloff, R. Brandt, M. Debeauvais, F. Fernandez, M.I. Krivopustov, B.A. Kulakov and M. Zamani
High flux neutron production from high energy nuclear reactions

Ž. Todorović, S. Savović and S. Jokić
Interaction of 12.7 GeV ^{4}He ions with U, Pb, Au and Ag targets

B. Grabež
New desintigration channels in ^{209}Bi + Pb (Ag) reactions at E/A=11.6 MeV

H.A. Khan, I.E. Qureshi, M.I. Shahzad, S. Manzoor, S.D. Barros and R.J. Peterson
Pion-induced fission in tin and bismuth observed with Makrofol detectors

14.00- 15:30 *Geoscience H & Radon III*
(Plenary, Hall A, Chair: 1. Hunyadi)

S. C. Bergman and J. Corrigan
Applications of fission track analysis in petroleum exploration

S.-L. Guo, W. Huang, X.-H. Hao and B.-L. Chen
Fission track dating of ancient man site in Guangxi, China and its significances in space research, paleomagnetism and stratigraphy

G. Jonsson, D. Alberracin, G.U. Bacmeister, C. Baixeras, H. Climent, R. Devantier, W. Enge, K. Freyer, LI. Font, R. Ghose, M.M. Monnin, G. Scicchetti, J.-L. Seidel, H.-C. Treutler Comparison of radon Measurements done by solid state nuclear track detectors and electronic devices in the frame of an EU-radon project

15:30 - 16:30 Posters

16:30 - 18:30 Methodology & Detectors M
(Parallel, Hall A, Chair: M.M. Monnin)

Anupam and S. Kumar
On the effect of cure cycle parameters and doparits on pre and post irradiation annealing response of CR-39 track detectors

D. Klein, C. Meunier, F. Palinino and A, Cliambaudet
Photo and thermal degradations of nuclear track detector (LR I / 5 and CR-39) characterisations (Applications for alpha measurements in the environment)

I. Csige
Post-irradiation sensitization of CR-39 track detctor in carbon dioxide atmosphere

K. Ogtira, M. Asano, M. Yoshida, H. Omichi, N. Nagaoka, H. Kubota and R. Katakai
Proton response of CR-39 copolymer with high sensitivity

G. Giacomelli, L. Patrizii, V. Popa, P. Serra and V. Togo
Some new results from exposures of nuclear track etch detectors to the lead beam at the CERN-SPS

C.S. Chong, 1. Ishak, R.H. Mahat and Y.M. Amin
UV-VIS and FTIR spectral studies of CR-39 plastics irradiated with X-rays

16:30 - 18:30 Dosinietry & Life Science I
(Parallel, Hall B, Chair: L. Tommasino)

R-Q.Huang R. Gu and Q. Li
Application of SSNTDs in radiobiologjcal investigations aboard recoverable satellites

Z. Lounis, S. Djeffal, M. Allab and M. Izerrouken
Characteristics of the CRS fast neutron personal dosemeter

T. Streibel, H. Rocher and W. Heinrich
Cosmic ray radiation effects caused by proton-induced target fragmentation

T. Hayashi, T. Doke, M. Kobayashi and A. Watanabe
Dip angle dependence on characteristics of surface track formation in CR-39 track detectors

A. Golovchenko, J. Skvarc, R. Iliac, R. Freeman, N. Pauwels, S. Tretyakova and R. Bimbot Dositnetry of 40 and 70 MeV/n "O beam

A. Gisbertz, 1. Kohler, E. Pitt and A. Scharmann
Improvement of response of SSNTD in fast neutron dosimetry

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INTS

Fragmentation of ^{32}S Nuclei in Photoemulsion at 3.7 AGeV

M. El-Nadi, A. Abdelsalam, A. Hussein, E.A. Shaat, N. Ali Mousa, Z. Abou Mousa, S. Kamel, Kh. Abdel-Waged, E. El Falaky and M. Fayed

Physics Department, Faculty of Science, Cairo University, Giza, Egypt

Fragmentation of ^{32}S nuclei in emulsion at 3.7 AGeV data are presented. The fragmentation are studied in terms of the impact parameter of collisions of the ^{32}S projectiles with the different target nuclei. The fragmentation cross section and the multiplicities of the different fragments are nearly independent of the sulphur incident energy. The fragmentation of ^{32}S nuclei into alpha isotopes are extensively studied. The transverse momentum spectra of the emitted fragments are fitted by two Maxwell-Boltzmann distributions of different average transverse momentum. The characteristics (multiplicities and P distributions) of the He-fragments produced in the central collisions are different from those emitted in peripheral collisions

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INTS

SSNTD and Radiochemical Studies on the Transmutation of Nuclei Using Relativistic Ions

I.G. Abdullaev, I. Adam, V. Bradnova, V.S. Butsev, M.I. Krivopustov, B.A. Kulakov, V.P. Perelygin, V.S. Pronskich, A.N. Sosnin, V.I.Stegailov
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Relatively small targets consisting of a metal core (diameter 8 cm, length 20 cm) are surrounded by a paraffin moderator of 5 cm thickness.The metal is either copper or lead. These targets are irradiated with deuterium-, alpha-, or carbon beams of 1.5 or 3.7 GeV/u at the SYNCHROPHASOTRON, LHE, JINR, Dubna, Russia. During this irradiation copious amount of secondary neutrons are produced and studied with SSNTD-detectors and radiochmical sensors, for example: 139-La (n, gamma) 140-La, beta decaying. The yield of reaction products allows an estimation of secondary neutron fluxes. First results of the experiments will be presented. It appears that carbon-beams are a factor of (2-4) more efficient then lighter ions to produce secondary neutrons in our target system at 3.7 GeV/u, when one normalizes to the same total ion energy.

In addition, some transmutation cross-sections in copper, lead and 127-J have been measured. Preliminary theoretical estimations based on the Dubna Cascade Model will be presented.

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INTS

THE CHARGE SPECTRUM OF ULTRA HEAVY NUCLEI, INCLUDING ACTINIDES, IN THE COSMIC RADIATION

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K.-P. Wenzel

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The Dublin-ESTEC Ultra Heavy Cosmic Ray Experiment (UHCRE), which was flown on the Long Duration Exposure Facility (LDEF) for approximately 69 months, collected more than 3000 cosmic ray nuclei with $Z \geq 65$ in the energy region $E > 1.5$ GeV/n. The main objective of the study was to search for signatures of nucleosynthesis processes in the relative abundances of ultra heavy elements or groups of elements in this charge region and gain insight into the origin and propagation of these rare nuclei. Approximately forty per cent of the exposed nuclear track detectors have been analysed to date. Charge distributions have been obtained using both a REL model with ω_o=1KeV and a primary ionisation model with constant K=200. Both approaches indicate a peak in the platinum region and the presence of a significant number of actinide elements ($Z \geq 88$). A study of nuclear interactions of the UH nuclei in the detector stacks is progressing in parallel with the main analysis. Initial results indicate that the actinide/sub actinide ratio is not affected in any significant manner by nuclear fragmentation.

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INTS

Radon in Caves

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Abstract

Caves occur everywhere on the Earth, although mainly in karst areas - as they are found mostly in limestone environments. It is obvious that the noble gas radon, which moves freely through the pores of the permeable rocks, will easily penetrate into subsurface cavities, even into huge caves. Recently, it has been found that from long-term extended radon measurements in caves not only a detailed dosimetric picture can be drawn, but using radon gas as a radioactive tracer, the subsurface and near-to-surface transport processes can be studied, too. In this context, including literature review, the results of radon measurements obtained by using nuclear track detectors in 150 measuring sites in Hungarian caves will be summarized. Simple models will be presented that can describe air exchange due to temperature and/or pressure differences between the surface and cave air. It will be shown that long-term radon monitoring by nuclear track detectors, in conjunctions with active detectors which enables detection of fast dynamic changes, offers very important information for naturally-occurring transport processes, selection of appropriate places for speleotheraphy, study permeability and porosity of covering rock and soil, discovery of new cave branches and estimation of radon risk in caves and in houses built in karst regions.

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INTS

RADON IN SOIL BEHAVIOUR AND VOLCANIC ACTIVITY

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Volcanic eruptions are frequently preceeded by chemical and isotopic variations in the fluids associated to the volcano structure. Continuous data acquisition systems to monitor the evolution of volcanic phenomena are required to perform any geochemical surveillance. In particular, the concentration fluctuations of radon in the soil, fumaroles or hot springs has been recognized as a geochemical parameter capable to provide information concerning sudden degasing.

Two active volcanoes have been monitored for soil radon during several years, The Popocatepetl volcano in Mexico, and the Piton de la Fournaise, La Reunion island, France.

The Popocatepetl is located at the Valley of Mexico, some 60 km from Mexico City. In December, 1994, an effusive eruption occured that lasted until March-April 1995. Two radon in soil monitoing stations, SSNTD operated, are under survey since 1991. In January, 1995, an automatic device was also installed in order to obtain long and short term fluctuations. The behaviour of soil radon is discussed as a function of the eruptive phase.

The Piton de la Fournaise volcano has also been under survey during several years with the same monitoring methods mentioned above. However, in the frame of Euopean Laboratory Volcanoes, a radon network based on 20 Clipperton II automatic probes started on July, 1994. A quiescence period of the volcanic activity allows to draw a pattern of the radon behaviour influence from atmospherical parameters.

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INTS

SUCCESSFULLY REDUCTION OF THE RADON CONCENTRATION IN MACRO EXPERIMENT AT THE LNGS

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Abstract

In this paper, results on radon measurements in MACRO (Monopole, Astrophysics and Cosmic Ray Observatory) experiment are presented. Due to the importance of reducing all possible contributions of radiation doses to the laboratory personnel and to reduce background radiation for the experimental apparatus, a constant monitoring of the radon gas has been carried out.

MACRO experiment is located in Hall B of the Gran Sasso Underground Laboratory (LNGS). It consists of three Halls excavated transversally to the 10.4 tunnel that goes through the Gran Sasso massif, in central Italy, and connected with a double highway L'Aquila with Teramo. The three halls are conventially named A, B and C; service and safety tunnels complete the underground laboratory. The MACRO detector consists of three type of detectors: Liquid scintillation counter, limited streamer tubes and CR-39 track-etch. The MACRO experiment is dedicated to search for the presence of GUT monopole in cosmic radiation, high energy neutrinos, muons from the cosmic point source and low energy neutrinos from stellar collapse etc.

For better accuracy in measurements, several methods were used. Pylon chamber and Alpha scintillation cells were used for instantaneous monitoring. The CR-39- nuclear track etch detector, Charcoal detector were used for integrated measurements. A new instrument AlphaGuard has also been employed to see correlation between radon emission and microclimatic parameters. The different methods were cross calibrated in 1990-91. Presently, most of data are given by the Pylon chambers, Alpha scintillation cells and AlphaGuard methods.

At the beginning of the measurements at 1991, the radon concentration were measured in Hall B with an average value of 135 Bq/m^3. There were some modification according to the suggestion in December 1992. The radon concentration reduced up to with an average value of 60 Bq/m^3. Finally, in July 1993, inversion of air flux and other modification, radon concentration reduced to 20 Bq/m^3. At present, the radon concentration is average 15 Bq/m^3.

From the results, it may be noted that radon concentration in Hall B were successfully reduced after many suggested modifications by a factor of 7, which is quite acceptable from the point of view of the radiation protection standard and of low energy experiment background. At the moment, the situation is under control by continuos radon monitoring. We have also a project for to find out the eventual correlation between radon content in water present in Valle Fredda fault (which crosses the laboratory and is monitored by an interferometer) and the fault slip.

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INTS

The Methodical Approaches To Measurements Of Radon, Thoron And Their Daughters In Air.

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We have carried out joint continuous measurements for levels of radon, thoron and their daughters in air of inhabited premises. For comparison application of integrated methods is considered: passive track detectors on a basis of nitrate cellulose film and etching method of processing, but also method on the basis of activated charcoal and liquid scintillation counting. A method of filtration on aerosol filters and subsequent liquid scintillation counting is applied for determination of the radon and thoron daughters.

The application of liquid scintillation spectrometer, Quantulus 1220™, produced by Wallac Oy, Finland, let us carry out an absolute measurements for both alpha and beta-emitting daughters nuclides for radon and thoron. The measurements were accompanied by hourly measurements of radon specific activity. For this purpose was used radonmonitor AlphaQuard produced by Positron GmbH, Germany. The radon fluctuation range in sampling site during our study was up to few times.

The observed laws in fluctuation of specific activity will be discussed alongside with methodical peculiarities of used measurement methods. Moreover correlation relations between determined components of pollution of air, caused by radon and thoron will be resulted.

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INTS

THORON AND RADON DIFFUSION THROUGH DIFFERENT TYPES OF FILTER

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ABSTRACT

Many studies of radon measurements in the environment involve using a dosimeter, e.g a can-type, containing a solid state nuclear track detector. The entrance face for radon into such a dosimeter is usually blocked by a filter. One of the main purposes of such a filter is to stop thoron gas from entering the dosimeter - which is usually calibrated only for radon (^{222}Rn, $\tau_{1/2}$ = 3.82d), the contribution of thoron (^{220}Rn, $\tau_{1/2}$ = 55.5 s) being disregarded. The aim of this work was to find a filter that could almost completely stop thoron from entering the active volume of the dosimeter, while allowing radon to diffuse fairly freely into it. A special diffusion chamber was designed. This metallic chamber consists of two equal halves, upper and lower, of 16 cm in diameter and 12 cm high each. Each of these halves has an inlet and outlet pipe for circulating radon gas inside the chamber, form a calibrated resevoir. The top half has also an electronic connection to a semiconductor surface barrier detector (SBD). Different filters, of diameter > 18 cm, could be placed between the two halves. Six different types of filters were used in this study. These were: microfibre quartz; fibre glass; fibre glass coated with Teflon; normal filter paper; commercial cling film; and normal A4 Xerox paper. It was noticed that the cling film (sealing film, made from extruded PVC; 50 μm thick) stopped most of the thoron from getting through (less than 2% having diffused through), and at the same time allowed an appreciable amount of radon to diffuse through. The other filter which showed a large reduction in the thoron entry (only about 10% diffused through) was microfibre quartz (0.45 mm thick). By comparing the performance of the cling film with that of the microfibre quartz filter, we conclude that the cling film is the better filter: first because it stops almost all thoron, and secondly because it is cheap and widely available.

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INTS

TRACK ETCH VELOCITY STUDY IN A RADON DETECTOR (LR115, CELLULOSE NITRATE)

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It is necessary, for radon dosimetry, to have a thorough knowledge of th detection area of the detector used for alpha particles emitted by radon and its tw daughters (Po 218 and Po 214).

Latent tracks in the detector, induced by alpha particles, are enlarged in a ho hydroxide sodium bath and observed through a microscope. This paper deals with th determination of the etched track velocity (Vt). We compare three different approache in calculating Vt :

The first calculation is made by assuming a Vt constant,

In the second one, we assume that Vt is directly correlated to the ionisation rat (I) that is created on the entire alpha particle range in the detector. This ionisation rat which depends directly on the alpha particle energy, is given by the TRIM programm (Biersack, Ziegler). For a specific alpha particle energy (Ei), the Vt(Ei) has bee determined experimentally. From this experimental value and the assumption, for given energy, of the constant variability of Vt(E) with I(E), we trace the Vt variations a a function of alpha particle energy.

In the third and last approach, Vt is also considered as a function of alpha partic energy. Vt is now determined by using an etch track model based on the experiment study of the track diameters for normal incidence depending on alpha particle energie The parameters of the Vt analytical solution are adjusted to fit the experimental data.

The knowledge of Vt enables us to determine the critical angle of incidence f each energy under which the alpha particle does not induce an observable track. Result for each approach are compared with the experimental data obtained with a specif irradiator system. Finally, track detection efficiencies of LR115 for radon and the standard deviations are proposed for special configurations.

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INTS

Experimental study of the annihilation of antiprotons at rest in nuclear photoemulsion

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The multiplicity and angular distribution for various secondary charged particles produced by antiprotons stopped in photoemulsion have been measured. The experimental data are compared with calculations based on the optical-cascade model.

Searches have been carried out of "rare" annihilation channels for antiprotons stopping on nuclei of photoemulsion.

The probability for the Φ_3^0 (1850)-meson to be produced in the $\bar{p} + [^4He] \rightarrow \Phi_3^0 + t$ channel on a nucleonic cluster in the surface layer of a heavy nucleus in photoemulsion has been found to be not less than $(3.2 \pm 0.9) \cdot 10^{-3}$.

Events have been observed, for the first time, of the production, departure and mesonic decay of the light hyperfragments ${}^3_\Lambda$He and ${}^4_\Lambda$He in the annihilation on the light (C, N, O)-nuclei of antiprotons stopping in nuclear photoemulsion. The lower limit of the production probability of ${}^3_\Lambda$He and ${}^4_\Lambda$He hyperfragments per single antiproton stopping in nuclear photoemulsion has been determined to be $(0.1 \pm 3.5) \cdot 10^{-4}$.

Possible schemes are considered for production and decay mechanisms of hyperfragments in annihilation processes of antiprotons on light (C, N, O) and heavy (Ag, Br) nuclei in photoemulsion.

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INTS

Fragmentation Cross Sections of ^{197}Au at 10 A GeV and ^{207}Pb at 158 A GeV

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We have measured total and elemental charge changing cross sections for the fragmentation of 10 A GeV ^{197}Au- and 158 A GeV ^{207}Pb-beams in different targets (C,CH_2,Al,Cu,Ag, and Pb) using stacks of CR-39 and BP-1 nuclear track detectors. Electromagnetic dissociation (ED) contributes to these interactions besides nuclear fragmentation. Based on the factorization of both components it is possible to separate ED cross sections from the measured data. The analysis for the Au-data is completed. The measured charge changing ED cross sections agree with model calculations. For the Pb-beam the analysis is in progress. First results will be reported.

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HIGH FLUX NEUTRON PRODUCTION FROM HIGH ENERGY NUCLEAR REACTIONS

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Abstract Last years a new type of Power Nuclear Reactor is under development. Their operation principle is based on high neutron multiplication which is obtained by heavy ion reactions at high energies (≥ 1 GeV) on heavy targets. The whole neutron multiplication depends on neutron production in the source, neutron moderation and reactor geometry.

In this work a neutron source is studied. Spallation neutrons were produced from ^{12}C ions at 1.5, 1.8 and 3.5 GeV/n on Cu and Pb targets. Thermalization of neutrons in appropriate moderators were also studied. The experiments were performed at the Dubna LHE Synchrophasotron. Results are given for thermal and fast neutrons produced in the target. For neutron estimation different experimental methods were used and compared.

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INTERACTION OF 12.7 GeV ^{4}He IONS WITH U, Pb, Au AND Ag TARGETS

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The processes of production of fragments $Z \geq 8$ in the interactions 12.7 GeV ^{4}He with U, Pb, Au and Ag have been analyzed using polycarbonate track detector Makrofol It has been used sandwich technique, which enables direct evidence of multiple fragments emission by a single nucleus. Fragments produced in the interactions were identified and an event by event model free analysis was performed. The decay channels ending with one, two or more (three, four) fragments were detected. A classification scheme based on the multiplicity M_H of heavy fragments ($Z \geq 20$) was used in order to define multi-fragmentation (M_H=0), associated spallation (M_H=1) and fission (M_H=2) events. Cross sections, excitation energies and multiplicities of intermediate mass fragments ($8 \leq Z < 20$) have been evaluated for various reaction mechanisms. The experimental features of the fragmentation process have been analyzed as a function of the target mass.

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NEW DESINTEGRATION CHANNELS IN ^{209}Bi+Pb(Ag) REACTIONS AT E/A=11.6 MeV

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The possible desintegration channels in the 11.6 MeV/u ^{209}Bi+Pb(Ag) reactions were examined by using CR-39 plastic track detector. Our results show that in heavy ion interactions at 10 MeV/u <E/A< 20 MeV/u there are more reaction channels as previously observed. The production of ternary events was explained in the earlier experiments by more or less inelastic collisions in the first step of the interaction and then the fission of the projectile- or the target-like nuclei in the second step.In our experiment for Bi+Pb interaction about 60% of ternary events can be explained in this way. But there are ternary events which are produced by the other reaction channels. For example in about 10% of ternary events the intermediate mass mass fragment (IMF) is present as a third fragment.Its origin can be the binary break-up of the target- or projectile-like nucleus in the second step of the interaction or they can be formed as the result of the surface instability of the binuclear system formed in the first phase of interaction. Also, among the events with four fragments in the exit channel about 50% can be interpreted by the fissions of target- and projectile-like nuclei after their initial collision. The IMF fragments are present in even 20% of the four prong events. The comparision of multiplicity and characteristics of products for Bi+Pb and Bi+Ag interactions enabled the study of the influence of target atomic number on the mechanism of interaction in heavy ion colisions.

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PION-INDUCED FISSION IN TIN AND BISMUTH OBSERVED WITH MAKROFOL DETECTORS

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Abstract

Pion is the field particle of nuclear force. Its interaction with the nucleons may lead to complete absorption resulting in the full deposition of the rest mass and kinetic energy within the nucleus. Consequently the nucleus can be excited to very high energies. This situation gives rise to binary decay even in those nuclei which are not normally prone to fission due to their high fission barriers. We have studied the occurrence of binary fission induced by pions of 500, 672, 1068 and 1665 MeV in the targets of Sn and Bi. The exposures have been made at the Brookhaven National Laboratory (USA) as well as Clinton. P. Anderson Laboratory (Los Alamos, USA). The experimental set-up was based on 2π-geometry with targets in the form of thin foils placed in front of Makrofol detectors. The fission events were counted manually with optical microscopes. The incident beam was monitored with the help of a scintillator and local fluences were determined in-situ. The fission cross-sections were calculated by using the known values of target thickness and local frequencies of fission counts. The measurements were done independently at Islamabad and Rio-de Jeinero and consistent results were obtained.

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Applications of Fission Track Analysis in Petroleum Exploration

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This report highlights the many ways in which fission track analysis (FTA) can be used at many stages in the exploration for and production of petroleum. A variety of trace or minor minerals in rocks containing very low U concentrations (>1 ppm) can be dated and used for cooling history determination. Virtues of FTA include the ability to detect individual fission events and the relative ease of imaging and measurement of fission tracks, requiring a simple optical microscope. FTA yields quantitative cooling history data for individual grains in a variety of rocks, providing the potential to unravel individual parts of complex detrital mixtures. Currently, apatite is the main focus mineral, although the higher blocking temperature phases, zircon and sphene, are receiving increased attention. The compositional controls on annealing and etching of fission tracks in apatite are currently the most problematic issues in the interpretation of apatite FT age and length data, and the focus of much research.

The primary geochronologic applications involve: thermal history and maturity modeling of basins, provenance determination, timing of hydrothermal alteration, timing of tectonic events or processes, determination of missing sections at unconformities, and stratigraphic correlation. Reconnaissance exploration in frontier basins requires a firm understanding of the major tectonic, subsidence and inversion events; FTA of uplifted regions surrounding basins constrains the timing of these events. Early phases of exploration following preliminary wildcat drilling in a basin provides subsurface samples for FTA with which to constrain the ambient thermal structure, paleogeothermal gradient, nature of reservoir provenance, timing of maturation and tilting events, and possible existence of significant unconformities and their corresponding amount of erosion. Finally, FTA provides a powerful tool for detailed reservoir description and correlation in and around producing fields. Local case studies involving Indonesia, SE Asia, New Zealand, Alaska, Greenland and Europe are presented which illustrate the plethora of applications of FTA in petroleum exploration and allied geoscience sectors.

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FISSION TRACK DATING OF ANCIENT MAN SITE IN GUANGXI, CHINA AND ITS SIGNIFICANCES IN SPACE RESEARCH, PALEOMAGNETISM AND STRATIGRAPHY

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Large number of artifacts (stone tools) have been discovered in Bose (Baise), Guangxi, China recent years. They show that ancient man were living in the south of China in very ancient times. During excavation, archaeologists and geologists discovered tektites in the same layer of deposits as that of the stone tools. The structure of the layers of deposits in this site was never disturbed, which is the evidence that the stone tools were left behind by the ancient man at the time when the tektites fell on the earth, which were covered slowly by layers of deposits over them. Fission track dating has been carried out for the tektites. The age of the tektites is 0. 732 ± 0. 039 Ma, which is also the age of the ancient man in Bose, Guangxi, China. Annealing degree of spontaneous fission tracks in the tektite was investigated by measuring track diameters. A correction of age for track fading has been made by track diameter technique. According to current understanding that tektites were formed by impact of big meteorites or comets onto the earth. The dating shows that a big impact onto the earth occurred 0. 732 Ma ago. The coincidence of the age of the tektites with the age of geomagnetic polarity reversal (~0. 73 Ma) from Matuyama Epoch to Brunhes Epoch proposes a plausible explanation that the possible cause of the geomagnetic polarity reversal is due to the big impact of space object onto the earth. The result of the dating also set up a standard for inferring the ages of the deposits in South China as well as in South-East Asia where laterite (red soils) deposits exist in the whole region. More details will be described in the paper.

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Comparison of Radon Measurements done by Solid State Nuclear Track Detectors and Electronic Devices in the Frame of an EU-Radon Project

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By the members of the EU-Radon project long term Radon measurements have been done all over Europe in many houses and in areas around the houses. These measurements were done at the very same place using passive solid state nuclear track detectors (SSNTD) like LR 115, CR 39 and Makrofol (PC) and active electronic devices. The active electronic detectors are able to give time resolved data while the passive SSNTD give time integrated data.
Data on four situations will be presented:
1) on regular field measurements taken with electronic devices and SSNTD which were placed in different holes in the soil,
2) on specific field measurements where the two kinds of detectors were in the same hole in the soil,
3) on real indoor measurements and
4) on measurements done in the lab in well controlled Radon chambers.
A critical discussion of the data will be given.

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ON THE EFFECT OF CURE CYCLE PARAMETERS AND DOPANTS ON PRE AND POST IRRADIATION ANNEALING RESPONSE OF CR-39 TRACK DETECTORS

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The highly versatile CR-39 track detectors find widespread use in cosmic ray and space physics studies where recording of damage and subsequent decoding of information by chemical etching are often done in different temperature environments. Further, owing to the fact that temperature is the most important environmental factor to influence the response, one is faced with the problem of variation of response with temperature to arrive at the correct results and hence systematic understanding of annealing effects becomes very important. In the present work, we have investigated the annealing characteristics of various CR-39 detectors manufactured in different cure regimes, some of them containing additives too [CR-39(8 hr), CR-39(32 hr), CR-39(96 hr), CR-39(DOP), CR-39(DIOP), CR-39(DNP)] and some relevant correlations with theory have been drawn. Pre as well as Post irradiation annealing of samples have been done in air at (a) 80°C, 95°C, 110°C, 125°C, 145°C for 5 hours and (b) at 95°C for different times -5, 10, 15, 20 hours. Bulk etch rate is found to have a greater tendency to increase with annealing temperature and time for detectors for which cure cycles are spread over shorter times and this effect seems to be related to intrachain mobility in the polymer. Further, bulk etch rate has a smaller tendency to increase for doped CR-39 detectors. Sensitivity of each detector, in general, decreases both in Pre and Post irradiation annealing, however, the effect is, of course, more in case of Post irradiation annealing. Possible explanation for loss of sensitivity on annealing prior to irradiation has been discussed. Further, track diameters in case of pre as well as post irradiation annealing have been found to be higher than in case of no annealing (in the annealing temperature-time range employed in the present study). Finally, it has been observed that for CR-39 detectors having no additive, an opaque layer starts forming on the detector surface for annealing at more than 110°C and it makes the observation of tracks very difficult. The effect seems to be related to accumulation of Poly Allyl Alcohol. Tracks having exceptionally large track diameters are also observed apart from the normally occuring ones in the event of opaque layer formation.

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Photo and Thermal Degradations of Nuclear Track Detector (LR 115 and CR 39) Characterisations (Applications for Alpha Measurements in the Environment)

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The use of nuclear track detectors is performed routinely for many environmental applications. In fact, all polymeric detectors are exposed to natural light and different temperature conditions during their preparation and treatment. Furthermore, in numerous other cases, they are openly exposed at different environmental temperatures for periods of 15 to 60 days, thus receiving a large dose of natural light (visible spectra range).

To show the effects of the photo and thermal degradations on the alpha response, different sets of detectors, LR 115 and CR 39, were exposed at time intervals directly to natural light, to varied temperature conditions and to varied barometric pressures.

In the first experiment, the surface modifications and the chemical degradations were evaluated through different techniques:

- surface analysis by microtopography observations and Atomic Force Microscopy (AFM),
- chemical characterisations by ultra violet (UV), infra red (IR) and X-ray diffractometry and differential scanning calorific (DSC).

In the second experiment, an aliquot of each set of pre-treated detectors were exposed to alpha particles from radium 226 sources to show the effects on the alpha particles registration. The track shapes and the geometric measures were observed by image analysis during the etching time.

Thus, the results of this research offer many answers to all users of alpha-track detectors to perform measurements in the environment.

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Post-irradiation sensitization of CR-39 track detector in carbon dioxide atmosphere

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Abstract.

The effect of post-irradiation treatment of CR-39 track detector in carbon dioxide atmosphere on the alpha particle registration sensitivity was investigated. Significant increase in etch rate ratio for 6.1 MeV ^{252}Cf alpha particles was observed. The sensitization increased both as a function of treating time and as a function of carbon dioxide pressure in the treating vessel. Energy dependence of the sensitization was found to be small in the 2-9 MeV alpha particle energy interval. Fading of latent tracks after the sensitization process was slow in a half year period. Pre-irradiation treatment in carbon dioxide showed also some sensitization, though less extent than post-irradiation treatment. However, exposing CR-39 to alpha particles in pure carbon dioxide atmosphere resulted in dramatic decrease in sensitivity. The role of dissolved oxygen and carbon dioxide in the primary latent track formation and in post-irradiation latent track transformation is discussed. Potential influence of the application of sensitization of CR-39 in radon, neutron and cosmic ray charged particle dosimetry is also discussed.

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PROTON RESPONSE OF CR-39 COPOLYMER WITH HIGH SENSITIVITY

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We have found that the copolymer of CR-39 monomer with N-isopropylacrylamide (NIPAAm) shows higher sensitivity than that of pure CR-39 to low LET particles such as protons and can record normally incident 20 MeV protons [1].

We studied the proton responses of copolymer by changing the curing conditions and contents of NIPAAM as well as adding small amounts of antioxidants. As a result, optimum stabilization and sensitization were obtained by the copolymer containing about 1 % of NIPAAm and 0.01% of antioxidants (Naugard 445).

6 ~ 20 MeV proton track responses of copolymers (CR-39 / NIPAAm / Naugard 445) as well as the etching properties will be presented. And also, the threshold energy of proton registration of CR-39/NIPAAM copolymer will be discussed.

[1] K.Ogura et al.,(1995).Radiat. Meas., 25, Nos 1-4, 159-162.

SOME NEW RESULTS FROM EXPOSURES OF NUCLEAR TRACK ETCH DETECTORS TO THE LEAD BEAM AT THE CERN-SPS

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Six stacks of nuclear track detectors were exposed in December 1994 to $Pb^{(82+)}$ ions of 160 GeV/nucleon at the CERN-SPS. Each stack was made of CR39 and Lexan sheets placed before and after a target. When passing through the stack the lead ions produce nuclear fragments with $Z < 82$. The main purpose of the exposures was the calibration of the CR39 nuclear track detector used in a large area experimental search for magnetic monopoles at the Gran Sasso Laboratory (experiment MACRO). Different targets were used in order to study also the fragmentation properties of lead nuclei. The exposures were carried out at normal incidence at a density of ~ 400 ions /cm^2. The typical number of events in a stack was ~1.5 x 10^4.

The measurements for the calibrations of CR39 have been essentially completed. We compared the response of CR39 etched in (a) NaOH 6N at 70 °C and (b) NaOH 6N at 40 °C, and (c) NaOH 8N at 80 °C. The sensitivity of the detector decreases with decreasing etching temperature and decreasing concentration of the solution; the highest charge resolution is for CR39 etched in the conditions (b). The lowest detected charge is Z=5 for CR39 etched as in (a) and (c) and Z = 8 if etched as in (b). The results indicate no relevant aging effects for the CR39 made more than 5 years ago.

The investigation of possible fading effects for CR39 stored in the Gran Sasso Laboratory and the study of the fragmentation properties of the lead nuclei are in progress.

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UV-VIS AND FTR SPECTRAL STUDIES OF CR-39 PLASTICS IRRADIATED WITH X-RAYS

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ABSTRACT

A study has been made on the UV-VIS and FTIR spectra of CR-39 plastics irradiated with 50 kVp tube X-rays in the dose range of 0.20 MR. The optical transmittance over the wavelength region of 200-1000 nm decreases with the X-ray exposure, much greater decrease being observed in the UV region. The IR absorption spectra of the irradiated samples show the presence of two new strong absorption bands at the frequencies 655 and 2340 cm^{-1}, indicative of the gas CO_2 produced inside the plastic. The absorbance of these bands increase linearly with the X-ray dose.

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APPLICATION OF SSNTDs IN RADIOBIOLOGICAL INVESTIGATIONS ABOARD RECOVERABLE SATELLITES

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It is a good way to carry out experiments aboard recoverable satellites for preliminary research of space applications. There are some advantages. For example, life time (5 ~ 15 days) is long enough for carry out experiments, the equipment and samples may be recoverable that is beneficial to analysis of results, provide constant environmental conditions such as temperature(15 ~ 26) ℃, vacuum (10^{-5}~ 10^{-6})Torr benefit to repeat a experiment. In recent years much work has been devoted to study of the biological effects of space environment on dry seeds in China. some new phenomene have been observed.

For experimental investigations in the field of biological effects of space environment on dry seeds, to obtain knowledge on the variation mechanism by which highly ionized particles damaged plant seeds, the biostack that the dry seeds of Triticum aesticum L. were sandwich — packed together with nuclear track detectors such as CR-39, Makrofol-E and Laxan plastic sheets were designed and carried by recoverable satellites lauched in 1988, 1990, 1992 and 1994.

After returning to earth, using standard relations for the geometry of etching track and a high precision locatization method for plant seeds relative to path of the penetrating particles determined the seed of to be hit by individual $Z/\beta \geq 26$ particles penetrating or stopping in the seed, or accumulation damage by several $Z/\beta \geq 10$ particles. The morphologically, cytologically and utramicroscopically of wheat seeds and seedling they produced were studied. Results showed that the average aberration frequence of the choromosome of wheat root tip cells was significantly higher than that of non hit.

It must be emphasized that the particles with $Z/\beta \geq 10$ not only inject random, but also the distributions are inhomogeneous inside satellite. In addition, the trajectories of heavy particles registed in the SSNTDs will be used for further investigations.

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CARACTERISTICS OF THE CRS FAST NEUTRON PERSONAL DOSEMETER

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ABSTRACT

The Radiation Protection and Safety Centre in Algiers, has developped a fast neutron personal dosemeter in as simple a form as possible to be used in routine monitoring. We had the opportunity to participate to the two last EURADOS-CENDOS joint irradiation at which the dosimetric aspects of the developed dosemeter such as neutron energy dependence, ambient dose equivalent, angular dependence and lower limit of detection have been investigated.

In this paper further investigations on the two steps electrochemical etched CR-39 detectors at elevated temperature are reported and discussed. The detectors, consisting of laser cut American Acrylics detectors, holded between two halves of holder made of polypropylene (CH_2) and sealed inside polyethylene bags with a mean thickness of about 100 µm have been irradiated using neutron energies ranging from 25 keV up to 66 MeV and ^{252}Cf neutron spectrum and at different angle of incidence, i.e. 0°, 30°, 60° and 85°. These detectors were also exposed to different ambient dose equivalent in the range of 0.4 mSv to 13 mSv of monoenergetic neutron beams of 1.2 MeV, 5.3 MeV and 15.1 MeV.

Irradiated detectors have been processed using a two - step electrochemical etching (ECE) cycle at low and high frequencies of 200Hz and 2 kHz respectively. The etching times were 5 hours and 15 minutes for the two steps, respectively, and the electric field strength was 30 kV/cm (rms). All the etching processes were performed in the 6.25 M KOH solution at 60°C. Under these etching conditions a flat energy response within (±30%) in the energy range lying between 25 keV and 66 MeV and a minimum dose equivalent value of about 80 µSv are achieved.

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Cosmic Ray Radiation Effects Caused by Proton-Induced Targetfragmentation

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High LET radiation effects of single particles can be caused by two fundamental mechanism On the one hand, a cosmic ray ion with a high linear energy transfer can deposit a high do along its path. On the other hand, in nuclear collisions, a high dose can be deposited by t short range particles emitted from a target nucleus. In low earth orbits of space crafts, a lar contribution to target fragmentation events originates from trapped protons which a encountered in the South Atlantic Anomaly. These protons have energies up to a few hundr MeV.

The proton-induced fragmentation of C-, O-, and Si-nuclei, which are the dominating targ nuclei of biological material and microelectronic devices, are of particular importance. W study these processes in inverse kinematics. In an experiment irradiated at the SIS, we used (ions with 80 MeV/nucleon. CR-39 plastic nuclear track detectors were mounted in front of a behind a C- or a CH_2 -target. The trajectories and charges of incoming beam particles a outgoing fragments were measured in these setups. Based on these data, fragmentation cro sections and transverse momenta were determined including all fragments with $Z \geq 2$. From t results of the two targets the interaction characteristics for collisions with H-target we derived. To achieve results with high statistical significance we have exposed 8 stacks wi CH_2-targets and 4 stacks with C-targets.

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Dip Angle Dependence on Characteristics of Surface Track Formation in CR−39 Track Detectors

(4 − Environmental, Earth Science, Archaelogy, Dosimetry and Life Science)

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ABSTRACT

Space radiation dosimetry measurements were made in the Spacelab (STS−65; IML−2 mission: 300 km x 28.5 °). In this experiment, three kinds of detectors were used. One is a newly developed silicon detector telescope called the RRMD. The other two are TLDs and CR−39 track detecors. Using the RRMD, the first successful real time radiation monitoring has been achieved, giving the LET(Linear Energy Transfer) distribution every one hour during flight. Also, the LET distribution by CR−39 has been obtained, by measuring the major and minor axes of the surface ellipse of an etched track. Then, two LET distributions were compared in the LET range of 3.5 keV/ μ m to 500 keV/ μ m for the entire flight time, where CR−39 track detectors were placed right above RRMD. These distributions are in good agreement in the region of LET of 15 to 200 keV/ μ m. For the difference in intensity by a factor 4 to 5 above 200 keV/ μ m, it would be explained by the possibility that most of slow heavy target fragments with extremely short range track in CR−39 plate become less efficient to be detected under the present etching condition of about 60 μ m removal layer, although the statistics of CR−39 data are very limited in this region. In the region of LET < 15 keV/ μ m, the surface ellipse of the CR−39 track become deformed at larger incident angles. Therefore, the LET value obtained by this deformed track would be estimated to be a value smaller than true one, resulting in lower intensity in this low LET region. So, in order to correct this effect of the low LET deformed tracks, the same kind CR-39 track detectors are exposed to accelerator heavy ion beams in several incident angles and the dip angle effect is investigated. After the correction of the deformed track effect, two LET distributions by RRMD and CR−39 are compared.

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DOSIMETRY OF 40 AND 70 MeV/n ^{16}O BEAM

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Radiobiological experiments with cells and animals as well as cancer radiotherapy with charged particles from protons to heavy ions require a precise knowledge of beam characteristics, i. e. fluence, LET (linear energy transfer), range, range straggling, angular spread of particles when passing tissue, fragmentation phenomena and, finally, depth dose distribution. The use of highly sensitive and low registration threshold CR-39 plastic track detectors in combination with semi and fully automatic track measurements can result in the necessary information on the properties of a beam of interest.

In this contribution some results of physical measurements obtained with ~ 40 MeV/n and ~ 70 MeV/n ^{16}O beams which were used in radiobiological experiment with white blood cells (GANIL, Caen, France) are presented. By using CR-39 plastic track detector the range values of ^{16}O ions at two different energies (initially in the beam line, 39.97 MeV/n and 69.98 MeV/n) were measured after exiting the beam pipe, and found to be (3050 ± 40) μm and (8210 ± 90) μm, respectively. The longitudinal and projected angular spread of oxygen ions of initial energy of 69.98 MeV/n in the region of the Bragg peak was derived from the measured geometrical parameters of the tracks. On the basis of a calibration curve (etch rate ratio vs LET_∞ in CR-39) and the measured track length distribution at the range end of oxygen ions, the complete depth dose profile (plateau, Bragg peak and residual ionization caused by projectile-like fragments) was obtained.

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INTS

Improvement of Response of SSNTD in Fast Neutron Dosimetry

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Abstract:

The 1990 recommendations of the International Commission on Radiological Protection, ICRP 60, requires the reduction of the lower detection limit of SSNTD when they are used as fast neutron dosemeters. This task can only be solved by a better understanding of the etch process. A model for electrochemical etching (ECE) based exclusively on physical parameters as the (n,p) scattering probability, track geometry and etch velocities has been established, which allows the estimation of a detector response.

The influence of variation of these parameters on the fast neutron response is discussed. Measurements of proton irradiated CR-39 detectors are presented. The geometry of etched proton tracks has been measured by atomic force microscopy. Consequences for the ECE technique are reported.

Thursday, 5 September

8:30 - 10.00 Dosimetry & Life Science II, Radon IV
(Plenary, Hall A, Chair: M.A.

L. Tommasino
Advanced applications of track detectors for the measurement of terrestrial and cosmic radiations

F. Spumy, J. Bednář, J.-F. Bottollier-Depois and V.E. Dudkin
Secondary particles contribution to the dose characteristics in high energy particles beams and fields

M.M. Monnin
Physical models related to radon emission in connection with dynamic manifestations in the upper terrestrial crust: A review

10:30 - 12:30 Dosimetry & Life Science III
(Parallel, Hall A, Chair W. Birkholz)

A.I Abd El-Hafez, H.M. Eissa, S A Eman and M.A. Fadel
Intercomparative studies of brachytherapy techniques combined with ^{252}Cf boron neutron capture therapy

P. Meyer, J.E Groetz, M Fromm, A. Lacourt and A. Chambaudet
Neutron dosimetry at high and weak flux with a SSNTD the CR-39

M. Luszik-Bhadra, E. Dietz, F. d'Errico, S. Guldbakke and M. Matzke
Neutron spectrometry with CR-39 track detectors and silicon diodes using unfolding techniques

M.M. Meier, J.-U Schott and K. Strauch
Particle detection with charge coupled devices (CCDs)

D.T. Bartlett, R.J. Tanner, L.G. Hager and J. Lavelle
The measurement using passive dosemeters of the neutron component of aircraft crew dose

J. Pálfalvi and L. Sajó-Bohus
Use of SSNTDs in neutron beam dosimetry

10.30 - 12:30 Nuclear Physics & Space Research III
(Parallel, Hall B, Chair: V P Perelygin)

R. Antanasijević, Ž Todorović, D. Šević, D. Joksimović, A Dragić and V. Udovičić
Analysis of hot spots in deuterium plasma focus with the SSNTD

L. Patrizii for the MACRO Collaboration
Search for magnetic monopoles with the nuclear track detector of the MACRO experiment at Gran Sasso

G. Hüntrup, T. Streibel, E. Winkel, M. Kurth, H. Röcher and W. Heinrich
Study of multifragmentation at beam energies from 1 to 158 A GeV

S.P. Tretyakova, Yu.Ts. Oganessian, M.G. Itkis, V L. Mikheev, E.M. Kosulin, M. Hussonnois, L. Calabretta and T. Güzel
The use of SSNTD for investigation of cluster radioactivity and spontaneous fission

V.V. Kushin, N.A. Klyachin, Yu.A. Akatov, G.D. Badhwar and E.V. Benton
Cosmic ray studies on board of the space-shuttle using different track detectors

V P. Perelygin, R.I. Petrova and J V. Bondar
Tracks due to $Z \geq 23$ galactic cosmic ray nuclei in olivine crystals from Omolon pallasite

14.00 - 15:30 Environmental Sciences & Radiography II
(Plenary, Hall A, Chair: S.-L. Guo)

V.P. Perelygin and Yu.T. Chuburkov
Man-made Pu in environment - possible serious hazard for living species
M.A. Gomaa
SSNT-Detectors in radiation protection
E.S. Flitsiyan
Use of the neutron-activation techniques for studying elemental distributions, applications in geochemistry, ecology and technology

16:30 - 18:00 Track Observation and Measurement
(Parallel, Hall A, Chair: J. Pálfalvi)

S.R. Hashemi-Nezhad and M. Dolleiser
A computer controlled optical microscope (CCOM) for three dimensional track analysis
F. d'Errico, M. Luszik-Bhadra, M. Matzke and M. Weiss
A line-scanner for routine fast neutron spectrometry with CR-39 track dosemeters
J. Pálfalvi, I. Eördög, K. Szász and L. Sajó-Bohus
A new generation image analyzer for evaluating SSNTDs
R.B. Gammage, C.S. Dudney, K.E. Meyer and G. Espinosa
Digital image system for track measurements
J. Vuković and R. Antanasijević
X-ray microscopy today. The century of X-ray (1885), radioactivity (1886) and electrons (1897)

16:30 - 18:00 Filters & Other Applications II
(Parallel, Hall B, Chair: P.Yu. Apel)

A.K. Pandey, J.N. Mathur, J.P. Shukla, P.C. Kalsi and R.H. Iyer
Application of track-etch membranes as novel supports for cations transport across supported liquid membranes
P. Vater, R. Sudowe, S. Abu-Jaber, R. Brandt and R.-D. Penzhorn
Filters with tiny holes ($d < 1\mu m$) as a tool to separate gases
N.C. Tam, K. Baricza and L. Lakosi
Study of disturbing effects in spent fuel assay using CR-39 detectors
A. Danis, E.G. Badea and E. Buzdugan
Time dependence of the U adherence on the insoluble plastics from dispersion systems
V. Vutsadakis and A.Yu. Didyk
Volume interconnection rates in track etched membranes with two dimensional, multi-plane angular distributions

18:00 Concluding Remarks
(Plenary, Hall A, Chair: M.A. El-Fiki)

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INTS

ADVANCED APPLICATIONS OF TRACK DETECTORS FOR THE MEASUREMENT OF TERRESTRIAL AND COSMIC RADIATIONS

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ABSTRACT

The most relevant contributes to the radiation exposure of the population come from terrestrial radiations and cosmic rays.
In both cases high-LET radiations are present, which can be efficiently registered by Solid State Track Detectors.
This paper describes the most advanced applications of damage track detectors, which are made possible thanks to the unique characteristics of these registration techniques.
In particular the recent developments in the field of neutron detection and spectrometry at commercial flights altitudes, and the measurements of thoron, radon and its daughters will be described.

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INTS

SECONDARY PARTICLES CONTRIBUTION TO THE DOSE CHARACTERISTICS IN HIGH ENERGY PARTICLES BEAMS AND FIELDS[1)]

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* SDOS-DPHD-IPSN, Nuclear Research Center Fontenay-aux-Roses, 92265 Fontenay-aux-Roses, France
** Research Center of Spacecraft Radiation Safety, 123182 Moscow, Russian Federation

ABSTRACT

High energy protons, photons and neutrons are not able directly form a track in a solid state nuclear track detector (SSNTD). Such detectors can, however, be used for the detection and the dosimetry in the field and beams of these radiation through the registration of secondary charged particles with sufficiently high values of linear energy transfer (LET). Analysis of track parameters of these secondary particles allows for the assessment of their LET spectra, and from them many other dosimetric information can be deducted.

Recently, a method of LET spectrometry of such type based on the analysis of charged particle track parameters in a chemically etched polyallyldiglycolcarbonate has been developed [1]. In this work its use in some, typically „low LET" radiation beams and fields is presented. LET spectra of secondary charged particles have been established in:

- high energy proton beams ($E_p \in \langle 100;250 \rangle$ MeV);
- high energy bremsstrahlung photon beams ($E_{max} \leq 50$ MV); and
- on the board of a satellite during a radiobiological programme.

LET spectra in all these cases are presented; dose and dose equivalent distributions obtained from them are also presented. The contribution of secondary charged particles to the total dose characteristics is appreciated and discussed.

[1)] Partially supported through the EC Project FI3P-CT92-0026 (1993-95) and the Project of the Grant Agency of Czech Academy of Sciences No. 335402 (1993-95)

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INTS

PHYSICAL MODELS RELATED TO RADON EMISSION IN CONNECTION WITH DYNAMIC MANIFESTATIONS IN THE UPPER TERRESTRIAL CRUST: A REVIEW

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Radon emissions that are enhanced by forthcoming events have been observed all over the World. Many of these observations have been carried out with equipments using SSNTDs as sensor. However, such radon "anomalies" are not one-to-one events and the technique has not yet reached the necessary level of confidence. In the mean time, the data collected by scientists are casting some light on the involved phenomena. Radon emissions seemed very simple in the beginning; they are now recognized as a rather complicated set of successive steps involving many aspects of geophysics and chemistry. Several models have been proposed as explanation of the experimental field facts. They will be reviewed in the proposed paper; ranging from radon outgassing related to geothermal fields to radon emission related to the particuliar behaviour of aquifers, leading to a possibility to measure residence times.

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INTS

INTERCOMPARATIVE STUDIES OF BRACHYTHERAPY TECHNIQUES COMBINED WITH ^{252}CF BORON NEUTRON CAPTURE THERAPY

Abd El-Hafez A. I., Eissa H. M., Eman S. A., Fadel M. A.*

National Institute For Standards

** Biophysics Department, Cairo University.*

ABSTRACT

In this work the depth dose distribution for γ-rays, slow and fast neutrons and nuclear recoils and α-particles inside a tumor phantom of 4.2cm inner diameter and 4.4cm length filled with 100 ppm ^{10}B in distilled water was measured. The depth dose distributions were measured and represented on three dimensional plots and iso-dose charts when a ^{252}Cf neutron source was situated in the three types of brachytherapy techniques known as interstitial, surface and intracavitary.

Comparison of the three brachytherapy techniques when combined with BNCT revealed that the damage induced in the tumor by the α-particles as nuclear recoils in the interstitial geometry is much more than the other two techniques.

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INTS

Neutron Dosimetry at High and Weak Flux with a S.S.N.T.D. : the CR 39

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Abstract

In the Laboratory of Nuclear Microanalysis, we have developed two techniques for neutron dosimetry; the first for high flux, the second for weak flux. These two techniques use a Solid State Nuclear Detector (S.S.N.T.D.) : the CR 39. The weak flux technique is based on the measurement of etched tracks resulting from a neutron-proton conversion. A Monte Carlo code simulates the (n,p) collision in the detector, and a numerical computer code of latent track etching allows the evaluation of the etched track parameters. The object of this is to obtain characteristics of a neutron flux from the measured etched track parameters.
When there is a high flux and high doses, CR 39 is unsuited for optical microscopy analysis. This is because of track overlapping which makes it impossible to carry out counting and exploitation. We therefore developed a new method permitting the reading of samples based on the measurement of the angular distribution of coherent light (He-Ne laser) transmitted through the irradiated etched S.S.N.T.D.
We present these two techniques and give examples of our initial results.

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INTS

NEUTRON SPECTROMETRY WITH CR-39 TRACK DETECTORS AND SILICON DIODES USING UNFOLDING TECHNIQUES

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We are developing a combined active/passive personal neutron dosemeter, consisting of a passive CR-39 track detector in front of a silicon diode. We show, that both, the passive and the active detector, can give spectrometric information for fast neutron fields when using measured response functions and unfolding techniques.

The chemically etched track detector can be evaluated by counting the number of tracks as a function of track diameters. A series of response functions has been determined with monoenergetic neutrons in the neutron energy region from 144 keV to 19 MeV. With help of these response functions and unfolding techniques we determine rough neutron spectra from measured track diameter densities in fields with broad neutron energy distributions. The method with automatic track counting is described in more detail in Reference 1.

In a similar way the pulse height spectra measured with the silicon diode can be used. The lowest detectable neutron energy depends on the photon sensitivity of the type of diode used. The response functions of different silicon diodes, which are under test for the development of the active/passive dosemeter, are determined and unfolded neutron spectra are compared with the corresponding results of the CR-39 track detectors.

The resulting uncertainties for the total dose determination as well as for the dose contributions in different energy intervals are discussed.

REFERENCES

1. F. d'Errico et al., this Conference.

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INTS

Particle detection with charge coupled devices (CCDs)

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DLR Institute for Aerospace Medicine, D51140 Köln

CCDs are widely used as optical sensors Imaging is obtained by photoinduced separation of charge in an array of p-n semiconductor transitions. The process of charge separation is also possible by particle induced ionisation. Free charge carriers, produced in such a way, provide signals for image analysis as well. Thus CCDs enable the combination of optical imaging with particle detection in a single microchip. This technique is applied to radiobiological experiments, which require spatial correlation of particle traversal to a metabolizing biological object, closely attached to the surface of the CCD [1]. An expansion of these investigations to the radiation environment of spaceflights demands the additional determination of relevant particle parameters. Starting point for that presents the investigation of δ-electrons, which are emitted from a foil arranged over the microchip by traversing of heavy projectils and detected with the CCD. The feasibility of this method in view of energy resolution and projectile identification is discussed.

[1] J. U. Schott Nucl. Tracks Radiat. Meas. 22(73), (1993)

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INTS

Abstract

THE MEASUREMENT USING PASSIVE DOSEMETERS OF THE NEUTRON COMPONENT OF AIRCRAFT CREW DOSE

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The cosmic radiation field at aviation altitudes can be measured with simple passive detectors. The non-neutron component may be measured by means of thermoluminescence dosimetry or other techniques, and the neutron component may be measured using poly allyl glycol carbonate (PADC) dosemeters as described in this paper.

Effective dose from neutron radiation becomes the larger component for altitudes above about 10 km in general, the dominance being more pronounced for higher latitudes. The neutron energies range up to the maximum of the incident protons, many GeV. However the majority of the dose is contributed by neutrons of a few hundred MeV and less, with two maxima in the fluence spectrum, one between 1 and 10 MeV and the other between 50 and 150 MeV.

We have used PADC dosemeters, electrochemically etched, to estimate the neutron component of effective dose. Up to 50 dosemeters are used in a single measurement to obtain an estimate of sufficient precision for total neutron effective doses of 50 μSv and less. The fluence response characteristics of the dosemeter have been measured up to 70 MeV. These are extrapolated up to 180 MeV. This extrapolation is validated, to some extent, by a comparison of measured and predicted readings in the CERN reference field. For the dosemeter readings, neutron fluence is estimated assuming an isotropic radiation field and the estimated neutron fluence spectrum. The neutron fluence may then be converted to effective dose using published values of conversion coefficients with the same assumptions of isotropy and known fluence spectrum.

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INTS

Use of SSNTDs in Neutron Beam Dosimetry

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ABSTRACT

A new Biological Irradiation Facility (BIF) has been constructed at the Budapest Research Reactor Centre (it is to be published elsewhere). The 10 cm diameter beam is led through a variable filter and collimator system, providing different neutron spectra from the nearly pure fission one to a well moderated 1/E spectrum with or without significant thermal neutron contribution.
To use the irradiator for biological irradiation and for investigating the response of neutron detector materials one must know the neutron spectrum, the beam intensity and profile in advance, and moreover, each irradiation should be adequately monitored to be able to correct the dose conversion factors against the burn-up of the fuel, change in the reactor thermal power etc. For the purpose a set of track detectors were developed and calibrated in known neutron fields. All the detectors are chemically etched and evaluated by an image analyser system called VIRGINIA (also presented on this conference).
Three types of detectors were developed:
i) Fission track detectors using depleted uranium and thorium with Lexan polycarbonate,
ii) CR-39 (TASTRAK) track detectors using the ^{6}Li and ^{10}B contents of commercially available TLD materials as alpha converters with or without B_4C spherical thermal filter,
iii) CR-39 track detectors with proton converter (polyethylene) turning this combination into a threshold detector of different thresholds when applying thin aluminium foils as proton filters and alpha converters in the same time.
We present the construction and the basic fundamentals of the detectors, including the response calculation model. The response of the detectors in terms of number of tracks per neutron for the various spectra were determined by calculations and measurements and would be presented in Tables and Figures along with the neutron spectra measured by activation foil technique and/or calculated by the Monte Cario code MCNP.
The low value of the minimum detectable fluence (10^6 n/cm^2 for thermal neutrons, for instance) allows to use the system in heavily filtered beams, as well. It has been proved that this detector system is adequate for determining unknown neutron beam spectra with enough accuracy for the biological experiments in the case that it is necessary to modify the neutron field by introducing external filters in the collimator.

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INTS

Analysis of hot spots in deutherium plasma focus with the SSNTD

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Analysis of hot spots in deutherium plasma focus was conducted by using of two kinds of pin-hole camera, with LR-115 i CR-39 detectors. Hot spots emitting positive particles were located, and their locations were compared with locations of hot spots emitting soft X-ray. In this experiments the neutron yield was $\approx 10^8$ n/pulse.

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INTS

SEARCH FOR MAGNETIC MONOPOLES WITH THE NUCLEAR TRACK DETECTOR OF THE MACRO EXPERIMENT AT GRAN SASSO

The MACRO Collaboration

We report the latest results of the search for magnetic monopoles with the MACRO detector at Gran Sasso. MACRO is composed of different subdetectors, among which nuclear track detectors, in order to cover a wide velocity range and to have redundancy on candidate events. No candidate events have been observed and flux upper limits for an isotropic flux of magnetic monopoles are estabilished.

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INTS

Study of Multifragmentation at Beam Energies from 1 to 158 A GeV

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We have investigated multifragmentation interactions of relativistic heavy ion projectiles using the plastic nuclear track detector CR-39 ($C_{12}H_{18}O_7$) . This detector material allows to measure relativistic ions with charges $Z \geq 6$.
Stacks with detector foils and different targets have been exposed to Au and Pb ions at the Berkeley BEVALAC, the GSI Darmstadt SIS, the Brookhaven AGS and the CERN SPS. These experiments have been performed with high statistical significance.
In this contribution we will report about charge yields, charge correlations and multiplicities of intermediate mass fragments determined for beam energies of 1 A GeV, 10.6 A GeV and 158 A GeV.
Our first experiments with 1 A GeV Au nuclei have shown that the transverse momenta of the fragments are enlarged in comparison to a simple statistical model (Goldhaber model). The new data for higher energies show a dependence of the momentum transfer on the beam energy.

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INTS

THE USE OF SSNTD FOR INVESTIGATION OF CLUSTER RADIOACTIVITY AND SPONTANEOUS FISSION

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In the present work the results of the properties investigation and an application possibility of different type SSNTDs for cluster decay and spontaneous fission study of heavy nuclei are given.

New results of cluster decay and spontaneous fission of 226Ra and 230U investigations by using SSNTDs and 1 year exposition are presented. Some arguments in favour of the general nature of the processes of cluster decay, spontaneous fission and alpha-decay are discussed.

For understanding the cluster radioactivity mechanism a possibility of performing the inverse reaction by cluster decay was examined. For this purpose the fission cross sections for the (208Pb+16O->224Th)reaction was measured for 78, 75, 73 and 68 MeV which are by 5 to 15 Mev below the Coulomb barrier. A target of 270mkg/cm2(99.1% enrichment) was evaporated onto a ~30mkg/cm2 carbon backing. Single fission fragments were detected in the backward angular range of 90-164 and 198-270 degree by using mica dielectric detectors with an area of170 cm2. The irradiated mica detectors were annealed during 6hours at 460C for decreasing the background events which arise in mica when the scattering oxigen ions interact with mica atoms and their compound nuclei give registered tracks. After annealing the background mica tracks were not observed. The first results of this experiment carried out in a scattering chamber using the Catania Tandem beam are presented and dicussed. The experimental sensitivity of this experiment was less than 1nb. The background from fissile element contaminations into the target, mica and other materials was determined by neutron radiography and was less than 0.003 event for the largest beam fluence.

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INTS

COSMIC PAY STUDIES ON BOARD OF THE SPACE-SHUTTLE USING DIFFERENT TRACK DETECTORS

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1- Moscow Physical Engineering Institute, Moscow 115409 Russia

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4- University of San Francisco, San Francisco, CA 94117 -1080, USA

Two joint Russian-American experiments (STS-60 and STS-63) were carried t in 1994-1996 [1] to study cosmic rays on board of the Spaceshuttle. In this port, part of tile results is presented only, relevant to tile measurements, made by gh sensitive nuclear emulsions and dielectric nuclear track detectors.

Energy spectra of trapped protons and linear energy transfer spectra in 0,3-00 keV/um limits were measured in tile experiments. Angular distributions of ferent components of cosmic rays were obtained. Anisotropic shape of trapped oton angular distribution is accounted for, mainly, by pancake-like form of ach-angular distribution of protons inside SAA, eastwest flux assymetry as well mass distribution on board and local shielding. The shape of angular tribution for galactic component differs from isotropic one due to strong fluence of mass distribution

Spectral data, obtained by track detectors, differ from AP8 model by factor out 2 and coincide with the results from TEPC detector used at tile same flights.

References

G.D.Badhwar, M.J.Golightly, A. Konrady et.al. In-Flight Radiation easurements on STS - 60 - Rad Measur. vol.26, No.1, pp.17-34, 1996.

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INTS

TRACKS DUE TO Z ≥ 23 GALACTIC COSMIC RAY NUCLEI IN OLIVINE CRYSTALS FROM OMOLON PALLASITE

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[2]Institute of Geochemistry and Physics of Minerals, Kiev, Ukraina

Abstract

The olivine crystals from Omolon pallasite meteorite were selected from different locations of two small fragments of that meteorite in the Meteoritic Committie, Vernadsky Institute, Moskow. The etching of the olivine crystals was performed in hermetically closed vessel in order to prevent evaporation of water during 36+72 hrs at T= 110°C. The volume etchable track length (VETL) of Fe– group tracks (23≤ Z ≥ 32) was determined to be equal (9,7 ± 0,5) μm.

The measured Fe- group track density varies from 3.10^4 up to 2.10^5 track per cm^2. In some track -rich olivine crystals the tracks due to VVH (Z ≥ 36) cosmic ray nuclei were observed. It means that the depth of ablation of Omolon meteorite does not exceed 7-8 cm out of preatmospheric surface for the most favourable location.

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INTS

Man-Made Pu in Environment - Possible Serious Hazard for Living Species

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Abstract

It is pointed out that, contrary to the situation with natural Rn, the growing concentration of man-made Pu in environment - natural water, soil, plants and food - can provide the serious danger for all kind of animals and especially for mankind. Really, as it was established recently, element Pu is accumulated in human body during all the life and the dangerous concentration estimated to be 10^{-12} - 10^{-13} gram Pu per gram of human tissues. Unfortunately up to now there is no simple nonexpensive methods of Pu determination at the level of sensitivity 10^{-14} - 10^{-15} g/g which can provide the determination of Pu even in 0.2 g of human tissue. We warn that now the average concentration of Pu in human body is not less than 10^{-14}g/g and much higher for some "hot" regions in Europe and Asia. We propose to discuss the problem of organizing world net exploration of Pu in environment - similarly to Rn exploration program - and personel Pu monitoring for inhabitants of Pu damaged regions.

Our approach to the problem is based on chemical separation of Pu, on determination of Plutonium by high cross section ^{239}Pu(n, f) reaction and by control of possible admixtures of ^{235}U isotope by ^{235}U(γ, f) reaction in Pu preparations.

The problem of increasing of sensitivity of Pu analysis up to 10^{-14} - 10^{-15} g/g is discussed in detail.

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INTS

SSNT-Detectors in Radiation Protection

M. A. GOMAA
Atomic Energy Authority , Cairo , EGYPT

ABSTRACT:

Latest radiation protection activities were reported in IRPA-9 (April 1996) of the International Radiation Protection Association. Solid State Nuclear track detectors (SSNTD) were reported among the detectors used. The track detectors were used for:

- Radon Measurements on natural radiation exposure,
- External Dosimetry
- Assessing exposure at the work place.

The aim of the present study is to review the role of SSNTD discussed in the latest IRPA-9 Congress.

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INTS

USE OF THE NEUTRON-ACTIVATION TECHNIQUES FOR STUDYING ELEMENTAL DISTRIBUTIONS. APPLICATIONS IN GEOCHEMISTRY, ECOLOGY AND TECHNOLOGY.

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The essence of the radiography method, sensitivity of which is within a range of $10^{-2} \div 10^{-7}$ g·mm^{-2} and resolution ability extend from 0.01 to 100 μm, consists in determining the distributions of ionising irradiation sources on a surface under study by using the two-dimensional field of their irradiation registrated by means of a photoemulsion or dielectric track detector.

Statistical analysis and computer processing of the radiographic images have allowed one to solve the two main tasks of the method, namely, the determination of true distributions of ionising irradiation sources on the surface of an object under study and the quantitative estimation within given accuracy of the content of an element under study in a sample.

A complex of radiographic techniques based on the registration of secondary irradiation of the activated nuclei, instantaneous products of the nuclear reactions, and fusion fragments of the transuranium elements, has been developed to solve a series of the problem in geology and geochemistry, as well as for an analysis of technological and environment samples.

Upon designing and constructing special comparison standards modelling a sample in composition and structure, the quantitative data on distributions of more than fothty elements in rock sections and these of the main microcomponents, including oxygen, in the superconducting ceramics samples have also been obtained.

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A COMPUTER CONTROLLED OPTICAL MICROSCOPE (CCOM) FOR THREE DIMENSIONAL TRACK ANALYSIS

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Abstract

A system has been developed that is capable of producing consecutive optical micro-images of transparent micro-objects, each image corresponding to a different depth of focus. The combination of the images can be used to produce a three dimensional (3D) image of the object. Multiple slices at arbitrary angles may be deduced from the 3D image.

The system consists of an optical microscope with a computer controlled stage with 3D movement, a CCD camera, a frame grabber, three digital position gauges (for X,Yand Z directions), an interface board for driving the stage and reading the gauges and a PC computer with appropriately developed software for Windows.

The CCOM can be used successfully in normal track parameters measurements, in particle identification in dielectric track detectors as well as in the detailed track geometry analysis along the etched damage trails.

In this paper the technical description of the system as well as preliminary results on the use of the CCOM in analysing charged particle tracks in plastic and mica detectors will be presented.

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INTS

A LINE-SCANNER FOR ROUTINE FAST NEUTRON SPECTROMETRY WITH CR-39 TRACK DOSEMETERS

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The characteristic parameters of neutron induced etched tracks measured with CR-39 detectors can be used for fast neutron spectrometry. In this work, we describe the results of simple automatic techniques, which may also be applied to routine individual neutron monitoring.

CR-39 track detectors have been irradiated at the PTB with monoenergetic neutrons of 0.144, 0.250, 0.570, 1.2, 2.5, 5.0, 14.8 and 19.0 MeV. After chemical etching, the track diameter distributions have been determined using two different automatic track analysing systems.

As a reference method, detectors have been first characterised with the PTB track analysing system. This is a conventional system with microscope and driving stage, and measures the tracks in an area of 0.5 cm^2 within 40 minutes.

Then a line-scanner has been employed which is currently developed in a joint effort by the authors. It acquires and analyses a 5000 x 40000 pixel image of a 2.5 mm x 20 mm strip in 3 minutes.

The resulting track diameter distributions are characteristic of the different neutron energies: at higher energies the proportion of larger to smaller tracks is greater. The measured track diameter spectra of the different monoenergetic irradiations can be combined and rough neutron spectra can be determined with the help of unfolding techniques.

Although results are not comparable with those from conventional neutron spectrometry, some valuable information can be inferred about the neutron field and improve the accuracy of the neutron dose determination from individual neutron dosemeters.

As regards the latter issue, in addition to providing some insight into the neutron spectrum, the new scanner may replace slower track counting systems and facilitate the use of CR-39 track detectors for routine neutron dosimetry.

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A New Generation Image Analyzer for Evaluating SSNTDs

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ABSTRACT

Utilizing more than 25 years of experiences on developing image analyzers for different scientific and industrial applications a new generation of analyzers (named VIRGINIA) was constructed and successfully applied for nuclear track detection. In this paper, we intend to briefly summarize the novel hardware construction and the basic software solutions how to use a special pattern recognition method to identify different particle tracks. As an illustration, we detail the way of the determination of the alpha spectrum emitted from the "skin" of glass sheets where ^{210}Po (the last but one daughter of radon) was embedded as the decay product of ^{210}Pb implanted by recoil. The image grabber part of the VIRGINIA system works in real time mode and solves most of the image enhancing and background elimination problems automatically. This activity is supported by the software too, applying different kind of filtration and transformations. From the different image modifying options (on the gray level and/or on the binary image) macros can be constructed, as many as needed, for different detector materials, etching conditions etc. to minimize the preparation of detector evaluation. Once a picture has been optimized, then the tracks are individually investigated using predefined parameters as diameters, area, circumference, convexity, symmetry, light density distribution along X-Y axes or in different directions.
The main feature of the system is that the operator can define, so called, pattern classes based on the combination of the track parameters. During the evaluation process the program puts the tracks into the classes, maintains real time statistical calculations on each class and displays the results and the statistical distribution curve of any selected parameter and class.
Classes can be defined by producing a set of calibration images using irradiated and etched detectors, having enough number of classes (i.e. energy intervals) the resolution can be as good as 200 keV. The software can "learn" the patterns in a simple way and at any time by selecting a number of appropriate tracks from the calibration image.This spectrometry method eliminates the work to solve analytically quite complicated equations based on simplified track formation models, where also the constants had to be experimentally determined or theoretically predicted.
Any individual image, the results of the evaluation and the associated parameters are stored in database files and can be plotted and printed out at any time. Stored images can be re-evaluated later on. Using automated microscope stage and autofocus options the complete detector evaluation procedure can be programmed.
The basic technical requirements to operate the system from DOS or WINDOWS makes the VIRGINIA a low cost with high benefit image analyzer system.

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DIGITAL IMAGE SYSTEM FOR TRACK MEASUREMENTS (1)

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BSTRACT

digital image system is being developed at Oak Ridge National Laboratory for counting and alysis of nuclear tracks in solids. The microscope operate at magnifications 4, 10, 20 and 40X. The ject is illuminated by reflected light. A mirrow below the object is instaled for homogenous light spersion and high light intensity. A CCD camera (Javelin JE. 7362), convert the light in an ctrical signal. This analog information is send to a Targa electronic card instaled inside a personal mputer using Global Lab.Image software. The system has the capability for automatic counting track densities, measurement of major and minor axis of tracks, measurement of track area with lues of the minimum, maximum, mean and standard deviations, track location on X,Y coordinates, centricity evaluation, histogram, manual track diameter measurement, a live track picture and size libration relative to a reference scale. The results shown high efficiency, speed and data producible on the track counting measurements. The system can digitalize tracks from 5 to 100 crons in diameter and is able to count from a few (background) to a thousand tracks per square timeter. Finally the data measurements are handled by calculus program in Excell software for rther analysis and graphics. The digital image system is simple, easy to handle and very affordable.

EYWORDS.

igital Image, Nuclear Tracks in Solids, Counting System.

Research sponsored by U.S. Department of Energy under contract DE-AC05-84or21400 with ockheed Martin Energy Systems, Inc.

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INTS

X-RAY MICROSCOPY TODAY

The Century of X-ray (1895.), Radioactivity (1896.) and Electrons (1897.)

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Nuclear tracks in solids (NTS) are visualized by the all methods in microscopy. ıe electron microscopy (EM) is dominant all over the world as an equipment and ıaracteristics (the resolution and the diversity of the electron interactions with solids). ıe modern X-ray microscopy is not so accessible because is no so easy to obtain the ɔurce of soft X-rays (SX: 1-30 nm). We need for SX big accelerators of synchrotron diation. However, the appearance the laser-plasma source and plasma focus devices generators of pulsed SX demand to know the state of art in high resolution (about) nm) X-ray microscopy (HRXM).

To analogue of EM there are transmission X-ray microscope (TXM) and also anning TXM (STXM). Contact X-ray microscopy (CXM) is analogue to the icroradiography or heavy ions microscopy in NTS. Also, miniaturised version of CT ed in medical diagnostic is X-ray microtomography (XMT). At the end there is X-ray ɔlography (XH).

The way of detection the image and the observation one is CXM are close to the ld of NTS. It means to know behavior of diferent recording resists (to light and X-rays, ectrons and ions).

We started to use our deuterium plasma focus device (Menthers type, 30 kJ) for XM of bioobjects.

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Application of Track-Etch membranes as novel supports for cations transport across supported liquid Membranes

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ABSTRACT

rted Liquid Membranes (SLM) are fast emerging as a potential separation and concentration techni ly for extremely low metal values. The advantage of SLM over other conventional techniques are y of concentrating the recovered metal-ion species during separation itself (ii) possibility of achie ration factors (iii) economic use of expensive, tailor made extractants (iv) lower capital and oper (v) low energy consumption. High performance membranes are readily made by immobilizing a l taining a carrier in a thin microporous substrate. Since the properties of the microphorous sub e support) such as its thickness, porosity, tortuosity of the pores (ratio of length of the pore t e thickness), inertness to the chemicals used in the separation, tensile strength etc. have an influen ll performance of the membranes, a membrane support has to be judiciously selected which ha , chemical inertness, high porosity and small pore size. This prompted us to initiate a programme fo ion and characterization of 'track-etch membrane' (TEM) and use them for subsequent testing as th port for supported liquid Membrane (SLM).

TEM preppared by bombarding SSNTDs (polycarbonate or polypropylene) with heavy-ions a ly enlarging the pore diameter by chemical etching was impregnated with the carriers (30% T for transport of U(VI) & Pu(VI), 0.4 M CMPO in dodecane for Am, 0.5 DCH-18-C6 crown et for Sr and 0.5 M Cynax in xylene for Pd). Filling the pores of TEM supports with the carrie lished by immersing the membrane in the organic phase for at least 8 hrs before use.

le stage SLM measurements were carried out with a two compartments permeation cell which consis olution chamber (2.5 cm^3) and receiving phase chamber (2.5 cm^3) separated by a liquid membrane h tive membrane area of 1.13 cm^2. The source and receiving phase were mechanically stirred to ation build up. The simultaneous separation of Pd, Sr and Am from a single feed using three for these cations were also carried out. The results of these studies along with advantages of TEM l membranes like radiation stability of TEM, its reusability, high tensile strength , uniform pore form pore geometry etc. will be discussed in this paper

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INTS

FILTERS WITH TINY HOLES (d < 1μm) AS A TOOL TO SEPARATE GASES

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The development of nuclear track microfilters, NTMF, with tiny holes (0.15μm < d < 1μm) is described for the polyimide foil UPILEX. These NTMFs were used to study the volume through-put of gases like He, CO, CO_2 and air as a function of the hole diameter d. First results will be presented, showing that it is possible to separate in particular CO and CO_2 gases to some extent. The experimental results will be interpreted by model calculations.

Study of disturbing effects in spent fuel assay using CR-39 detectors

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By virtue of their small size, etched track detectors are suitable to get a close access to spent reactor fuel assemblies stored usually under water. This is essential because of the short range of fast neutrons in boric acid containing water.

A nondestructive method for in-field burnup monitoring was developed using CR-39 detectors introduced inside assemblies stored in a spent fuel pond. This method is less sensitive to adjacent assemblies than that using the detectors placed above the assembly to be measured. In further development of the method, shape selection of tracks was an important step toward reducing the effect of disturbing events. Out of these, the effect of adjacent assemblies was first examined. As a result of our on-the-spot measurements in a nuclear power plant, it was proven that the overall effect of the neighboring assemblies was within the statistical uncertainty (5 %), i.e. negligible, even for the shorter one of possible storage distances (160 and 225 mm) in a hexagonal lattice. Another effect to examine was the influence of the large gamma-background on the response. This effect was evaluated to be 23 ± 5 %/kGy gamma-dose, while the gamma-dose for typical exposures falls in the interval of 0.5-3 kGy. By reducing the observed number of tracks according to this effect, providing more correct burnup data is possible, also better corresponding to calculated results obtained by our formula reported earlier for neutron emission from spent fuel, including burnup, cooling time and initial enrichment of the assemblies.

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TIME DEPENDENCE OF THE U ADHERENCE ON THE INSOLUBLE PLASTICS FROM DISPERSION SYSTEMS

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The liquid radioactive wastes represent complex dispersion systems that contain in their dispersed phases, one or more radionuclides - the pollutants.

The physical methods used for the removal of these pollutants resort to aggregation of dispersed phase and then to its sorption on the insoluble beds.

In our previous studies we tested the influence of different physical and chemical factors both on the changing of dispersion system states in aggregation direction and on the colloid sorption properties of certain plastic beds.

The physical depollution methods are efficient if the dispersed phase aggregation and aggregate sorption on the insoluble beds, take place in a very short time and in a high proportion.

In this paper we described the time dependence of the aggregate adherence on the different insoluble organic plastic beds. Five materials - organic plastic beds - were used for U sorption from dispersion systems: T-1, T-2, CEPO-9, E-OXCLH, FSOH-0.3 (all patents).

The investigate dispersion systems were:

a) an U homogeneous dispersion system, i.e. a homogeneous solution of uranil acetate, $C_U = 400$ mgU/l;

b) an U ultramicroheterogeneous system that was obtained by changing the state of an aliquot part from the U homogeneous solution, i.e. an U solution in colloidal state obtained from the U homogeneous solution of $C_U = 400$ mgU/l that had been undergone to the certain physical factor action.

Each plastic bed sample was separately immersed in different aliquot parts having the same volume, at the same temperature, for the different time durations: 5 min, 15 min, 30 min, 1 h, 2 h, 6 h, 12 h, 24 h. After immersion the samples were analysed by the fission track method in the following conditions: - muscovite mica as track detector;

- neutron irradiations at the fluence of $\sim 10^{14}$ thermal neutrons/cm^2 ;
- etching conditions: HF≥40% , four hours at room temperature;
- fission track studies by optical microscopy.

The experimental results obtained for plastic bed samples were compared among them and discussed.

POSTERS

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VOLUME INTERCONNECTION RATES IN TRACK ETCHED MEMBRANES WITH TWO DIMENSIONAL, MULTI-PLANE ANGULAR DISTRIBUTIONS

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Multi-angled tracks in nuclear track etch membranes interconnect at significant rates both on the surface and in the volume of such membranes. An ananlytical expression is derived for the volume and surface interconnection rates in terms of measurable parameters. The relationship between surface and volume interconnection rates is presented. Predictions of the closed form formulas are compared to results from a monte carlo simulation of the formation of tracks with complex multi-plane angular distributions.

The effect of such interconnections on diffusive and convective flow rates of fluids is estimated.

Track Formation

N.K. Sood, Tarsem Singh and A.S. Sandhu
A global model for annealing in solid state track detectors

S. Kumar, S.K. Sharma and Anupam
Comparative study of various stopping power formulations for heavy ions in solids

D. Fink, R. Klett, V. Hnatowicz, J. Vacik, H. Omichi and F. Hosoi
Corrosion effects of ion tracks

M. Chekirine, H. Ammi and A. Adjerad
Energy loss of 1000-2600 keV alpha, in Mylar, Kapton, Makrofol and Nitrate of Cellulose foils

H. Ammi, M. Chekirine and A. Adjerad
Energy loss of 1000-2600 keV protons, in Mylar, Kapton, Makrofol and Nitrate of Cellulose foils

K.K. Dwivedi, D. Sinha, S. Singh, A. Srivastava and D.K. Avasthi
Energy-loss of 20-80 MeV ^{12}C ions in polymeric solids

A. Srivastava, D. Sinha, S. Singh, S. Ghosh and K.K. Dwivedi
Maximum etchable track lengths of ^{161}Dy in ZnP-glass detector

S. Ghosh, D. Sinha, S. Singh, A. Srivastava, K.K. Dwivedi and R. Brandt
Mean ranges of ^{161}Dy in Hostaphan and Kapton

P.J. Meoli, G.H. Olivera, R.D. Rivarola, G. Saint-Martin, P.D. Fainstein and O.A. Bernaola
Qualitative analysis of track registration in Makrofol E

P. Zhai, Y. Xing, Y. Zhang, S. Feng, Y. Kang, X. Tang, Y. Wang, W. Zhao and S. Yan
Scanning tunneling microscopy observation study of latent track induced by H^+ on the surface of HOPG

H.S. Virk and G.S. Randhawa
Stopping power and range relations for low and high Z ions in solids: a critical analysis

L.P. Biro, A.Yu. Didyk, J. Gyulai, K. Havancsak and V. Vutsadakis
Study of swift heavy ion irradiation track phenomena on silicon and pyrolithic graphite with the use of atomic force and tunneling microscopy

A.Yu. Didyk and V. Vutsadakis
The dependence of the distribution of damage on track structure along swift heavy ion projected range

V.A. Ditlov, V.A. Myltseva, E.A. Silaev, V.A. Smirnitsky, O.C. Egorov, E.D. Kolganova, E.A. Pojarova and D. Kuzovkin
Theoretical prediction of latent track regression in neutrino experiment with nuclear emulsions

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GLOBAL MODEL FOR ANNEALING IN SOLID STATE TRACK DETECTORS

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A systematic study of annealing phenomenon in solid state ack detectors (S.S.T.D.) is presented using a quasi-equilibrium pproach for the defects migration process. The nonlinear nature the mechanism is also taken into account, which leads to an teresting formula for rate of annealing. Some of the perimentally tested empirical/semi-empirical formulae can also deduced from it under certain approximations. The importance the concept of relaxation time/hopping time is stressed.The mperature dependence of rate of annealing follows automatically om this formulation. Suggestion is made for experimental easurement of half life of fractional thermal fading of tracks that the nonlinearity parameter can be computed and annealing ocess can be better understood.

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COMPARATIVE STUDY OF VARIOUS STOPPING POWER FORMULATIONS FOR HEAVY IONS IN SOLIDS

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Passage of heavy ions through matter and understanding of the various interaction processes continue to be of central importance to many scientific disciplines such as nuclear physics, astrophysics, elementary particle physics, radiation dosimetry, material science, radiation biology, health Physics. Charged particle detectors have played an indispensable role in experimental research in all energy domains. However, use of a charged particle detector in general, and in the present context, that of a solid state nuclear track detector, entails its proper calibration for which precise knowledge of the stopping power and range relations is essential. Although our understanding of various interaction modes and their relative contributions to the total energy loss has become quite elaborate now and many correction terms with adequate microscopic details have been introduced in the basic stopping power relations yet precise calculation of stopping power despite having very precise and exact formulae is still elusive owing to the empirical base and bias in the determination of effective charge and adjusted mean ionization potential. Over the past couple of years, our group is engaged in making a relative comparison of the various energy loss formulations in different energy domains. In continuation to our earlier work, we have done a comparative study of different stopping and range formulations e.g. Benton and Henke (1968), Mukherjee and Nayak (1979), Ziegler et al. (1987) and Hubert et al. (1989) for different projectile target combinations in the projectile energy range 0.5 to 5 Mev/n. Our analysis indicates that Hubert formulation which is valid in the energy range 2·5 to 500 Mev/n gives the best results in the energy range above 2.5 Mev/n whereas Benton and Henke and Ziegler formulations provide reasonable agreement with experimental results in the energy range 0.5 to 1.5 Mev/n.

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INTS

Corrosion Effects of Ion Tracks

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Usually ion tracks are studied ex-situ, i.e. after their removal from the evacuated irradiation vessel. The exposure to ambient air leads to degradation effects which are frequently neglected and consequently have hardly been studied at all. This contribution summarizes the knowledge which we have recently obtained in this field.

It appears that the surface of pristine polymers is usually badly permeable for e.g. oxygen and moisture - probably due to some chemical or structural modifications resulting from the exposure to ambient atmosphere. Upon ion irradiation - no matter whether we deal with energetic ions in the GeV range or with low energy ions of some 100 keV only - this protective surface layer is destroyed, and both oxygen and moisture are allowed to enter into the polymeric bulk. Whereas the indiffusing oxygen appears to distribute in both the ion tracks and the neighboring pristine matter, indiffusing moisture seems to penetrate only along the ion tracks.

Consequently, oxygen-sensitive mobile dopants in ion tracks bond to oxygen and are eventually immobilized, thus modifying the dopant distribution. The oxydation of polymeric fragments along the ion tracks appears to result in a number of new volatile products, with the consequence that the free volume along the track increases.

The penetration of water vapor into the ion tracks leads to some faint ion track conductivity. For fresh tracks, this conductivity correlates exponentially with the ambient air humidity. Conductivity of aged tracks is characterized by statistically occuring break-through events.

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ENERGY LOSS OF 1000-2600 keV ALPHA, IN MYLAR, KAPTON, MAKROFOL AND NITRATE OF CELLULOSE FOILS

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ALGERIE

Abstract

The energy loss of Mylar, Kapton, Makrofol and cellulose nitrate for 1000-2600 keV ^{4}He ions have been determined.

The experimental energy-losses are compared with the predictions of two semiemperical models, used in conjunction with Bragg's rule and with the energy-losses values obtained by the TRIM-90 computer code. The maximum deviations form the calculated values observed for Mylar, Makrofol, Kapton and cellulose nitrate were 5%, 13%, 10% and 5%, respectively. Comparisons have been performed with the scanty experimental data in the literature

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ENERGY LOSS OF 1000-2600 keV PROTONS, IN MYLAR, KAPTON, MAKROFOL AND NITRATE OF CELLULOSE FOILS

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Abstract

The energy loss of 1000-2600 keV ^{1}H in 10μm Makrofol, 6μm Mylar, 8μm Kapton and 6μm Nitrate of cellulose (LR-115) foils have been determined. Good agreement with the calculated values obtained by using Bragg's rule and the Ziegler semiemperical parameters were found in Mylar and LR-115 cases. Maximum deviation of 3 % from the semiemperical curves were observed.

In the case of the kapton and Makrofol foils, however, maximum deviations of even 7% for Makrofol and 11% for Kapton were obtained. The energy loss data are compared with the available literature values.

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ENERGY-LOSS OF 20-80 MeV ^{12}C IONS IN POLYMERIC SOLIDS

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The knowledge of energy-loss or the way a given impinging heavy ion loses energy as it passes through the impeditive material gives information regarding the material itself. This in turn can be utilized as a pointer to its application in different fields including material science. At present there is a decided paucity of the experimental energy-loss data in elemental and complex media for heavy ions having energy above 1 MeV/A. It has been reported by some workers that a triple beem of Boron, Nitrogen and Carbon when implanted in Kapton polyimide resulted in hardness of the polymer to such an extent that it was found to be three times harder than steel. In view of this we have made an attempt to characterise different polymeric solids by heavy ions.

Here, we present the results of an experiment we have carried out on the characterisation of six polymeric solids by energetic ion beams, in terms of energy-loss of 20-80 MeV ^{12}C ions in Kapton, Hostaphan, Makrofol-N, Makrofol-KG, Triafol-TN and Triafol-BN. These polymeric solids have found applications in the form of windows, backings, absorbers and degraders in many nuclear physics experiments besides in the manufacture of microfilters and single pore membranes for applications in the fields of environmental science, biomedical science, superfluidity etc.

The energy-loss data of ^{12}C in six polymers obtained in the present work are compared with the values derived from most widely used theoretical prescription TRIM and the one developed in our group RANGE with a view to check their applicability for complex solids.

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INTS

QUALITATIVE ANALYSIS OF TRACK REGISTRATION IN MAKROFOL E

P.J. Meoli[1], G.H. Olivera[2], R.D. Rivarola[2], G. Saint-Martin[3], P.D. Fainstein[4] and O.A. Bernaola[3]

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[4] National Atomic Energy Commission. Bariloche. Argentina

ABSTRACT

The track radius calculation reported by Tombrello was applied to experimental data of tracks of several ions and energies in Makrofol E. Qualitative analysis of tracks registration in this material is discussed.
These data were also analyzed by the CDW-EIS approximation

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MAXIMUM ETCHABLE TRACK LENGTHS OF ^{161}Dy IN ZnP-GLASS DETECTOR

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easurement of maximum etchable track length of heavy ions in mplex material is of great importance due to several practical plications. In last three decades, different nuclear track tectors have been used to accomplish such measurements. In this periment the track lengths of energetic ^{161}Dy ions in ZnP-Glass tector have been measured. Four aluminium degrader foils were unted on a ZnP glass plate in a stair-case configuration. They re then irradiated with 13.0 Mev/A ^{161}Dy ions at an angle of °. An optimum ion fluence of $5X10^4$ ions/cm^2 was maintained. ximum etchable track length of ^{161}Dy ions at five different ergies in ZnP-glass detector were accurately measured. The perimental data have been compared with the corresponding eoretical values from three computer codes (a) RANGE, (b) TRIM d (c) the code of Henke and Benton.

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MEAN RANGES OF ^{161}Dy IN HOSTAPHAN AND KAPTON

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Solid state nuclear track detector are quite useful to measure ranges and energy-loss rate of heavy ions in elemental media. Such measurements are possible for all heavy ions whose entire range could be revealed as tracks in the detector foils. In this experiment, the measurements of the range and energy-loss rate of ^{161}Dy ion in Kapton and Hostaphan were carried out using CR-39 as the track detector. Stacks of Kapton and Hostaphan films in staircase configuration were mounted on CR-39 and were exposed to a well collimated beam of 13.0 MeV/A ^{161}Dy at an incident angle of 45° to the detector surface. An optimum fluence of $5X10^4$ ions/cm^2 was maintained. The maximum etchable track lengths of ^{161}Dy ions degraded by Kapton and Hostaphan targets were accurately measured. With the help of a range-energy calibration curve for ^{161}Dy in CR-39, the energies of the degraded ions were determined. From the energy loss curve of ^{161}Dy in Kapton and Hostaphan, the mean ranges corresponding to 13.0MeV/A ^{161}Dy in these two materials were derived. The experimental ranges were compared with theoretical values obtained from three different computer codes 'RANGE ','TRIM' and the code developed by Henke and Benton to check their validity.

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Scanning tunneling microscopy observation study latent track induced by H^+ on the surface of HOP

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Abstract

Highly oriented pyrolytic graphite (HOPG) with cleaved fresh surface was irradiated by H^- with 3.0MeV at a high dose of $1x10^{16}$ /cm^{-2} from a 2x1.7MV tandem accelerator. The HOPG sample was observed with a STM system working in air at room temperature. The tunneling current and tip bias voltage were 0.8nA and 150mV respectively. The areas scanned usualy were 9nmx9nm and sometimes 12x12-150x150nm^2. No defects similar to the damage induced by H^-on the surface of unbombarded HOPG have been found.

457 STM images with areas of 9nmx9nm were successfully collected from the surface of HOPH bombarded by H^- and from them 163 STM images with regular atomic arrangement and damages were found.

Our observation shows that the size of damage was 0.2-0.8nm, the largest was above 1.8nm and that the probability of damages by H^- on the HOPG surface was about $1.8x10^{-4}$ (damage number density /ion dose). The possible process of damages is analysed and discussed.

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STOPPING POWER AND RANGE RELATIONS FOR LOW AND HIGH Z IONS IN SOLIDS: A CRITICAL ANALYSIS

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A critical analysis of various stopping power and range formulations has been made by comparing the calculated stopping power and range values with corresponding experimental values for different low Z ($1 \leq Z \leq 8$) viz., H, He, Li, C, N, O etc. and high Z projectiles ($54 \leq Z \leq 92$) viz., Xe, La, Au, Pb, Bi, U etc. in different targets, e.g. Be, C, Al, Au, Pb, CR-39, Lexan, Mylar, LR-115, CH, $(CH)_n$, TRIFOL-TN, etc. at various low and high energies. A detailed study has been made by taking into consideration different target and projectile combinations, e.g., heavy ion-light target, light ion-heavy target and light ion-light target. Overall the Ziegler et al. (1985) formulation (TRIM-95) provides the best agreement with the experimental results for all projectile and target combinations except for heavy ion-light target combination where it underestimates the stopping power data and overestimate the range data in the limited range of energy of the projectile. Mukherjee and Nayak formulation [Nucl. Instrum. Meth., 159 (1979) 421] totally fails at relativistic and low energies of the projectile, irrespective of the projectile-target combination. Northcliffe and Schilling [Atomic data and Nucl. data tables, A7 (1970) 233] formulations does not show any particular trend. Benton and Henke [Nucl. Instrum. Meth., 67 (1969) 87] formulation gives good agreement between experimental and theoretical data within the range of experimental errors.

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Man-Made Pu in Environment - Possible Serious Hazard for Living Species

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Abstract

It is pointed out that, contrary to the situation with natural Rn, the growing concentration of man-made Pu in environment - natural water, soil, plants and food - can provide the serious danger for all kind of animals and especially for mankind. Really, as it was established recently, element Pu is accumulated in human body during all the life and the dangerous concentration estimated to be 10^{-12} - 10^{-13} gram Pu per gram of human tissues. Unfortunately up to now there is no simple nonexpensive methods of Pu determination at the level of sensitivity 10^{-14} - 10^{-15} g/g which can provide the determination of Pu even in 0.2 g of human tissue. We warn that now the average concentration of Pu in human body is not less than 10^{-14}g/g and much higher for some "hot" regions in Europe and Asia. We propose to discuss the problem of organizing world net exploration of Pu in environment - similarly to Rn exploration program - and personel Pu monitoring for inhabitants of Pu damaged regions.

Our approach to the problem is based on chemical separation of Pu, on determination of Plutonium by high cross section ^{239}Pu(n, f) reaction and by control of possible admixtures of ^{235}U isotope by ^{238}U(γ, f) reaction in Pu preparations.

The problem of increasing of sensitivity of Pu analysis up to 10^{-14} - 10^{-15} g/g is discussed in detail.

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Use of SSNTD for Measuring Nuclear Reactions

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Abstract

The solid state nuclear track detectors (SSNTD) are reviewed .The nature and the registration sensitivity of the most commonly used SSNTDs for α - particle measurements are presented.The track -pit formation during the etching process is described. A special attention is paid to the study of Makrofol-E films using a proposed as an optimum etching solution .The etching rate was 10.5 μm / hour . The energy resolution was measured and is estimated to be ~300 and ~400 kev in the energy ranges 1 - 2 MeV and 2 - 3 MeV respectively . Basing on these results the sensitivity threshold for α- particles in Makrofol - E is shifted up to 1 Mev otherwise , there will be no descrimination between the etch - pits of α- particles with energies ranging from 0 to 1 MeV . The full angular distribution of the α- groups are measured in one run by means of a SSNTD sheet surrounding the target . A scattering chamber designed for α- particle angular distribution measurements is described . An example of the influence of the energy loss in degrading Al foils in eliminating the energy- angle dependence is given . The numerous curves of the range - energy dependence of α- particles in Makrofol - E after passing Al foils of different thicknesses are scaled in one schematic normograph . The later simplifies the process of chosing the suitable Al foil thickness or of determining the range - energy relation . The angular distributions of five α- groups from the ^{59}Co (p . α) ^{56}Fe reaction in the proton energy range 1.6 - 2.4 MeV have been measured using the designed chamber . A Makrofol - E film of 300 μm thickness has been exposed to the reaction products for 5 hours . This time was enough to get the angular distributions for $d\sigma / d\Omega$ in the range 5 - 72 μbarn / ster .

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THEORETICAL PREDICTION OF LATENT TRACK REGRESSION IN NEUTRINO EXPERIMENT WITH NUCLEAR EMULSIONS.

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Neutrino interactions are very seldom events. That is why in neutrino experiment of Cern collaboration large amount of AgBr nuclear emulsion and long exposures with duration of several years are used. The latent tracks during such long exposures undergo the regression.

The aim of this work is to analyze properties of Russian nuclear emulsion type-R, used in neutrino experiment, and to develop a method of prediction the behavior of latent tracks on the base of our approach /1/.

The theoretical base of this approach is many-hit model of local response with additional preposition that frequency of effective events ξ_{ion} produced by quick ion is not absolute definition and depends not only on ion parameters but on the visualization conditions parameters too. So, it depends on large set of parameters. One of these parameters is t - time interval between ion passing through the detector and track visualization moment and it is possible to write in kind /1/:

$$\xi_{ion} = \xi_o \cdot (Q + (1-Q) \cdot e^{-\frac{t}{\tau}}) + \xi_b(t) \qquad (1)$$

where

ξ_{ion} - is mean number of effective events per one sensitive microregion, produced by fast ion along its track,

ξ_b - is a similar mean number of effective events , produced by hypothetic or real background radiation,

Q - part of the stable states of sensitive microregion with local response "Yes" and $(1-Q)$ is unstable part of states with "time life" - τ.

In the work there is presented a numerical material about time behavior of tracks in the emulsion and analyzed several hypotheses of time dependencies of value ξ_b.

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STUDY OF SWIFT HEAVY ION IRRADIATION TRACK PHENOMENA ON SILICON AND PYROLITHIC GRAPHITE WITH THE USE OF ATOMIC FORCE AND TUNNELING MICROSCOPY

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Silicon samples were irradiated with 210 MeV Kr ions in a direction parallel to the [100] plane. The defects produced by the irradiation were evaluated, without any sample preparation, by Atomic Force Microscopy (AFM) and spreading resistance (SR) measurement on the [100] plane. Both methods indicate a penetration depth of 28 m, in good agreement with the value given by t he TRIM code. AFM measurements allowed distinction among four depth zones to which different damage production mechanisms can be ascribed.

Pyrolithic graphite samples were irradiated perpendicular to surface and then investigated with scanning tunneling microscopy (STM). The ion fluence was 10^{12} ions/cm^2. It was observed that crater structures appeared on the irradited surface and the surface density of the craters is equal to the ion fluence. From this fact we conclude that each crater was created by a single heavy ion.

The theoretical model for this phenomenon is discussed.

Methodology & Detectors

A. Kumar, N.P. Singh and R. Prasad
A comparative study of track registration characteristics of Makrofol (KG, KL, N) to ^{136}Xe ions

O.A. Bondarenko and P.L. Salmon
A new principle of alpha particle spectroscopy using SSNTD

A. El-Rahmany, M. Mansy, A. Hussein, E.M. Ibrahim and E. El-Araby
Alpha track profile study and range determination in CR-39 plastic detectors

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An approach to nuclear charge identification with CR-39 polymeric nuclear track detector

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Comparison of responses of CR-39, PM-355 and CN track detectors to energetic hydrogen, helium, nitrogen and oxygen ions

T. Phukan, H.L. Das and T.D. Goswami
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H.L. Das, T. Phukan and T.D. Goswami
Dielectric response of gamma radiated CR-39 SSNTD

Anupam and S. Kumar
Effect of cure cycle parameters and dopants on the etching response of CR-39 track recorders

D. Sinha, A. Srivastava, V.G. Dedgaonkar, S. Ghosh and K.K. Dwivedi
Effect of gamma rays on different track detectors

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Etching and annealing characteristics of BP-1 phosphate glass

S.R. Hashemi-Nezhad
Geometry of etched charged particle tracks in crystalline detectors

F. Abu-Jarad, A.M. Hala, M. Farhat and M. Islam
High gamma exposure effect on CR-39 nuclear track detector properties

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D. Nikezić and D. Kostić
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Studies on the track formation mechanism of heavy ions in CR-39

C.-Q. Tu, S.-L. Guo and Y.-L. Wang
Study of bubble damage detectors for neutron detection

D. Gopalani, S. Kumar, R. Kumar, V.K. Sundaram and S.K. Mehta
Study of degraded neutron spectra through material matrix composites using CR-39 films

P.Yu. Apel, F. Häussler, M. Hempel, A. Kuklin, S.G. Stetsenko and I. Yanina
Study of shortly etched tracks in polymer: A comparison of different experimental methods

O.A. Bernaola, G. Saint-Martin, I. Nemirovsky, P.J. Meoli and G.H. Olivera
Submicroscopic analysis of tracks in mica

X.-H. Hao, S.-L. Guo and B.-Y. Li
Techniques for calibration of sensitivity of CR-39 detectors using Am-Be neutron source

V.A. Ditlov
The definition of registration parameters for the detection theory

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The effect of etching solution combination on the response of an electrochemical etched CR-39 detector

R. Isabey, M. Guelev, E. Duverger, L. Makovicka, D. Klein and A. Chambaudet
Thermoluminescent detector response simulation by the use of the EGS4 (Monte-Carlo code)

M.H.S. Bakr
Use of SSNTD for measuring nuclear reactions

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A comparative study of track registration characteristics of Makrofol (KG, KL, N) to ^{136}Xe ions

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ABSTRACT

Makrofol polycarbonates being threshold type are applied for ionographic registration, and are well suited for the study of cosmic rays, heavy ion reaserch and are most suitable for microfilter technology [1]. The shape and size of heavy ion tracks in polycarbonates depend on the mass, charge and relative velocity β (= v/c) of the track forming ion as well as on the stopping power of target material. The valuable information regarding the distribution of radiation damage and its dependence on the effective charge of the track forming ion can be obtained from bulk and track etch rates.

In the present study track registration characteristics of ^{136}Xe ions in different types of Makrofol polycarbonates *viz* Makrofol KG, KL, and N have been studied. A comparison is also done in the present work.

The stacks of circular discs (5cm dia. and 40μm thickness) of Makrofol polycarbonates were exposed with a well collimated beam (10^5ions/cm^2) of ^{136}Xe (11.56 MeV/n) ions at an angle 45° to the exposed surface from UNILAC, GSI Darmstadt, Germany. The exposed detectors were etched in 6.25N KOH at four different etching temperatures (55°, 60°, 65° and 70°).

The etched track parameters *viz.* cone angle sensitivity, etching efficiency and etch induction time were obtained. The results show that the sensitivity decreases towards higher etching temperature while the cone angle increases. There is a slight decrease in etching efficiencies with temperature at four etching temperatures. The variation of etching rates with temperature were found to be exponential and follow the Arrhenious equation The values of activation energy for bulk etching of Makrofol-KG, KL and N are found to be 0.99 ±0.08, 1.18±0.08 and 0.089±0.04 eV, respectively. Activation energy for track etching are found to be 0.62±0.04, 0.71±0.04 and 0.59±0.04 eV, respectively. Maximum etchable track length/range were also obtained and compared with the theoretical values obtained from computer programme RANGE [2]. From the results it is found that the polycarbonate detectors (KG, KL, N) manufactured by different processes have slightly different behaviour.

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A NEW PRINCIPLE OF ALPHA PARTICLE SPECTROSCOPY USING SSNTD

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A new principle of alpha particle spectrometry is advanced. It is based on measurement of the end diameter of an etched out track. A simple linear ratio links the track end diameter and the range of alpha particle in detector. A special calibration procedure is worked out in order to compensate the track end diameter dependence on the alpha particle incidence angle. This procedure lets avoid direct measurement of etching rates V_t and V_b and makes attainable transfer to the energy scale.

As a result the energy resolution achieved so far is 2% within the energy range between 4 and 6 MeV. Additionally the method gets a high value of the absolute registration efficiency, i.e. up to 25%. It is explained that a few part of tracks are rejected in the course of analysis, namely these are almost vertical tracks and those which incidence angle exceed the critical angle.

Also new applications are discussed where the method of SSNTD alpha spectrometry can be successfully used.

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ALPHA TRACK PROFILE STUDY AND RANGE DETERMINATION IN CR-39 PLASTIC DETECTORS

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Abstract

In this paper an extensive study of alpha particle track profile has been determine In CR-39 plastic detectors. Track profile geometry and parameters have been studied Various values of alpha energies were used and the etch-rate ratio (V) was measured as a function of the residual range (RR) along the alpha particle track and a mathematical formula between V and RR was extracted.

Also in this work alpha particle range in plastic foils has been measured at various energies using two methods; namely the track profile technique (TPT) and the ove etched track diameter method. A comparison between the measured ranges an calculated ones is presented and a good agreement has been found.

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AN APPROACH TO NUCLEAR CHARGE IDENTIFICATION WITH CR-39 POLYMERIC NUCLEAR TRACK DETECTOR

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ABSTRACT

The etch-rate ratio, V of CR-39 nuclear track detector as a function of initial range, R for $1 \leq Z \leq 26$ nuclei have been determined. On the base of the sensitivity function, V(R) , an attempt has been made to study the possibility of the single-sheet particle identification technique in CR-39 by plotting the calculated etched-track cone length versus the initial range for various ions in the range $0.1 \leq E/A \leq 140$ MeV/u . A correlation has been established between the nuclear charge and the etched-track parameters. The present calculation show the possibility of identifying the charge of a nuclear particle with appreciable charge resolution.

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COMPARISON OF RESPONSES OF CR-39, PM-355, AND CN TRACK DETECTORS TO ENERGETIC HYDROGEN-, HELIUM-, NITROGEN-, AND OXYGEN-IONS

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Abstract

Solid-State Nuclear Track Detectors (SSNTDs) are now widely used in the radiation dosimetry, in various fields of experimental physics, and even in geoscience, medicine, space research, etc. Such applications require the knowledge of accurate characteristics of the detectors used. In particular, for a selected SSNTD one should know a dependance of track diameteres on a type and energy of particles, under chosen etching conditions.

In some experiments on controlled nuclear fusion, to measure fast primary ions (usually deuterons) escaping from a high-temperature plasma, and to investigate nuclear fusion reaction products (mainly fast neutrons, protons, tritons and He-ions), as well as heavy impurity ions, there were applied mostly the CN and CR-39 detectors [1-4]. Recently, more modern plastics of the PM-355 type have also been used [5-6].The main aim of this paper has been to compare responses of modern CR-39 and PM-355 plastic detectors with those of CN-type detectors used previously.

In order to perform the calibration of the selected detectors, the samples made of the CR-39 and PM-355 plastics were irradiated with quasi-monoenergetic beams of protons, deuterons, and alpha particles produced by various accelerators. For different samples, energy of the particle beams was changed in steps equal to 0.2 MeV within a range from 0.2 MeV to 4.5 MeV. The irradiated samples were etched chemically under controlled conditions, in a 6.25-N water solution of NaOH, at a temperature of 70° C, during periods lasting from 2 hrs to 20 hrs. The etching procedure was stopped every two hours, and track (microcrater) diameters were measured with a great accuracy by means of an optical microscope. For the investigated SSNTDs and chosen light ions there were obtained the detailed calibration diagrams showing track diameters versus ion energy for different etching times [5-8].

Recently, analogous calibration measurements have also been performed for monoenergetic N^+, N^{+2}, N^{+3}, and O^+ ions. The paper presents the new calibration diagrams, as obtained for the CR-39 and PM-355 plastics, as well as those obtained for two types of the CN films.

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DIELECTRIC PROPERTIES OF CR-39 SSNTD

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CR-39 is a sensitive SSNTD. Track sensitivity of an SSNTD is a function of i dielectric properties, electrical conductivity and lattice structural attributes. In this wor an experimental study on the variation of the dielectric constant and dielectric loss wit applied frequency and ambient temperature has been undertaken. The motivation of the work is to have a clear understanding on the track sensitivity of CR-39 track detector from the solid state properties point of view.

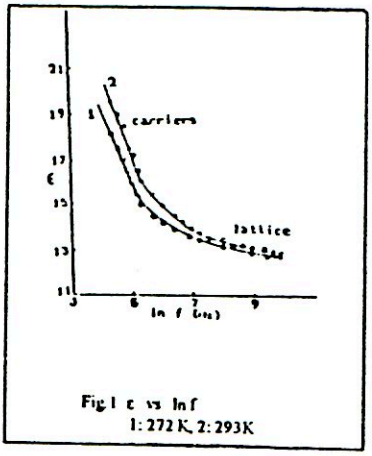

Fig.1 ε vs ln f
1: 272 K, 2: 293K

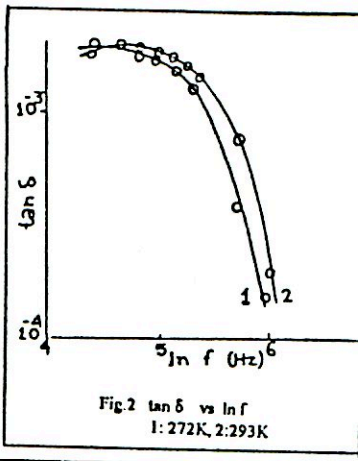

Fig.2 tan δ vs ln f
1: 272K, 2:293K

The capacitance of CR-39 has been measured in vacuum (~ 10^{-2} Torr) with the help of a Universal Marconi bridge of accuracy ± 1%.

The frequency dependence of the dielectric constant at two ambient temperatures is shown in Fig.1. At any particular temperature the dielectric constant decreases with frequency and at any particular frequency it increases with temperature. The increase of dielectric constant with temperature may be attributed to the fact that polarization increases with temperature /1/. The variation of tan δ (= ε" / ε') as given in Fig.2 with frequency reveals the nature of the lossy dielectric relaxation process in CR-39. The dielectric constant shows a somewhat weak temperature dependence as shown in Fig.3 An attempt has been made to make a correlation between the dielectric properties o CR-39 to its SSNTD properties on the basis of carriers and lattice dielectric relaxation processes /2/.

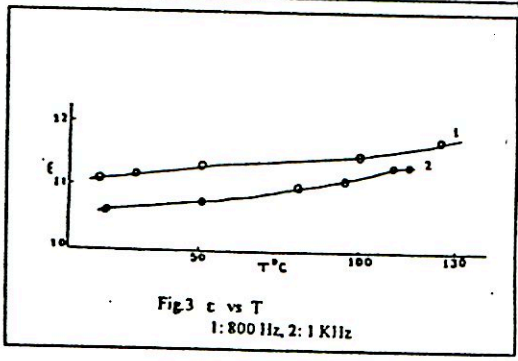

Fig.3 ε vs T
1: 800 Hz, 2: 1 KHz

Reference:
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2. A.K.Jonscher, Thin Solid Films, 50, (1978), 187

DIELECTRIC RESPONSE OF GAMMA RADIATED CR-39 SSNTD

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The dielectric properties and electrical conductivity are important physical attributes of a solid state nuclear track detector (SSNTD) which determines its track sensitivity for nuclear particles. It may be noted that materials of low dielectric constant are characterised by higher track sensitivity /1/. A systematic experimental study has been undertaken to assess the effect of gamma irradiation on the dielectric properties of CR-39 SSNTD. The relative change of the dielectric constant in gamma irradiated CR-39 compared to fresh samples is thus expected to indicate the track sensitivity in these detectors /2/.

CR-39 polymer detectors of 250μ m thickness have been exposed to various doses of gamma radiations from a ^{60}Co source. The capacitance of the samples have been measured with the help of an Universal Marconi bridge (accuracy ± 1%) in vacuum of 10^{-2} torr. The dielectric constant has been measured in gamma irradiated samples before and after these are annealed. The annealing has been done at 40°C for 1 hour.

Fig.1. depicts the ε vs ln f curves for fresh and gamma radiated CR-39 samples. It is observed that the dielectric constant decreases with dose. From these results it may be inferred that irradiation enhances the free carrier density. Fig 2. depicts the ε vs ln f curves for annealed and unannealed gamma irradiated (0.8 gray) CR-39 samples. There is hardly any difference in the dielectric constant measured in the two states of CR-39. It is observed that all the curves have two regions of dielectric response coming seperately from the lattice and the carrier contribution which have been indicated in the figures /3/.

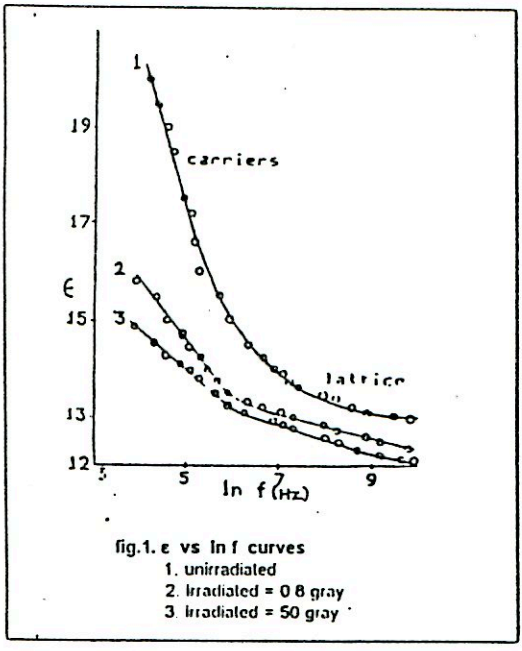

fig.1. ε vs ln f curves
1. unirradiated
2. Irradiated = 0.8 gray
3. Irradiated = 50 gray

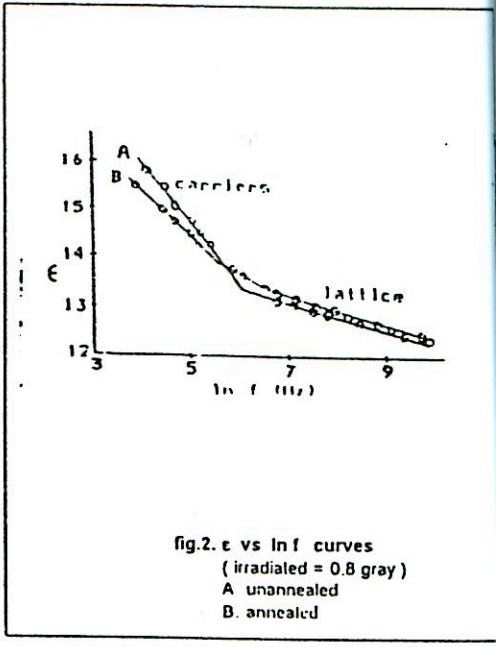

fig.2. ε vs ln f curves
(irradiated = 0.8 gray)
A unannealed
B. annealed

References:
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EFFECT OF CURE CYCLE PARAMETERS AND DOPANTS ON THE ETCHING RESPONSE OF CR-39 TRACK RECORDERS

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Ever since its induction in the family of track recorders, CR-39 has continued to hold a leading place owing to its excellent recording, etching and optical properties. Subsequent attempts have been made to improve sensitivity by copolymerizing the CR-39 monomer with diethylene glycol bis allyl sulphonate (SR-86). Another polymeric detector SR-90 containing oligodiethylene glycol carbonate linkages has been reported to be more sensitive. It is well known that specifically controlled temperature time cure regimes are employed to ensure a more uniform and reproducible response of CR-39 track recorders. In the present work, we have made efforts to investigate the relative etching response of CR-39 detectors having different cure time history and some of them containing dopants too, and the factors possibly responsible for the apparent trends have been identified. Pershore CR-39 detectors [CR-39(8 hr), CR-39 (32 hr), CR-39 (96 hr), CR-39 (DOP), CR-39 (DIOP), CR-39(DNP)] were exposed to 5.45 MeV α particles from ^{241}Am source in vacuum (10^{-2}torr) and in air (at atmopsheric pressure) and etched in 6.25N NaOH solution at 60°C. Bulk etch rate for detectors having a cure cycle spread over longer time is found to be less and V_B for CR-39 containing dopants has been observed to be less than that for CR-39 (no additive) manufactured under identical conditions. Sensitivity has been observed to increase with increase in curing time (in the energy loss region characterized by 5.45 MeV α-particles). Further, doped CR-39 detectors have been found to be more sensitivite. Possible explanations consistent with experimental results have been worked out. Depth dependence of etch rates has also been investigated. Finally, a comparison of optical properties on prolonged etching in high concentration solutions suggests a possible correlation between optical properties and ease of removal of the polymeric etch product Poly Allyl Alcohol (PAA).

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INTS

EFFECT OF GAMMA RAYS ON DIFFERENT TRACK DETECTORS

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The variation of detector properties such as the bulk-etch rate and track-etch rate as a function of gamma exposure dose have been studied in this work. Different plastic detectors such as CR-39 and Makrofol-E were exposed to gamma radiation from a 2kCi ^{60}Co source both before and after exposure to fission fragments from a ^{252}Cf source. The total gamma doses vary from 1 to 10^6 Gray. The effect of post and pre gamma exposure on the two types of detectors were quantified in terms of the activation energy at various doses of gamma radiation.

The thermal responses of the detectors have also been studied by thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The significance of the experimental results is discussed.

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INTS

ETCHING AND ANNEALING CHARACTERISTICS OF BP-1 PHOSPHATE GLASS

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Samples of barium phosphate (BP-1) glass, were irradiated by using ^{238}U (11.4 MeV/u) ion beam available at GSI UNILAC heavy ion facility. Etching characteristics were studied using HF (48 Vol%) and NaOH (6.25N) at different temperatures. The sensitivity, ($S=V_t/V_b$) of BP-1 glass is found to vary between 33 to 63 between temperature range 40 to 70 °C. In comparison with soda and quartz glasses , BP-1 phosphate glass displays far higher sensitivity for heavy ion detection.

For study of annealing characteristics, both isothermal and isochronal experiments were performed on BP-1 glass irradiated with ^{238}U (11.4 MeV/u) and fission fragments from ^{252}Cf source. The annealing kinetics of BP-1 glass can be explained by 'Single Activation Energy model' proposed in our laboratory [Modgil and Virk, Nucl. Instrum. and Meth. B12 (1985) 212]. The activatioin energy of annealing for BP-1 glass is found to be 0.41±0.01eV.

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INTS

GEOMETRY OF ETCHED CHARGED PARTICLE TRACKS IN CRYSTALLINE DETECTORS

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Abstract

Studies on the shape of etched heavy ion tracks in crystalline detectors show that the track geometry carries valuable information on the crystal structure of the detector involved.

The geometry of the etched tracks in crystalline detectors is a prism formed of certain crystal planes. For given etching conditions the type and number of the planes depend on the incident angle and the extent of the radiation damage along the track.

In a single track the type of crystal planes forming the track prism may change along the track resulting in dramatic variations of the track geometry at certain depth of focus. This is contrary to isotropic detectors where track geometry is always conical and the only variable parameter along the track is the cone angle which can change as result of variations of the track etch ratio which itself is a function of the ionisation rate.

In this paper results of our studies on the geometry of HF etched fission tracks in phlogopite mica, using our computer controlled optical microscope will be reported.

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HIGH GAMMA EXPOSURE EFFECT ON CR-39 NUCLEAR TRACK DETECTOR PROPERTIES

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ABSTRACT

CR-39 Nuclear track detectors exposed to high doses of gamma's of up to $5x10^5$ Gy (50 MRad), with an incremental dose of 2.5 MRad from a 9.03 TBq (244) KCi, Co-60 source. The source is used as an industrial irradiator for medical syringe sterilization. The effects of high gamma exposure on bulk etch rate (V_b), tracks etch rate (V_t) and sensitivity (V) of the detectors have shown that they increased linearly with the gamma exposure. As an example, the 40 MRad gamma exposure has shown after 0.5 h etching time with 30% KOH and 60 °C that V_b = 18 μm/ h, V_t = 39 μm/ h and V= 2.2. The gamma exposure from 1 to 20 MRad showed no effect on the surface of the detector. While the surface of the detectors become rough after the 20 MRad. Irregular opening in alpha and fission fragment tracks around the 30 MRad exposure was noticed. The fission fragment tracks disappeared quickly with etching time for the exposure rate above 30 MRad due to the high bulk etch rate. Thus, etching time for few minutes is enough to study the fission fragment tracks while unexposed samples could be etched up to 3 h without any difficulty.

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ON THE CRITICAL ETCHING PARAMETERS OF TRACK DETECTORS

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It is well known that the latent damage trails of heavy ions in solid dielectrics are conveniently revealed by suitable chemical etching process and that the optimal use of any track detector is largely dependent on standardization of various etching parameters. The formation of etchable tracks in a track detector depends on certain critical etching parameters which must be experimentally determined under a suitable etching condition. The determination of critical etching parameters is essential for employing track detectors in the fields of alpha micro-mapping, micro-analysis, radon dosimetry, particle identification, low energy particle dosimetry and in determination of the true track length of heavy ions.

The etching characteristics of mica, Lexan and cellulose acetate have been studied for fission fragment tracks. Under suitable etching conditions a few critical etching parameters (viz. critical track diameter, critical cone angle and critical angle of incidence) for these three track detectors have been determined. An empirical relationship between complete etching time and the etching temperature has been established.

XVIII International Conference on Nuclear Tracks in Solids

Cairo, Egypt, Sept. 1996

SIMULATION OF THE TRACK GROWTH AND DETERMINING THE TRACK PARAMETERS

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ABSTRACT

We found the equation of the etch pit wall in solid state nuclear track detectors
ws:

$$y = -\int \frac{dx}{(V(x)^2 - 1)^{1/2}} + C$$

Where: x is the distance along particle track; V(x) is ratio of track etch rate to the b
rate; C is integration constant that can be determinated from particle penetration de
y is the normal distance from the particle trajectory to the etch pit wall. The equatio
ved assuming the increasing track etch rate V_t along the particle trajectory.
This equation can be used for simulation of the track growth and calculating of ma
minor axis of etch pit opening. The corresponding computer program is set up.
uts of this program are alpha particle energy, incidence angle and removed layer;
out is track parameters. The result obtained by this method are compared with anot
roach given by Somogyi and Szalay.

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INTS

STUDIES ON THE TRACK FORMATION MECHANIZM OF THE HEAVY IONS IN CR-39

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The ionisation damage created by an energetic heavy ion in detector material is caused by the deposited energy of the ion. The measure of this damage is the energy loss rate wich depends on the mass, charge and energy of the ion and on the atomic composition of the detector material.

While the bulk etch rate for a given detector only depends on the etching condition, track etch rate varies with the radiation damage, consequently varies along the track trajektory. The etching properties of CR-39 detector were studied for ^{129}Xe and ^{209}Bi heavy ions with a maximal energy of 13MeV/u.

The irradiation was performed at the UNILAC G.S.I. Darmstadt. The bulk etch rate was measured by gravimetric method, while the track etch rate was derived directly from the function of the successive measured track lenght vrs. etching time. A correlation betwen the track etch rate and energy loss rate is given for heavy ions.

The experimental determination of the track lenght distribution and maximum etchable track lenght for ions by several different energies are also given. A comparison of the measured and calculated track lenght data is presented.

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INT

STUDY OF BUBBLE DAMAGE DETECTORS FOR NEUTRON DETECTION

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Bubble damage detector developed in Canada is one of the most attractive detectors for neutron detection. Remarkable temperatare dependence of its neutron response and limited stability for long use are some of the problems to be solved. The development of bubble damage detectors suitable for use at different places without worrying about temperature and for long time is therefore necessary. We have begun to develop this type of bubble detectors. The results of preparation and calibration of the detectors will be presented.

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INTS

STUDY OF DEGRADED NEUTRON SPECTRA THROUGH MATERIAL MATRIX COMPOSITES USING CR-39 FILMS

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ABSTRACT

Solid state nuclear track detectors have found potential use in nuclear studies and high exposure gamma ray dosimetry. In addition neutron spectrometry work has also been undertaken by various investigators using these detectors. In spectrometry the energy of neutrons was determined either from minor axis of protons tracks observed on the surface of detector or from the use of polyethylene radiators of selected thickness with varying etching time. Using this latter method degraded neutron spectra through material matrix composites (MMC) viz. Al-Li, Pb-Li, Pb-Cd, Al-B_4C, Pb-B_4C have been studied using CR-39 films. These MMC samples were prepared by using powder metallurgy technique. Degraded neutron spectra were obtained by exposing these samples to ^{252}Cf source housed in a camera and the detector used was CR-39 films covered with 1 mm PE radiator. After exposure these films were etched in 6N-NaOH at 60 ^{o}C for different time interval and the etched proton track densities were determined respectively. In addition the other parameters viz. etch induction time, critical removed layer, response function of the detector were also measured. For the calculation of neutron sensitivity theoretically at different energies, a computer programme has been developed. These sensitivity values have been used for obtaining the degraded neutron spectra through different MMC samples. The comparison of these degraded spectra with bare neutron spectrum of ^{252}Cf source shows that there is not much degradation in the energy range from 1 MeV onwards there by suggesting that these materials are useful for attenuation of thermal neutrons in the mixed radiation field. These spectra will also be validated by using Monte Carlo code MCNP.

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STUDY OF SHORTLY ETCHED TRACKS IN POLYMER: A COMPARISON OF DIFFERENT EXPERIMENTAL METHODS

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Polyethylene terephthalate (PET) film samples with the thickness of 10 μm were irradiated by a parallel beam of accelerated Xe and Kr ions. The ion fluence ranged from 10^8 to $3x10^9$ cm. After the subsequent chemical etching the samples were investigated by different experimental methods: small angle neutron scattering (SANS), conductometric technique, and gas flow rate (GFR) measurements. Unlike the usual practice of using SANS for the latent track parameter measurements [1], our study was focused on the initial phase of track etching corresponding to the pore size range of 0 to 50 nm. The radii of gyration found from the SANS experiments were compared with the effective pore sizes extracted from the conductometric and GFR measurements. The agreement and disagreement of the data at different etching times are analyzed and discussed. The present SANS results gave no evidence for capillary contraction of shortly etched track which has been detected by the conductometric and GFR methods [2]. Similarly, no induction time in etching was observed.

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SUBMICROSCOPIC ANALYSIS OF TRACKS IN MICA

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ABSTRACT

Spatial distribution of damage within the activated region of tracks is observed into Å scale. Tracks of 49 MeV ^{35}Cl in mica muscovita were analyzed by transmission electron microscopy up to 10 Å resolution applying the track replica method. An etching induction time of 20 s was determined.

The enlargement of the track radius was measured as a function of etching time from the "new born" track region up to the bulk zone. The track shape evolution shows circular tracks for very short etching times. By increasing the etching time the tracks gradually become ovals, showing different axial track etching velocities. Finally for larger etching times the tracks show the characteristical rhombic shapes of the bulk region.

These data indicate the existence of an amorphous central region close to the ion incidence axis. The shape of the tracks gradually tends to the crystalline structure of the mica by increasing the etching time.

A non continuous decrease of the radial track velocity is reported. We suggest that probably by a post-irradiation rearrangement of the damaged material, a high density crust shell is formed in the region located between the central amorphous zone and the non-perturbed crystalline mica.

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TECHNIQUES FOR CALIBRATION OF SENSITIVITY OF CR-39 DETECTORS USING Am-Be NEUTRON SOURCE

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Techniques for calibration of sensitivity of CR-39 track detectors have been developed by using a Am-Be neutron source, which are divided into short etching technique and long etching technique. The former lies in determining volume track density in CR-39 detectors by measuring areal track density and removal thickness of the CR-39 after short etching time. The Latter lies in determining asymptotic areal track density after long etching.

Two types of CR-39 detectors, type SY-2 made in China and another made in USA, have been calibrated by the techniques. It shows that both techniques are practical and both types of the CR-39 detectors have high sensitivity for detection of fast neutrons.

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INTS

THE DEFINITION OF REGISTRATION PARAMETERS FOR THE DETECTION THEORY.

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Because of the physical nature of a phenomena, any theoretical approach to the problem of measurable track parameters description must be divided in long sequence of separate tasks with its own set of physical parameters corresponding to reciprocal stage of track formation. In general case, this sequence begins from moving of quick ion through detector matter and ends at the moment of track parameters measurement.

This fastest stage of latent track formation, common for any substance, is described by atom collisions parameters such as a cross-section of atomic interaction and characteristics of impacting quick ion. A fast ion strikes out from atom the current of δ-electrons with some energy spectra and this phenomena gives the main input in at the first stage of latent track formation. It almost does not depend on temperature or aggregate state of substances and theoretical calculation methods of this stage of latent track formation are the same for all kinds of detectors.

The primary ion actions together with δ-electrons may switch on long chains of secondary processes depending on concrete material of detectors. In all kinds of detector latent tracks consist of some local structure changing, distributed over track volume. The main parameters of these structure changing are its geometric sizes and characteristic energy need for their initiation. The sizes of these changing are very small and lays in nanometer region. And from mathematical point of view it is comfortable to consider, that this changing are local response of some sensitive micro region existing before exposure.

In some cases the size of microregion is defined only by discrete structure of detector. For example in nuclear photographic emulsions this parameter is defined by size of microcrystal AgBr. In biological issue it is defined by size of separate cell. For polymer or crystal detectors the definitions of sensitive microvolume and its size are not so distinct because in these cases it is formed by two fundamental factors - by spatial frequency of quick ion and δ-electrons interaction with material of detector from one side, and by further physical and chemical processes inside a detector from the another side. The last factor participates also in the formation of the characteristic energy value. So, the parameters of single sensitive region of such a detector may be in state of continues changing. In order to find these parameters by theoretical way it is necessary at microscopic level to solve the next tasks - transformation of atom and molecular excitation energy in set of chemical reactions, diffusion of atoms and molecules from point to point of detector and their further participation in chemical reactions, and in local phase transformation. In some cases there is possible some kind of interactions and energy exchange between different excited microregions of detector matter. It necessary to add the influence of outside conditions at these processes.

The next tasks are connected with a visualization of latent tracks, In order to measure track parameters we have to use any visualization procedure and the registration parameters inevitably depend on some set of this procedure parameters.

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INTS

THE EFFECT OF ETCHING SOLUTION COMBINATION ON THE RESPONSE OF AN ELECTROCHEMICAL ETCHED CR-39 DETECTOR

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Abstract

Etching solutions of different combinations were applied at room (22°C) temperature for electrochemical etching. The background developed during electrochemical etching in a CR-39 track detector was investigated. Detectors irradiated with alphas of 6.1 MeV were measured also. It was found that the PEW solutions (Potassiumhydroxid, Ethylalcohol, Water) showd good sensitivity. One of them ($PEW_{10/10}$) was applied for neutrons of AmBe source. The registration sensitivity achieved was about 10^{-4} spot/cm^2 after 4 hour etching time.

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INTS

Thermoluminescent Detector Response Simulation by the Use of the EGS4 (Monte-Carlo code)

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The first version of EGS4 took root in Stanford (Nelson and Ford). Numerous adaptations (Rogers, Bielajew, Nahum) followed, facilitating its distribution and success, essentially in the dosimetric domain. Its interactivity and complexity insured almost permanent evolution on a planetary level.

We used this EGS4 code, based on a Monte-Carlo method, to simulate a thermoluminescent detector, elaborated by the Nuclear Institute at Sofia.

The simulation was achieved using a source in ^{137}Cs (radius = 0.15 cm) placed on the detector's surface which emitted perpendicularly to the surface. Various parameters were altered : the material of the filter, of the phantom, of the cover and of the presence or not of the phantom.

Since the dimensions are thin, the geometrical decomposition was carried out with the aid of plans and cylinders. In the simulations we defined as many as 33 sectors in which we could determine the distribution of the secondary electrons. All the physical processes (photons : Compton scattering, coherent diffusion, photoelectric effect, production of pairs; electrons: Möller diffusion, Bhabha scattering, bremsstrahlung emission) were taken into account, except for x-ray fluorescence. The calculation of the cross-sections in each medium was achieved with the aid of theoretical formulae, by an arithmetic preprocessor (PEGS4). The follow-up of the particles was executed until an interaction took place, or until its energy fell below a predetermined energy, or when it penetrated into a particular region of space outside the studied geometry. Every particle was taken into account up to 10 keV. The electrons were recorded solely in $CaSO_4(Dy)$. The width of channels were 1 keV. This paper presents the principal results and the comparison with experimental measurements.

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R. Antanasijević, J. Vuković, D. Šević, D. Joksimović, A. Dragić, V. Udovičić, J. Purić and M. Ćuk
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T.A. Islamov, A.A. Kholmatov and V.A. Ditlov
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I.E. Qureshi, , M.I. Shahzad, S. Manzoor, M.S. Zafar and H.A. Khan
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Investigation of nuclear reaction products by atomic force microscopy

E.U. Khan and F.N. Khattak
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E.U Khan, R. Zafar and F.N. Khattak
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Some salient features of the reaction Xe + U at 17 MeV/N beam energy

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Studies on nuclear fission of actinides and preactinide elements using solid state nuclear track detectors

V.P. Perelygin, S.G. Stetsenko, R.I. Petrova and D.S. Yadav
Study of fossil tracks due to Fe-group and Z ≥ 36 cosmic ray nuclei in olivine crystals from Luna- and Luna-24

S.-L. Guo, Y.-L. Wang, C.-Q. Tu, R. Brandt, P. Vater, B. Sa, Y. Zheng, Y.-L. Liu, W.-J. Zheng, X.-Hu, B.A. Kulakov, M.I. Krivopustov, V.S. Butsev and V. Bradnova
Systematic studies of neutron generation from relativistic heavy ion interactions by CR-39 and nuclear emulsions

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INTS

Angular distribution of positive particles emitted from deutherium plasma focus

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Angular distribution of positive particles emitted from deutherium plasma focus device was determined using LR-115 detectors. Discrimination of positive particles was achieved by varying the widths of Al layers. The angular distributions of different positive particles were compared, also.

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APPLICATION OF AgBr EMULSION DETECTOR IN β-SPECTROGRAPHY TO ANALYSIS OF NUCLEAR STATES

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The spectra of the conversion electron emitted by the radioactive rare-h elements with short-life were explored by the precise β-spectrograph the base of the photographic glass-plates covered with the R-type nuclear lsion which is a variety of the solid track detectors and produced by the earch Institute for Chemical Photo-Engineering.

The spectra obtained were worked by using the optical black turning ed by the tracks of β-electrons, in the automatic microphotometer con-ed with IBM computer. The errors of the black turning densities and of intensities of the lines of the conversion electron spectra were elaborated. It was obtained the experimental dependence of the sensitivity of the tographic glass-plate with the nuclear emulsion on the electron energy in rval from 3 to 3000 keV. The same dependence was calculated by using ov's method considering emulsions as a private case of solid state detector including multiply scattering of electrons in frame of one-hit response el of the AgBr microcrystals. A good agreement of the theoretical and rimental results was demonstrated.

On the base of calculated and experimental data, the lines of conversion rons that correspond to more than 100 γ-transitions on L-, M-sub-shells oms with Z=50÷75 were studied. This allowed us to analyze the prop-s of the complex nuclear states.

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Application of Quartz Glass Tubes as the Track Detectors for Chemical Identification of Short-Lived Isotopes of Elements 104, 105 and 106

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Abstract

The guartz glass open cromatographic columns with thermal gradient, which usually were used for investigations of chemical properties of short-lived Z≥104 nuclides, were first used as the track detectors of spontaneously fissing isotopes of elements 104, 105 and 106. The recoil nuclei of these elements were captured by the flow of gaseons chlorides then go to the guartz tube with reducing thermal gradient 400°-100° C. The positions of trace radioactive elements - chemical analogs of elements 104-106 in quartz glass column were determined by β-counting. After experiments the guartz tube was etched in 40% HF during 7-11 min.The tracks due to spontaneous fission of isotopes ^{259}104, ^{262}105 and ^{263}106 which were etched at the internal wall of guartz tubes were counted under optical microscope. Diameter of guartz tube was ~ 4 mm, the thickness of the walls - 0.4-0.6mm.

In order to improve the guality of fission fragment track image we cover the top part of tubes with 60 μm thick high quality polyterephtalate plastic with immersion oil between plastic cower and glass tube. The special microscope stage provides us the scanning each tube along the inner surface and rotating around the main axe of tube. The spetial water-wapour quartz glass which contains ≤ 10^{-15} g/g of U was used for manufacturing of quartz glass tube columns for the experiments on investigation of chemical properties of short lived isotopes of elements 104, 105, 106.

DOUBLE SEQUENTIAL FISSION IN THE REACTION (16.7 MeV/u) U + Au OBSERVED WITH MICA DETECTORS

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Abstract

One of the main advantages of using dielectric track detectors in the study of heavy ion interactions is the possibility of observing each multi-prong event individually with complete kinematical details. It is thus possible to analyse even those reaction channels that have very low branching ratioes. In the study of reactions induced by 16.7 MeV/u uranium ions incident on natural gold targets, we have observed 18 four-pronged events in a total detector area of 24 cm^2. Using a polynomial range-energy relationship, empirically fitted to the observed data of binary and ternary events, it was possible to perform kinematical analysis of 12 out of 18 events. The masses, Q-values and relative velocities of the reaction products, determined in this analysis were compared with theoretical prediction based on double sequential fission process. An agreement within one standard deviation with respect to experimental values has been found for all analysed events.

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INTS

Effect of space environment on the response of $CR-39(DOP)$ Detectors

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Ionization states of individual ions in the low energy (10-150 MeV/N) anomalous cosmic rays (ACR) are determined in the Anuradha experiment conducted onboard Space Shuttle Spacelab-3 mission during April-May 1985. A combination of the most sensitive passive plastic detector ($CR-39(DOP)$) and an active electromechanical system allow us to obtain accurate information on the arrival locations and directions of individual ACR ions . We present here some of the results of our measurements from the scanning of complete top stack (area $\sim 800cm^2$) of the Anuradha detector. This instrument has passive as well as active thermal control and the detector module was kept at 0.1 atmosphere pressure during the space exposure. Our analysis of the data has shown that the response and the charge resolution of the detector is changed. The response function of $CR-39(DOP)$ has linear as well as exponential parts and it is the linear part of the response function which is affected by the space exposure. It is also shown here that the temperature and the pressure during exposure are important parameters for improving the charge resolution beside the measurement errors.

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HEAVY ION RADIOACTIVITY STUDIES USING THE FOSSIL TRACKS IN MINERALS

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Due to the difficulties to produce a large area source of heavy ion emitter radionuclides, the authors tried to obtain information about natural heavy ion radioactivity using fossil the tracks registered during geological time in minerals with crystalline layer . The U and Th impurities in minerals represent the heavy ion source (especially U and Th inclusions are considered). Three minerals - apatite, biotite mica and muscovite mica - were studied from the following points of view:

- the U and Th contents;
- the easiness to distinguish the tracks;
- the possibility to discriminate the tracks of different particles such as: spallation recoils, heavy ions, fission fragments, interactions with mineral constituents and crystalline layer dislocations;
- the registration of heavy ions predicted in [1] to be emitted by U and Th, i.e. $^{24-26}$Ne, ^{30}Mg and ^{32,34}Si ions;
- the possibility to study a large mineral area at low magnifications by optical microscopy.

From the three minerals, the muscovite mica was chosen. An area of 4680 cm^2 of muscovite detector was studied by optical microscopy.

For these mineral the branching ratio λ_{H1} / λ_{SF} has been determined after solving the following problems:

- calibration of muscovite mineral detector for the heavy ions of theoretically predicted mass, atomic number and energy (A, Z, E) . A HV-FN Van de Graaff tandem accelerator was used to obtain the beams of nearly heavy ions;
- discrimination of tracks which belong to different registered particles by using the track patterns;
- establishing of possible track origins in muscovite mica;
- preserving of the track patterns at high etching durations.

Reference:

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Investigation of Neutron Spectra emitted from 44 and 22 GeV $^{12}C+Cu$ Interactions by Nuclear Emulsion.

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Fast neutron spectra produced in 44 and 22 GeV $^{12}C+Cu$ interactions have been measured and analysed with nuclear emulsions of 8 cm in length, 2.2cm in width and 400 μm in thickness made in China Institute of Atomic Energy, Beijing, China. The irradiation of the emulsions were carried out at the accelerator SYNCHROPHASOTRON, Joint Institute for Nuclear Research, Dubna, Russia. The neutron spectra were obtained by measuring the recoil protons in emulsions and the track parameters of α particles from interactions of $^{12}C(n,n')3\alpha$ in emulsions. The experimental neutron spetra were compared with the Monte–Carlo calculations. The more details will be described in the paper.

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Investigation of Nuclear Reaction Products by Atomic Force Microscopy

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ABSTRACT

The use of Atomic Force Microscope (AFM, from Corporate Head, Santa Clara, California, USA) opened a new way to study latent nuclear tracks. It gives a possibility to investigate the dynamism of the track formation in the early stage of chemical etching, it gives information about the extent of the demaged zone etc. and by this way it could become possible to review the track formation models and mathematical procedures, applied so far, to make relations between measurable track parameters and damaging charged particles.

In our experiments we used plastic track detectors of the type CR-39 (Columbia Resin No. 39) which was polymerised from $C_{12}H_{18}O_7$ monomer and became a transparent, solid plastic nuclear track detector with a good optical characteristics. Cross-linking between different layers provides a strong binding. Impinging ions with energy above a threshold of 300 keV can alter the molecular structure forming latent tracks. Since nuclear latent tracks have diameters in the range of 10 to 1000 nms, they can be visualised by AFM without or with a slight chemical etching (6 min in 6 n NaOH solution at 70 °C).
The latent tracks are significant for the energy, momentum and the mass of the incoming particles.

In our study, passive CR-39 detectors were irradiated by secondary particles produced by the bombardment of ^{103}Rh by ^{16}O and ^{12}C in a wide range of energy (1 amu to 33 amu) at the MP Tandem generator of the Laboratorio Nazionale del Sud in Catania, Italy.
The experiment was carried out in order to identify the secondary particles and to determine their density and the spatial distribution. In the same time, the latent track formation properties and natural background of the track detector was studied by the AFM and would be reported along with the details about the nuclear reaction mentioned above.

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INTS

INVESTIGATION OF THE REACTION Pb + Au AT 14.0 MeV/N USING TWO DIFFERENT THRESHOLD SSNTD

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We have studied the reaction Pb + Au at 14.0 MeV/N using two different thresho detecors, mica and cellolose nitrate. In the present paper, we will prese partial cross sections of various multiplicitis as observed in both the detecto and discuss the result in light of the light particle emission.

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INTS

REGISTRATION OF PARTICLES AT WIDE ANGLES EMITTED IN THE COLLISION OF RELATIVISTIC HEAVY IONS WITH COPPER BLOCKS

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A copper target of 1 cm thickness was irradiated with 3.65 AGeV O^{16} beam at the Joint Institute of Nuclear Research, Dubna, Russia at normal incidence. The copper block was of 2 cm diameter. A stack of 100 CR-39 detectors was placed at an angle of 25° with respect to the beam direction so that the first detector was at the distance of 17 cm from the target. After the irradiation of the stack, a number of CR-39 detectors were etched in 6 N NaOH solution at 60°C for various times in series of steps up to a maximum of 15 hours. The tracks were measured for sizes and densities in each step in the detectors placed at various positions in the stack. A comparison of the data obtained from the above mentioned stack was made with the data obtained from the stack placed in the beam hollow in order to calibrate the detectors.

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INTS

SEARCH FOR THE TERNARY CLUSTER-DECAY OF Cm ISOTOPES WITH SSNTD

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The discovery of the cluster radioactivity as well as the observation of resonant phenomena in light "alpha-cluster" nuclei caused a search for possible clasterization effects in heavy nuclei.Some indications of the preformation of three nearly equal clusters in spontaneous fission of 244Cm were obtained in the preliminary experiment at Fobos set-up (electronic device) in the FLNR JINR.

This work aims at continueing the search for the ternary cluster decay of the 244Cm. 50 "sandwiches" made of 185mkm Melinex sheets with thin 246Cm layers between the sheets were prepared. For correlation of fission fragment tracks each "sandwich" was irradiated, treated and scanned together with a special support. The experimental procedure and the first results are presented in this work.

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INTS

SOME SALIENT FEATURES OF THE REACTION Xe + U AT 17 MeV/N BEAM ENERGY

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We have studied the heavy ion nuclear reaction of Xe + U at 17.0 MeV/N beam energy using muscovite mica as SSNTD. After bifurcation of elastic data from the all observed binary events, reaction cross section was determined using two independent methods. Inelastic binary and multi-prong events have been analysed to determine the velocities and masses of all the final fragments. Gottschalk's empirical range-mass-energy relationship was used for the purpose for which the coefficient were determined from the experimental data of the elastic events. Some useful information has been derived about the first and second reaction satges.

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APPLICATION OF SSNTDs FOR STUDY OF BORON DISTRIBUTION IN ALLOYS

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Well-known SSNTD technique has been applied to study boron behavior and its distribution in some boron doped materials such as iron-base and nickel alloys subjected to various treatment conditions. The technique is based on detection of $^{10}B(n,\alpha)^{7}Li$ reaction products with etchable track detectors. The irradiation facilities had been used were research WWR (INP, Tashkent) and TRIGA MARK-3 (KAERI, Seoul) reactors.

Boron being a surface active element is known to tend to precipitate on various imperfections like dislocations, structure damages, grain boundaries and others under proper treatment conditions. Two kinds of iron-base specimens, viz., austenitic stainless and low alloy steels, and also nickel alloys with a variety of boron content have been subjected to boron distribution study.

Boron segregation on grain boundaries of both austenitic and low alloy steels has been observed. The latter specimen was hot rolled with final deformation temperature of 850^{0} C. For the samples of another treatment conditions (heated and furnace cooled, and heated and water quenched) any preferable localization was not observed.

From the experiments with nickel alloy ingot boron has been clearly shown to precipitate strongly at grain boundaries and interdendritic spaces. After hot and/or cold rolling boron rearrangement along with the proper deformation of the structure took place.

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STUDIES ON NUCLEAR FISSION OF ACTINIDES AND PREACTINIDE ELEMENTS USING SOLID STATE NUCLEAR TRACK DETECTORS

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ABSTRACT

SSNTDs have been in use in our laboratories for over two decades as an experimental tool for carrying out a number of basic investigations in nuclear chemistry and physics. Extensive use of these detectors has also been made for applications in many areas such as microanalysis, dosimetry, uranium exploration and very recently as supported liquid membranes for cation transport. In this paper, an overview of the current research in BARC on nuclear fission and related areas using SSNTDs are discussed. Basically this paper is divided into 4 parts.

1- ^{4}He-ION INDUCED FISSION OF THE LOW Z ELEMENTS

The helium-ion induced fission excitation functions of natural ytterbium (Z=70), natural erbium (Z=68), holmium (Z=67), dysprosium (Z=66) and terbium (Z=65) were studied in the He ion energy range of 30-70 MeV using the Variable Energy Cyclotron at Calcutta. The helium-ion-induced fission of ^{197}Au was also studied as a representative lighter element in the closed shell region to enable a comparison of the properties of nuclei in the deformed region with those in the closed shell region. The fission cross sections of these system were measured by using lexan plastic detectors. The experimental details and the methods of data analysis are described in some of our published papers[1]. The fission excitation functions were analysed using a statistical model. From this analysis, the fission barriers for ^{201}Tl, $^{177.1}$Hf, $^{171.3}$Yb, ^{169}Tm, $^{166.5}$Er and ^{163}Ho compound nuclei were determined to be 19.3±2.5, 26.7±3.0, 27.8±3.0, 29.8±3.0, 29.2±3.5 and 31.5±3.5 MeV respectively. The data from the present experimental work have been used along with similar data available in the literature to bring out some systematics in the fission properties of low Z elements. In this paper major conclusions of the present study on ^{4}He ion-induced fission of the low Z elements are discussed.

2- HEAVY-ION-INDUCED FISSION OF LOW Z ELEMENTS

The study of heavy-ion-induced fission of low Z elements provides unique opportunities to understand the fission properties of high spin fissioning systems and to test theoretical models. With a view to understanding the effect of angular momentum and entrance channel on fission probability and fragment anisotropy, the fission cross sections and fragment angular distributions of the ^{181}Re compound nucleus produced by two target + projectile combinations (^{12}C+^{169}Tm and ^{16}O+^{165}Ho) and the compound nucleus ^{213}Fr (^{16}O+^{197}Au) were studied at several bombarding energies above the fusion barriers using the heavy ions from the BARC-TIFR Pelletron facility in TIFR, Bombay. 'Lexan' track detector was used for detecting fission fragments. Lower energies were chosen for ^{181}Re compound nucleus where no experimental data are available and where the average angular momentum, $\langle l \rangle_{av}$, of the ^{16}O+^{165}Ho system is lower than that of the ^{12}C+^{169}Tm system. The data obtained in the present studies were used to test the models which predict angular dependent fission barriers. Since the present studies provided fission fragment anisotropies over a large range of $\langle l \rangle_{av}$ values at medium excitation energies where only single chance fissions are probable, it was interesting to examine the variation of anisotropy as a function of $\langle l \rangle_{av}$ and get some new insights regarding effective moment of inertia, J_{eff} and the shape of the nucleus at the saddle point. In an effort to obtain a sigle variable which accounts for the effects of both X and $\langle l \rangle_{av}$ and which can explain the variation of J_{eff}, 105 experimental values of J_{eff} obtained from the fission fragment angular distributions of 26 compound nuclei were analysed. From the analysis of the J_{eff} data, it was observed that the J_{eff} values over a wide range of X and $\langle l \rangle_{av}$ are well represented by the single parameter.

3- MEASUREMENT OF ABSOLUTE FISSION YIELDS IN THE FAST NEUTRON FISSION OF ACTINIDES

The measurement of absolute fission yields in the fast neutron fission of actinides is important not only because these are required for an understanding of the nuclear fission process in general but also because of the fact that accurate fission product yields are needed for a number of applications such as reactor safety, burnup, spentfuel management, safeguards etc. The measurements of absolute fission product yields require the fission rate to be monitored. As part of an IAEA supported project, we have measured the absolute fission product yields in the fast neutron fission of ^{238}U (99.9997 atom percent), ^{237}Np, ^{240}Pu (99.48 atom percent), ^{241}Am (99.998 atom percent) and ^{244}Cm (99.43 atom percent). The total no. of fissions occuring in the target were determined by fission track technique and the number of atoms of a given fission product nuclide by high resolution gamma ray spectrometry. The targets were irradiated in the swimming pool reactor APSARA and also in the pneumatic irradiation facility of CIRUS reactor at Trombay (for short lived fission products). The absolute yields of several fission products with half lives ranging from 1 minute to several months were measured. Most of the yields of short-lived fission products in the fission of ^{238}U and ^{237}Np and all the yields in the fission of ^{240}Pu and ^{241}Am are measured for the first time time[2].

4- BASIC DEVELOPMENT IN THE TRACK TECHNIQUE FOR THE APPLICATIONS IN FISSION STUDIES

In this section, the results of following studies are also discussed :

1- Development and optimization of a sequential etching procedure for revelation of alpha and fision tracks in CR 39 and its application in measurements of alpha to spontaneous fission branching ratios of actinides.

2 New Lexan catcher techniques for measurement of absolute fission yields in spontaneous fission and neutron induced fission of actinides.

References:

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STUDY OF FOSSIL TRACKS DUE TO Fe- GROUP AND Z≥ 36 COSMIC RAY NUCLEI OLIVINE CRYSTALS FROM LUNA-16 AND LUNA-24

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The olivine crystals from lunar regolith samples taken by the Soviet unmanned spacecrafts Luna-16 and Luna-24 were investigated.

The olivine crystals were mounted in epoxy, polished and then etched in modified WO_4 solution. The track densities up to 10^8 t/cm^2 (VH-group) were measured under optical microscope. The tracks of length a greater than 20 microns are counted for VVH track density determination. The track density of VH and VVH tracks is plotted in Fig.1 for 11 lunar olivine crystals.

Fig.1 shows that the crystals for which VH track density is about 10^8 t/cm^2 had probably been at least once on the moon surface during their irradiation history while the crystals which possess low track density (10^6 t/cm^2) might have suffered vigorous mixing or had never been on the lunar surface. The VVH/VH track density ratio for these lunar olivine crystals varies from 1.25×10^{-4} to 2×10^{-3}. It corresponds the depth of these crystals in lunar soil 2-8 cm.

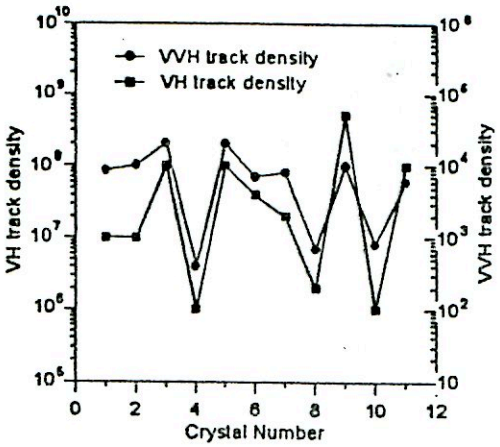

Fig.1 The track density of VH and VVH nuclei in various lunar olivine crystal

Lunar crystals well suited for VVH track studies due to a very high track density. The crystals are annealed at 430° C for 32 hrs. This anneals iron groups tracks completely and leaves etchable tracks of nuclei with Z≥50 even in the olivine crystals with Fe- group tracks up to $1\text{-}2.10^8$ t/cm^2 were able to measure two tracks with the length 195 and 210 μm, which were produced with Th-U group of Galactic cosmic ray nuclei. It means that lunar olivine crystals can be used for the investigations of 50≤ Z≤110 cosmic ray nuclei..

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SYSTEMATIC STUDIES OF NEUTRON GENERATION FROM RELATIVISTIC HEAVY ION INTERACTIONS BY CR-39 AND NUCLEAR EMULSIONS

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Neutron generation in relativistic heavy ion interactions is an important subject not only in nuclear reaction mechanism at very high energy but also in applications of fast neutrons in accelerator-driven subcritical reactors. Systematic studies have been carried out of neutron generation in the interactions of 44 and 22 GeV ^{12}C with Cu and Pb targets. The properties studied include:

(1) Angular distributions of secondary neutrons measured with CR-39 stacks around the targets from 0° to ~150° to the heavy ion beam, which show that the emission angle of fast neutrons has a strong forward preference.

(2) Energy spectra from 0.4 to ~ 1000MeV of secondary neutrons measured by means of recoil protons and ^{12}C (n,n') 3α reactions in nuclear emulsion, which show that most of the neutrons have energy less than 20 MeV and the number of neutrons decreases rapidly as the energy of neutrons increases, but there are existed measurable high energy neutrons.

(3) Relative yields of secondary neutrons generated in 44 GeV versus in 22GeV ^{12}C bombardment to Cu target and also to Pb target, the ratios of which are around 2, which are larger than the values of theoretical calculations.

(4) Relative yields of secondary neutrons produced in Pb target versus in Cu target. The ratios obtained are 2.54 ± 0.20 and 2.56 ± 0.20 for 44 GeV and 22 GeV, respectively. More neutrons are generated in Pb target than in Cu target.

(5) Average numbers (yields) of secondary neutrons produced per each heavy ion have been derived by integrating over all directions and all energies.

The implications of the above properties are expounded in nuclear reaction mechanisms and in applications in accelerator-driven nuclear reactors.

The studies show that inexpensive solid state nuclear track detectors combining with nuclear emulsion can bring about plenty informations on relativistic heavy ion interactions and another advantage of these detectors is providing chances for scientists in developing countries to catch up with the advanced countries in the studies of frontier sciences.

Environment & Radiography

Z. En, N. Jumaev, M.M. Usmanova, H.J. Kim, J.H. Ho and J. Jang
Application of SSNTDs for study of boron distribution in alloys

P. Saritepe, T. Güzel, T. Akyüz, Yu.Ts. Oganessian, C. Bolcal, S.P. Tretyakova, T. Saltoğlu, N. Kirath and N. Cağtay
Determination of concentrations of fissionable elements in the Black Sea sediment samples before and after Chernobyl using dielectric detectors

S.F. Boulyga, N. Erdmann, H. Funk, M.K. Kievets, E.M. Lomonosova, A. Mansel, N. Trautmann, O.I. Yaroshevich and I.V. Zhuk
Determination of isotopic composition of plutonium in „hot" particles of the Chernobyl area

T. Güzel, T. Akyüz, C. Bolcal, P. Saritepe, S.P. Tretyakova, Yu.Ts. Oganessian and T. Saltoğlu
Determination of uranium and thorium concentrations in Turkish lignite coal ashes using neutron radiography

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Track detectors in radiation monitoring of sunken submarine "KOMSOMOLETS"

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Uranium measurements in soil, rock and plant samples of Himachal Pradesh using solid state nuclear track detectors

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INTS

THE DEPENDENCE OF THE DISTRIBUTION OF DAMAGE ON TRACK STRUCTURE ALONG SWIFT HEAVY ION PROJECTED RANGE

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Samples of silicon have been irradiated by heavy ions of Krypton with energy 210 MeV in a direction parallel the [111] plane at fluences from 8.0×10^{12} to 3×10^{14} ions/cm^2. The distribution of damage concentration at various fluences has been investigated by x-ray difractometry step by step along the projected range of ions. Before each experiment of x-ray analysis the irradiated samples were polished to feature size of 0.5 mkm with diamond paste. Therefore the changes of the lattice parameter of silicon was investigated with this spatial resolution. The dependence of the silicon lattice parameter (R = a/a) on fluence has been used to recalculate the vacancy concentration.

It was observed that the vacancy rate increases with fluence at low fluences (between 8×10^{12} and 4×10^{13} ions/cm^2) and that the straggling zone (Bragg peak) has single peak structure. At higher irradiation fluences the shape of this zone became two peaks one.

This result may be understood with the help of a mechanism of production of the the special structure in silicon by each heavy ion. According to the creation of a heavy ion track is associated with a decrease of atom volume density around the ion trajectory. Calculations of the reduced density have been carried out.

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DETERMINATION OF CONCENTRATIONS OF FİSSİONABLE ELEMENTS IN THE BLACK SEA SEDİMENT SAMPLES BEFORE AND AFTER CHERNOBYL USING DIELECTRIC DETECTORS.

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ABSTRACT

The Black sea is surrounded by Bulgaria, Georgia, Romania, Russia, Ukraine and Turkey. It is the largest anoxic marine basin in the world and is a restricted basin connected to the Marmara Sea through the Bosporus strait.

Black sea sediment samples (total 69) obtained in 1978 and 1989 as surfacial sediments. The fissionable elements content, particularly uranium, of the samples were determined by fission fragments radiography using solid state nuclear track detectors. Irradiations were performed on MT-25 Microtron of FLNR, JINR, Dubna. The sensitivity of used technique is very high, it is possible to measure radioactive element concentrations from 10^{-8} to 10^{-15} g/g.

The evaluation of degree of pollusion incured in the Black Sea sediments, before and after Chernobyl has been investigated. The degree of pollusion in the east part of Black sea, especially near Georgia region is higher both in before and after Chernobyl samples.

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DETERMINATION OF ISOTOPIC COMPOSITION OF PLUTONIUM IN "HOT" PARTICLES OF THE CHERNOBYL AREA

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addition to the determination of the total content of transuranium elements (TUE) in ironmental samples the knowledge of their isotopic composition is of great interest because m these data statements about the origin of the TUE can be made. So far mainly radiometric hods as well as neutron fragment radiography have been used for the detection of the fissile alpha emitting nuclides of the TUE with the disadvantage that these methods have itations in the isotopic resolution. An alternative technique is resonance ionization mass ctrometry (RIMS) which possesses an excellent sensitivity and a good isotopic resolution and allows the measurement of the content as well as the isotopic ratio of a desired nsuranium element.

e of the most radiotoxic element released during the Chernobyl reactor accident was tonium with the alpha emitters ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu and the beta-emitter ^{241}Pu which ays into ^{241}Am. The determination of plutonium in "hot" particles from the Chernobyl ctor was accomplished in such a way that "hot" particles have been extracted from samples erosols collected in the vicinity of the Chernobyl Nuclear Power Plant after identification h solid state nuclear track detectors (SSNTD) registering the alpha particles. The most ve particles have been measured by alpha spectroscopy after chemical treatment. The lts are given in Table 1.

Table 1. Alpha-activities of plutonium isotopes in "hot" particles, Bq

Isotope	1	2	3	4	5	6
$^{239+240}$Pu	$2.8\cdot10^{-4}$	$3.8\cdot10^{-4}$	$3.1\cdot10^{-4}$	$4.3\cdot10^{-4}$	$7.6\cdot10^{-4}$	$8.1\cdot10^{-4}$
^{238}Pu	$1.3\cdot10^{-4}$	$1.6\cdot10^{-4}$	$1.3\cdot10^{-4}$	$1.8\cdot10^{-4}$	$3.2\cdot10^{-4}$	$3.2\cdot10^{-4}$

thermore, one of the "hot" particles has been investigated by RIMS in order to perform a plete analysis of the isotopic composition.

le 2 gives the data of this measurement together with calculated values [2] taking into count the operation data of the Chernobyl reactor. There is a rather good agreement. The iation for ^{238}Pu is due to the fact that the number of atoms in the sample for RIMS was er small causing a large error.

Table 2. **Isotopic composition of plutonium in a "hot" particle measured with RIMS in comparison with calculated data [2].**

Pu-isotope	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu
Measured isotopic composition [%]	0.8	69	23	5	1,5
Calculated [2] isotopic composition [%]	0.22	64,6	27,6	5,5	2,2

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DETERMINATION OF URANIUM AND THORIUM CONCENTRATIONS IN TURKISH LIGNITE COAL ASHES USING NEUTRON RADIOGRAPHY.

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ABSTRACT

Uranium and Thorium concentrations in lignite coal ashes, obtained from lignite coals that were taken from different 'Lignite Deposits' of Turkey, have been determined by neutron radiography using solid state nuclear track detectors (SSNTDs).

It is known that some low quality lignite coals contain uranium, thorium and some other radionuclides in significant amounts. The low grade lignite, in coal power plant, is pulverized and during the combustion process; the uranium that is bounded to lignite organically, is enriched in the inorganic matrix, i.e., it is accumulated in the ash. Therefore, there are uranium, thorium and some other radioactive elements in the volatile ashes and precipitated ashes, arising from combustion by products. These ashes are deposited outside the fabrication areas. They form ash hills, by time. Some technologic studies have been done to use these ashes economically. For example, using the ash as an absorber of organic parts from the waste-water. It should be noted that these ashes can be dangerous for environment, since they contain toxic and radioactive materials.

Neutron irradiations were performed on MT-25 microtron of FLNR, JINR (Dubna). The total concentration of uranium and thorium is found between 10^{-4}- 10^{-6} g/g. The usual acceptable concentration of the fissionable elements in soil is 10^{-6} g/g. For the irradiation conditions on this experiment, the efficiency is 10^{-8} g/g.

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INTS

DISTRIBUTION OF THORIUM IN GAS LANTERN MANTLES

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Abstract

Natural thorium is used for producing luminescence in gas lantern -manil@. @orturn ls introduced into the mentales by impregnating the fabric mesh with thorium nitrate. This was confirmed by I-spectroscopy. The distribution of thorium in mantle sample was studied through detecting alphas emitted by thorium and its danghters using nuclear track detectors type CR-39, 2 x 2 cm2. The Detectors were placed over a gas mantle for different periods. It was found that there is a linear relationship between exposure time and alpha track density and for the same exposure time, alpha track density is nearly equal on the different locations of the same mantle.

The distribution of thorium in the whole gas mantle was also checked by placing the mantle directly on x-ray film and on CR-39 detector successively to detect emitted alphas. The results confirm uniform distribution of thorium in the mantle fabric.

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INVESTIGATION OF BORON DISTRIBUTION IN SEMICONDUCTORS AND Mo-Re ALLOYS BY SSNTD METHOD

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Boron is in wide use as doping element in semiconductors, metals and alloys. Such processes as boron ion implantation and thermal diffusion in the $Cd_xHg_{1-x}Te$, SiC, Si and some alloys are characterized by non-uniform surface and volume distribution of boron because of damages of crystalline structure.

SSNTD techniques have been developed to control non-uniformity of boron distribution on a surface of $Cd_xHg_{1-x}Te$, to study boron behavior in polycrystalline β-silicon carbide, to determine local boron concentration and its microdistribution in monocrystalline silicon carbide, silicon, "mosaic" silicon structures and Mo-Re alloys.

The boron distribution determination techniques were based on the detection of alpha-particles from the $^{10}B(n,\alpha)^7Li$ reaction with cellulose nitrate film.

To study deep boron diffusion in layered silicon structures a technique of small angle section about $1\text{-}5^0$ has been elaborated.

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INTS

INVESTIGATION OF RADIOACTIVITY AND SIZE DISTRIBUTION OF HOT PARTICLES BY MEANS OF SSNTD

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By means of solid detectors the structure of track "stars" created by "hot" particles trapped by filters from atmosphere near Chernobyl PS has been studied.

Thin filters (about 1 μm thickness) containing "hot" particles were driven into a contact with a detector (mica ftorflogopit) and they were irradiated by the flux of thermal neutrons. Separate tracks and stars of tracks of hot particles were observed in the optical microscope after a chemical etching of the detector. Some filters were studied by means of detector CR-39. The structures of track stars of fragments and track stars of alpha-particles created by the same hot particle were compared.

It has been shown that stars of fragment tracks make possible to define sizes and forms of hot particles with a much greater accuracy than stars of alfa-tracks and to analyse the distribution of the disintegration impurity in the volume or on the surface of hot particles.

We have established the following:

1. Sizes of hot particles change in wide ranges - from fractions of 1 μm up to 0.1 sm.
2. Both free particles and particles attached to carriers have been observed.
3. Concentration of the disintegrating impurity changes from 10^{-6}% to 10^{-3}%.
4. Atoms of disintegrating impurity are concentrated mainly on the surface of particles. Only separate particles contain disintegrating impurity not only on the surface but in the bulk.
5. About 10 % of particles have a non-spherical form. As a rule in such particles a disintegrating impurity is distributed along the whole bulk.
6. Sometimes localized clusters of hot particles joined by the common carrier are met.
7. By means of local micro-X-ray spectral analysis there was found established the material of separate large particles-carries.

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INTS

Measurement of Natural Radioactivity in Jordanian Sand

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Abstract

The natural radioactivity in construction materials is a major source of indoor radiation exposure to the occupants. For proper selection of the dwelling materials, it is essential that the activity contents in these materials must be measured. Sand is a major constituent of the materials used in the construction of dwellings. To measure natural radioactivity, 25 sand samples were collected from Amman, 25 from Jarash-Irbid and 23 from Ghor-Karak areas. Radium-226, thorium-232 and potassium-40 activities in these samples were measured using gamma ray spectroscopy technique. The measured Ra-226 activity in the sand samples, collected from Amman area, varies from 16.35 to 25.16 Bq/kg, Th-232 activity varies from 7.11 to 13.21 Bq/kg and K-40 activity varies from 81.23 to 99.23 Bq/kg. For sand samples collected from Jarash-Irbid region, Th-232 activity varies from 3.45 to 17.14 Bq/kg, Ra-226 activity level ranges from 14.82 to 59.43 Bq/kg and K-40 activity level ranges from 65.8 to 263.2 Bq/kg. For Ghor-Karak region sand samples, Th-232 specific activity ranges from 16.3 to 28.5 Bq/kg, Ra-226 activity ranges from 22.7 to 32.36 Bq/kg and K-40 activity ranges from 330.7 to 379.4 Bq/kg.

The average values of the radium equivalent activities calculated for sand from Amman, Jarash-Irbid and Ghor-Karak areas are 41.06 Bq/kg, 54.7 Bq/kg and 85.53 Bq/kg respectively. These measured values are well below the recommended upper limit (i.e. 370 Bq/kg) for safe use of construction materials for dwellings.

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INTS

Natural Radioactivity in Marble Stones - Jordan

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Abstract

It is an established fact that all the construction materials contain trace amount of natural radioactivity. This activity is a major source of external and internal radiation exposure. It is therefore essential that the activity of the construction material should be determined to assess the possible radiation hazards.

Marble stones are mined and supplied mainly from three different areas namely Amman, Ajlun and Azrak in Jordan for the construction purposes. It is used in the form of tiles, slabs and chips. In order to measure natural radioactivity in marble stones, samples were collected from 71 different sites from the above mentioned areas. Radium-226, thorium-232 and potassium-40 activities in these samples were measured using gamma ray spectroscopy technique. The measured Ra-226 activities in the stones collected from Amman varies from 264.9 Bq/kg to 369.5 Bq/kg and the average value is 308.87 Bq/kg. For Ajlun and Azrak the maximum values of Ra-226 are 28.3 Bq/kg and 23.41 Bq/kg, respectively.

The average values of the radium equivalent activities calculated for Amman, Ajlun and Azrak areas are 322.91 Bq/kg, 43.40 Bq/kg and 42.87 Bq/kg respectively. The measured value of radium equivalent activity in marble stones from Amman area is very high as compared with the others two areas. For marbles from Amman area, estimated average value of the external hazard index is 0.873 and that of internal hazard index is 1.71. Since the value of internal hazard index is more than unity, therefore, the excessive use of this material in the construction of dwellings may result in significant external and internal exposure.

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INTS

NEW ENVIRONMENTAL APPLICATIONS FOR PASSIVE RADON MONITORS (1)

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ABSTRACT

Alpha-track detectors and electret ionization chambers are established, commercially available, passive radon monitoring devices. Our objective is modify, test and validate these devices for the purpose of making field measurements on alpha-contaminated soils. This presentation focuses on the most difficult of monitoring tasks, that of making meaningful in-situ field measurements on soils with contamination levels of 100 pCi/g or less. At higher alpha activities, a measurement time of one hour or less is sufficient to make an in-situ measurement. Low level measurements require overnight or multi-day deployment which subject the detectors to additional complications, especially soil radon and weather related stresses. Compensation for radon effects is achieved by making a pair of differential measurements, one on bare soil, the other with a thin, radon-permeable filter (Tyvek) on the soil. Moisture condensation, which occurs when temperatures fall below the dew point, is prevented or minimized, by using an insulating cap. Adequate protection must also be provided against rain and high winds. The results of field tests at an eastern sight with high rainfall and a western arid sight will be discussed.

KEYWORDS

Passive Radon Monitors, Alpha Track Detector, Environmental Measurement

(1) Research sponsored by the U.S. Department of Energy under Contract DE-AC05-84OR21400 with Lookheed Martin Energy Systems, Inc.

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INTS

STUDIES OF THE URANIUM BIODISTRIBUTION IN ANIMALS CONTAMINATED BY INGESTION USING FISSION TRACK METHOD

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In the present paper , the uranium internal contamination by ingestion was studied by the fission track method. A correlation between the amount of the uranium intake and the amount of the uranium retained by the contaminated subject as well as the uranium eliminated in urine and excrements was established.

Two Wistar-London breed rats were contaminated by ingestion of a uranium solution containing $2.2 \cdot 10^{-3}$ gU ; pH=6. The contaminated subjects were sacrified at 3 and 10 days respectively, after contamination. Their vital organs and the rest body of the rats as well as their evacuation samples (urine and excrements) were analysed by the fission track micromapping technique. For each analysed sample, two uranium fission track micromappings were obtained in muscovite track detectors.

Uranium micromappings were used both to determine the uranium atom distribution and the uranium content in the respective organs. A biological reference material calibrated in uranium - prepared in our laboratory - has been utilized.

A comparison between the experimental data obtained for two contaminated subjects as well as their physical interpretation have been made.

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TECHNIQUE FOR THE INVESTIGATION OF URANIUM DIOXIDE DISTRIBUTION DISSOLVED IN SILICATE COMPOSITIONS CARRIED OUT AT SOLID STATE NUCLEAR TRACK DETECTOR

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At present solid state nuclear track detectors (SSNTD) are of wide use for registration of the charged particles. Due to high sensitivity and resolution at reliability and simplicity when treating information SSNTD can be used for obtaining data on concentration distribution of an radioactive element in various compositions.

At the work presented the method of α-radiography has been used for having a concentration picture of uranium dioxide distribution in silicate compositions based on fixation of α-tracks at the contact of α-particles of SSNTD with the specimen.

The plates CR-39 have been used as SSNTD for obtaining α-radiograms of sectional specimens. The chosen time of exposure has ensured a good space resolution and a sufficient density of tracks of α-particles ($8 \cdot 10^5$ cm $^{-2}$) at the detector.

The photographs of α-radiograms at the enlarging x100 have been done for the estimation of the density of α-tracks, and the area of counting equal to 0.1 mm^2 and common for all the specimens has been chosen.

The results of the treatment of α-tracks density as to sectional areas of the specimens are represented by graphic dependencies of the distribution of densities along the chosen directions.

In order to have a quantitative concentration picture of the distribution of the dissolved uranium dioxide in the specimen the formula has been obtained, which connects the mass of uranium dioxide m_{UO2} in the unit of the volume of the tested source (specimen) with the number of tracks B being formed by α-particles on the unit of the detector's area per unit of time:

$$m_{UO_2} = \frac{N_s \cdot \rho \cdot M_s \cdot \sqrt{M_s}}{N_A \cdot \rho_s \cdot \sqrt{M} \cdot B_s} B$$

where - N_s, M_s, ρ_s, B_s - the number of uranium nucleus in the unit of volume, a molecular mass, the density of the substance and the density of tracks of α-particles for the standard, correspondingly; and ρ and M are the density and the molecular mass of a silicate composition with the dissolved UO_2, correspondingly.

In the experiment an initial uranium dioxide applied for studying the dissolving process has been used as the standard, the value B for uranium dioxide has been registered and calculated according to the technique used in the work presented.

The results of the concentration distribution of UO_2 having been obtained with the help of this technique have been used for the estimation of diffusion and solubility of UO_2 in silicate melts.

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TRACE ELEMENTS ANALYSIS OF AEROSOL SAMPLES FROM SOME ROMANIAN URBAN ZONES

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Air samples from 10 Romanian cities, of different industrial levels. The samples were collected using air sampler by sucking the air through filter papers. For the analysis of the trace elements included in the air, Particle Induced X-rays (PIXE) and Neutron Activation Analysis (NAA) were used. It was identified the traces of K, Ca, Fe, Cu, Zn, As and Pb in the range of (ppm). The gradient of the pollution in the different cities is proportional to the industrial levels.

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TRACK DETECTORS IN RADIATING MONITORING OF THE SUNKEN SUBMARINE "KOMSOMOLETS"

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The track method using NC-detectors and of CR-39 type (SSNTD) has been applied alongside with many other methods in radioecological monitoring of the water in the vicinity of the sunken nuclear submarine (NS) "KOMSOMOLETS". The track detectors can work in a "watch" mode for a long time (with protective films for more than a year) and record possible plutonium leakage irrespective of the moment of the process start; they can also give radiographic information of the disperse structure of the hydrosols. In the expeditions in 1994 and 1995 with the help of the deep-water vehicle (DV) "MIR" detecting assemblies have been placed both inside and on the hull of NS, as well as nearby and on the buoy station 5 miles away (background measurements). The assemblies have been mounted both for a short period of time (5-20 days) and for a long time (up to a year). Besides SSNTD, selective sorbers on the basis of titanium have also been applied to concentrate uranium and plutonium from water which were analysed after the exposition for alpha-activity and the presence of fissile nuclides irradiated by thermal neutrons with the fluence of $6 \cdot 10^{13}$ cm^{-2}. Thirty four immersion detectors have been used. The averaged measured data of the total alpha-activity are presented in the following Table.

Site of detectors	The total alpha-activity, Bk / l (the same after filtration)		
	1994 5-20 days	1994-1995 ~ 1 year	1995 ~ 10 days
ventilation tube of the reactor compartment	50 ± 25	20 ± 5 (2)	-
NS hull	730 ± 100 (<65)	-	300 ± 200
independent station on the bottom	-	700 ± 150 (1,4)	-
buoy station	14 ± 9 (<8)	-	-

The Table shows that the total alpha-activity of the water on the NS hull and on the hull of the station on the bottom nearby is some hundreds of Bk/ l. It proves to be due to the natural radionuclides of bottom sediments raised as a result of the work of the DV "MIR". In the places where the raised sediments were absent (inside NS in the ventilation tube of the reactor compartment and on the buoy station) the summed alpha-activity was dozens of times less. The analysis of selective sorbents due to their own background permitted us to evaluate only the upper limit of alpha-activity of uranium (< 0.5 Bk/ l) and its content in water (< 5 μg/l) that corresponds to the uranium background in the ocean water. Congestions of tracks ("stars") have not been found. The results of the track investigations do not contradict the data on the absence of plutonium leakage outside NS obtained by other methods.

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Uranium Measurements in Soil, Rock and Plant Samples of Himachal Pradesh using Solid State Nuclear Track Detectors.

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Fission track technique has been used to estimate the concentration of uranium in soil, rock and plant samples from some areas in Himachal Pradesh, India. High values of uranium content have been observed in some plant and rock samples in the area. These values are significant and may be correlated with uranium mineralization reported earlier by some workers in the area.

Dosimetry & Life Science

A CR-39 Based Thermal Neutron Dosimeter

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2 - Nuclear Energy Department, MEMR, Amman, Jordan.

Abstract

Both chemically and electrochemically etched CR-39 detectors are widely used for the detection of fast neutrons. CR-39 is insensitive to thermal neutrons. In practical situations, fast neutrons are always accompanied with thermal neutrons. Therefore, the response of CR-39 based neutron dosimeter has to be extended to thermal neutrons. To do so, a radiator/converter like LiF has to be introduced in front of the CR-39 detector and an optimum thickness of the LiF film has to be determined such that similar response as that of fast neutrons is achieved. In this context, thin films LiF of various thicknesses were prepared using a thin film coating unit and the response of the CR-39 detector was studied as a function of film thickness for thermal neutrons.

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INTS

A STUDY OF THE RADIATION ENVIRONMENT ABOARD THE SPACE SHUTTLE FLIGHTS STS-55, 57, 65 AND STS-63

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G.D.Badhwar (NASA Johnson Space Centre, Houston, TX 77058, USA)
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The results of experimental study of the integral spectra of linear energy transfer (LET) of cosmic ray particles and the fast neutron energy spectra obtained from four Space Shuttle flights using the nuclear emulsion.

These measurements are essential for the determination of total absorbed and equivalent doses of radiation from the charged and neutral cosmic ray components.

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INTS

Experimental and Simulation Study of Neutron Dosimetry at Various Neutron Energies

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ABSTRACT

A Monte Carlo Neutron Photon (MCNP) transport code has been employed to simulate CR-39 plastic track detector as neutron dosimeter at various neutron energies. In each simulation a monoenergetic neutron source of a particular energy was embedded in the centre of a sphere made of CR-39. Surrounding the source there were concentric shells of 2 μm CR-39 track detectors. The code, MCNP, was run on personal computer for 7.5×10^6 histories. The number of proton recoils in each shell of 2 μm of CR-39 were determined. The simulation results show that apart from proton recoils about 50% recoils are due to heavy charged particles i.e. Oxygen and Carbon in CR-39. This indicates that etched tracks are not only due to recoil of protons but also due to recoil of heavy charged particles. The upper limits of the track registration efficiencies have been determined as a function of neutron energies. These simulation results have been experimentally verified using CR-39 track detectors at various known energies of neutrons. The proton and heavy charge particle recoil tracks in CR-39 were made visible by etching in NaOH solution, at 70±1°C.

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INTS

MEASUREMENT OF DOSE ENHANCEMENT BY NEUTRON CAPTURE OF BORON IN ^{252}Cf INTERSTITIAL BRACHYTHERAPY

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ABSTRACT

In this work the effect of boron concentration in water on the gamma, fast and slow neutrons and alpha particles components at the central, forward and backward surfaces inside tumor phantom of 4.2 cm diameter and 4.4 cm height, during brachytherapy by neutrons from ^{252}Cf were investigated. The source was at the centre of a cubic shape water phantom of 30 cm side. The study was carried for different concentrations of boron from $H_3B\ O_3$, $Li_2B_4O_7$ and $H_3{}^{10}B\ O_3$ while the central axis of the tumor phantom was kept fixed at 5 cm from the point source. The effect of source to tumor distance on the different components of radiation was also measured.

The results indicated that the use of ^{10}B compounds enhances the damage and is recommended for successful boron neutron capture therapy (BNCT).

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INTS

MEASUREMENT OF REACTION RATE DISTRIBUTIONS IN A PLASTIC PHANTOM IRRADIATED BY 40 AND 65 MEV QUASI-MONOENERGETIC NEUTRONS

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ABSTRACT

From the view point of radiation protection of high energy accelerators, it is important to establish a calculation method for high and intermediate energy radiations. Therefore, experiments were carried out for 40- and 65-MeV quasi-monoenergetic neutrons generated by the ^{7}Li(p,n) reactions with 43- and 68-MeV protons at an AVF cyclotron facility, TIARA (Takasaki Ion Accelerators for Advanced Radiation Application) facility, of Japan Atomic Energy Research Institute. Reaction rate distributions in a plastic phantom (30 x 30 x 30 cm) were measured with solid state nuclear track detectors (SSNTDs) and a ^{238}U fission counter.

Measured distributions were compared with those calculated by using the HERMES code system. In the code system, neutron energy spectra above 19.6 MeV were calculated by the HETC-KFA2 code and those below 19.6 MeV were calculated by the MORSE-CG code with the DLC-119/HILO86 multi-group cross section library. In the calculation, the relative energy spectra of source neutrons below 6- and 7-MeV were assumed to be the same as the measured ones at 6- and 7-MeV for the nominal "40 MeV" and the "65 MeV" sources, respectively. The calculated fission distributions are in good agreement with the experimental ones at the depth up to 15 cm in the phantom, while the calculations overestimate about 25% at the depth of 25 cm. The neutron energy spectra for whole region were also calculated by the MORSE-CG code with the HILO86 library. The calculated distributions with these energy spectra are also in good agreement with the experimental ones even at the depth of 25 cm.

Reaction rate distributions of the SSNTDs were also obtained from the neutron spectra and an energy response calculated by a newly-developed Monte Carlo code in which the energy range of incident neutrons had been expanded to intermediate energy. The calculated distributions of reaction rates of SSNTDs for the "40 MeV" agree with the measured ones within 15% at the depth between 10 and 25 cm in the phantom, while those for the "65 MeV" are about 50% higher than the measured ones at the depth after 20 cm. These disagreements probably come from the error in the energy response of SSNTDs for the incident energy of around 65 MeV. At the depth up to 5 cm, the calculated distributions for both the "40 MeV" and the "65 MeV" are lower than the measured ones. Calculated responses for the neutron energy of 40 MeV and 65 MeV are also lower than measured ones at the "40 MeV" and the "65 MeV". These discrepancies can be attributed to the assumption of source neutron spectra below 6- and 7-MeV. The contribution of the incident neutron spectra below 6- and 7- MeV to reaction rate distributions is estimated to be about 30% for the SSNTDs at the depth up to 5 cm. For the fission counter, the contribution is estimated to be less than 4%.

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INTS

Neutron Flux Distribution Measurement Methods & Comparison

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Abstract

In this paper the results of thermal neutron flux distribution measurement with different methods are presented and also compared. This measurement methods have been applied for the external neutron beam of powder neutron diffractometer (PND) system for second collimator , as shown in figure 1.

The results reported here are those obtained by CR-39 plastic track detector with boric acid converter and neutron radiography film with Gadolinium converter.

The collimator system consists of a stainless steel (SS) rectangular tube with two thin SS plate inside. The system was covered thoroughly with Cadmium , which it make three horizontal neutron channels, as shown in figure 2.

It was also found the agreement between the results of the neutron beam profile by a good approximation.

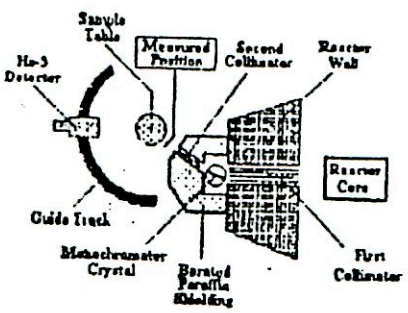

Figure 1 : Powder Neutron Diffraction System (PND).

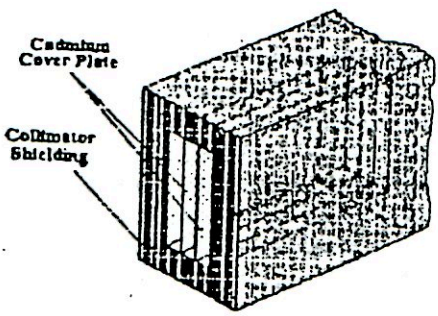

Figure 2 : Second Collimator System

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INTS

NEUTRON FLUX MONITORING BY MEANS OF THIN-FILM BREAKDOWN COUNTERS

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Neutron induced fission cross sections of some heavy nuclei (209-Bi, 232-Th, 235-U, 238-U) are internationally recommended as secondary standards for neutron flux monitoring in the energy region above 20 MeV [1]. A number of neutron flux measurement techniques utilizing fission reactions are well known in applied and fundamental researches, in particular, the techniques using solid state nuclear track detectors (SSNTD) for fission fragment detection [2].

Monitor devices including 238-U targets and thin-film breakdown counters (TFBC) for fission fragment registration [3] were elaborated at V.G. Khlopin Radium Institute. The main advance of the TFBCs is that they combine threshold detection properties of SSNTD with fast timing. The devices allow to obtain "on-line" information on absolute value of neutron flux as well as on neutron spectrum.

Design and general properties of the monitor devices are described. To illustrate performance of the devices, examples are presented of their first applications at the quasimonoenergetic neutron beam facility at the Svedberg Laboratory in Uppsala .

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INTS

RESPONSE OF CONVERTER SEMICONDUCTOR DETECTORS ON NEUTRON RADIATION

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For the dosimetry in neutron fields active detectors based on Si semiconductors are being developed. These dosemeters are constructed as combined converter semiconductor detectors where the incident neutrons interact with the converter isotopes and produce charged particles which can migrate into the semiconductor and cause a signal.
The aim of this work is the determination of the response of such detectors to incident neutrons by experiment and by computation. The response is here defined as the distribution of energy depositions in the active layer per neutron fluence. Due to the detection principle the computational model consists on two parts: 1. Simulation of the interaction of neutrons with passive and active layers of the detector and in consequence of the scattering or reaction process the creation of recoil particles, the energy and direction of the particles and is based on the ENDF/B - cross sections. 2. This part of the model simulates the migration of the ions in the detector layers and the energy loss to the lattice and to the electrons of the semiconductor, which can approximately be identified with the recorded signal of the dosemeter. The ion transport is simulated by the application of a version of the program TRIM (TRansport of Ions in Matter, Biersack - 1995).
Comparisons of measured and computed pulse height distributions are performed. An analysis of pulse height distributions and an outline for the spectroscopic interpretation with respect to the energy of the incident neutrons is presented.

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INTS

SOME DATA ON RADIATION ASSESSMENT ABOARD TRANSATLANTIC FLIGHTS

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An attempt is made to assess radiation exposure received by the transatlantic flights crew at the altitude of 10-12 km using nuclear emulsion as a detector.

This paper describes the results of absorbed doses of radiation and equivalent doses from fast neutron energy spectrum inside planes crossing the Atlantic along different routes.

Special attention is paid to measuring total cosmic ray particle flow, recorded in these conditions

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Spatial dosimetry and spectometry with neutron activation of remaining Ag from nuclear emulsion.

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Abstract
Certain characteristics of nuclear emulsion make it suitable for dosimetric measurements in space. It serves as integrating medium of all ionizing effects i.e. the total dose absorbed within the detector, which leads developable grains. Their number or the mass of silver respectivily remaining after processing can be determined neutron-activation of the Ag nuclides.
Using emulsions with different sensitivity thresholds (Ilford K5-K0) allows to differentiate LET- (linear ener transfer) thresholds and LET-classes of the ionizing radiation, and to obtain a rough composition of the flux.
The results of the calibration with gamma rays, protons and Oxygen for emulsions of different sensitivities a given. Results from different space experiments (Kosmos 16, D-IL1, ERA, MIR, D2, EUROMIR, IML2) a presented too

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INTS

SPECTROMETRY OF LINEAR ENERGY TRANSFER WITH A TRACK ETCH DETECTOR[1)]

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ABSTRACT

Etchable track formation in a track etch detector is a process directly related to the density of energy deposition by a charged particle in the detector. It is known that the V, the ratio of etch rates inside and outside of a track is, at least in a partially limited region, proportional or directly related to the linear energy transfer (LET) of a particle, resp. to some restricted values of it. The analysis of track parameters would therefore permit to determine the LET of a particle and theirs spectra in exposed track detectors.

The contribution describes the method of LET spectrometry based on the analysis of parameters of tracks created in chemically etched polyallyldiglycolcarbonate (CR 39). It is based on the etch rates ratios determination, the calibration was performed in beams of heavy charged particles. The V-values between > 1 and < 15 can be established by means of this method, it corresponds to LET in tissue between 100 and 6000 $MeV.cm^2.g^{-1}$. The method was tested in the field of a ^{252}Cf neutron source, dose and dose equivalent distributions in LET obtained have been found out in quite good agreement with LET spectra measured with microdosimetric tissue equivalent proportional counter.

Advantages and limitations of the method are discussed, some exemples of applications are designed.

[1)] Partially supported through the Project of the Grant Agency of Czech Academy of Sciences No. 335402 (1993-95)

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INTS

STUDY OF RADIOBIOLOGICAL EFFECTIVENESS WITH TRACK ETCH DETECTORS

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Study of the killing effects of radiations on biological cells is an important area of research in the biomedical sciences. The Legnaro Laboratories group has been investigating over the years the effectiveness of radiations on Chinese hamster cells making use of the active electronic devices. Experience has shown that electronic devices fail to give correct answer to the estimation of low energy deposition on cells due to their decreasing signal to noise ratio. Moreover, simultaneous measurements of the given dose and determination of the beam energy of particles impinging upon the cells is extremely difficult. In this experiment we have utilized for the first time the CR39 track etch detectors for survival fraction (S.F) studies of Chinese hamster V79-753B cells with the low energy proton beams. The incoming fluence & beam energy as well as energy of the beam impinging upon the biological cells have been correctly determined. Results from S.F studies have been compared with the model calculations.

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INTS

Studying the Response of some Selected Neutron Dosimeters in the light of ICRP-60 Recommendations.

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2 - Nuclear Energy Department, MEMR, Amman, Jordan.

Abstract

The International Commission on Radiological Protection (ICRP) made recommendations in their Report No. ICRP-60 which have serious consequences for many operational neutron dosimetry services. The new recommendations include the reduction in dose limits from 50 mSv to 20 mSv per year, change in the quality factors and the dose estimation in some circumstances down to a few mSv per year. The overall effect of the ICRP-60 recommendations is to reduce the detection threshold in order to account for the reduction in the dose equivalent limit. We have studied the impact of ICRP-60 recommendations on the response of cubical neutron dosimeter and BD-100R bubble detector. The results of this study are presented in this article.

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THE USE OF NUCLEAR TRACK DETECTORS AS A PERSONAL UV SOLAR RADIATION DOSIMETER

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ABSTRACT

Investigation of using CR-39 nuclear track detectors as a personal monitoring tool for measuring exposure to ultra violet (u.v.) solar radiation was studied. The track etch diameters were calibrated with the total exposure to u.v. solar radiation. The nuclear track detectors were irradiated with Cf-252 (alpha and fission fragments) before exposure to sun light. The exposure of nuclear track detectors to u.v. solar radiation were carried out in two different conditions (i) movable position: where the detectors fixed on the metal body of the solar sensor which always rotate towards the sun, and in (ii) fixed position. The measurements were performed for different periods extended from one to 8 weeks continuously in Dhahran- Saudi Arabia. The period extended from the middle of July to middle of September: the hottest months in Saudi Arabia. The weekly integrated u.v. solar radiation measured by Eppley u.v. solar radiation sensor was from 2400 kW. m^{-2} for one week to 21000 kW. m^{-2} for 8 weeks. The results indicate good correlation between the track diameters of alpha and fission fragment with the total exposure to u.v. solar radiation. Also, good correlation between the bulk and track etch rates with u.v. solar radiation was found. Based on the obtained results, it is possible to use the nuclear track detectors as a personal monitoring tool for the exposure to u.v. solar radiation especially in hot country like Saudi Arabia.

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Abstract

Threshold Measurements of the Energy Dependence of Response of the NRPB Neutron Personal Dosemeter and its Response to Workplace Neutron Spectra

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It is common practice to measure the energy dependence of response of neutron personal dosemeters using a combination of monoenergetic neutrons from accelerators and radionuclide sources. The resultant response function can then be folded with measured workplace spectra to determine the probable biases which would be experienced when making measurements in such fields. This process is reliant upon good interpolation between the data points for different energies, and would hence be improved by a greater understanding of the precise nature of the energy dependence of the response characteristic.

For most neutron energy ranges the interpolation between data points is relatively simple using a four point Lagrangian, but problems result at the low energy threshold for most neutron personal dosemeters: this corresponds to the 100-500 keV range for most PADC (poly allyl diglycol carbonate or CR-39) based systems. Consequently a greater knowledge of the nature of the response in this region would help explain the readings obtained on dosemeters in known fields, particluarly those which have a significant component in this energy range.

A facility now exists at the National Physical Laboratory for the simultaneous irradiation of dosemeters with neutrons in the range from 100 to 250 keV. Results from such an irradiation have been taken along with monoenergetic data to cover the whole relevant energy range, to produce a more accurate folding of measured spectra with the dosemeter response. These results are discussed for two different etch processes in terms of their implications for the accuracy of dosimetry and the relevance of this low energy threshold for personal dosimetry.

Geoscience

A.S. Sandhu, S. Singh, H.S. Virk and J.A. Westgate
Annealing studies of fission tracks in natural glasses

B.S. Bajwa, S. Singh and H.S. Virk
Application of fission track techniques for U estimation, isotopic equilibrium/disequilibrium and uranium distribution. Study in some geological samples

A.A. Qureshi, N.U. Khattak, M. Akram, K. Mehmood, C.A. Majid, S.A. Durrani, A. Haleem, I.E. Qureshi and H.A. Khan
Applications of solid state nuclear track detection techniques in the study of fossil bones

S.-L. Guo, Y.-L. Wang and C.-Q Tu
Detailed study of fission track annealing behaviors in minerals

P. Zhai and Y. Zhao
Response characteristics of domestic dosimeter glass to recording fission tracks

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INTS

ANNEALING STUDIES OF FISSION TRACKS IN NATURAL GLASSES

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The correlation between reduced track-diameter and reduced areal track density, during isothermal annealing, has been studied for moldavite and tektite glass with varying chemical etching conditions. The samples containing induced tracks are heated for various times ranging from 1 to 30 days at 150 C. The heated samples are etched in 25% HF at 25 C for various etching times. Each of these samples is etched along with the parent unannealed control sample. The mean track diameter and areal track density are determined for each heating event. A graph showing the relationship between percentage reduction in mean track diameter versus percentage reduction in areal track density is plotted for various etching durations. A nearly 1:1 linear relationship is observed for adequately etched tracks having track diameter in the range of 6 to 8 micrometer. However, for underetched tracks the curve diverges from 1:1 relationship and the reduction in diameter becomes much larger than the reduction in areal track density. The experimental results support a better fit to the 1:1 relationship of track density to reduced track diameter, which makes it useful to apply the correction to thermally lowered fission-track age of natural glass, on the basis of the difference between mean track diameter of induced and spontaneous tracks [1].

References:

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The correlation between reduction in fission-track diameter and areal track density in volcanic glass shards and its application in dating tephra beds. Earth. Planet. Sci. Lett., Vol. 131, 1995, pp. 289-299.

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INTS

Applications of Fission Track Techniques for U estimation, Isotopic Equilibrium/Disequilibrium and Uranium distribution Study in some Geological samples

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ABSTRACT

The alpha-autoradiography of the geological samples permits the determination of their uranium contents,which is done by counting the number of alpha/cm^2/sec on a solid state nuclear track detector and by substituting, the obtained number in the appropriate equations.

However, the derived equations for this purpose are based on the assumption of the existence of a radioactive equilibrium. In other words, they take into account the emission of eight alpha rays in ^{238}U series. But if one of the decay members or more of this series are totally or partially missing, the equivalent uranium contents found by this method will be remarkably lower than the true ones. Thus a comparison between the contents determined by autoradiography and those by other methods . e.g. homogenized fission track technique, allows the indication of the existence of radioactive disequilibrium.

The results of uranium content, as determined by fission track analysis, are distinctly different from those of autoradiography, indicating the existence of radioactive disequilibrium in some fossil bone samples.

The fission and alpha auto-radiograph of some of the samples are clearly giving their replica, which allows positive, rapid location of uranium bearing phases.

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APPLICATIONS OF SOLID STATE NUCLEAR TRACK DETECTION TECHNIQUES IN THE STUDY OF FOSSIL BONES

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*Nuclear Materials Division, PINSTECH, P.O. Nilore, Islamabad, Pakistan
**Department of Physics, Birmingham University, England, U.K
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ABSTRACT

Mammalian fossil bones have been discovered in the rocks of Siwalik System at Chakwal (PAKISTAN). These bones, possibly belonging to an animal similar to a present days rhinoceros, have been studied using petrography, γ-spectrometry, fission track dating, fission track mapping and α-autoradiography techniques. Two mineral phases, fluorapatite [$Ca_5 F(PO_4)_3$] and calcite ($Ca CO_3$), present in the bone were identified under petrographic microscope. The bone samples are composed of three distinct compositional layers. Outer most zone is composed of fluorapatite (≈ 95%), the middle zone is composed of fluorapatite and calcite in equal proportion, while the inner most is composed of the mineral calcite (≈ 100%).

Presence of uranium in bones, now petrified to fluorapatite, has been identified by fission track and alpha autoradiography methods. Uranium contents in the outer most and middle zone were found to be 85 ppm and 43 ppm respectively, whereas the inner most calcite zone was almost free of any uranium content. The bones could not be dated by fission track method ,but they have been given Middle Miocene age (≈12 my) on the basis of their stratigraphic position in the rocks of Chingi Formation of Lower Siwaliks having a paleomagnetic age of 10 to 14 my.

Interestingly, the petrified bones still contain well preserved bone cells and blood vessels in their original shape and red blood colour, perhaps due to the sudden burial of the animal in an anaerobic atmosphere.

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DETAILED STUDY OF FISSION TRACK ANNEALING BEHAVIORS IN MINERALS

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Fission tracks in minerals are successfully applied in geological and archaeological dating and geothermal history studies. Track annealing plays basic roles in both subjects. The effect of track annealing is double-edged on these applications. If track annealing occurred during the geological history of the minerals is negligible, then age determination is straightforward, but geothermal history information is less retrieved. Partial fading gives more informations on thermal history, but it makes dating more difficult. In order to describe the annealing process of fission tracks in minerals more precisely and give more systematic and analytical formulation in dating and study of geothermal history, it is necessary to study track annealing behaviors in more details. Various apatites from different sources and with different compositions have been exposed to thermal neutrons in nuclear reactor and heavy ions at accelerators. Some of them are annealed in laboratory. Confined and projected track lengths are measured and activation energies for track annealing are analysed. The results of measurements and their implications are discussed.

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RESPONSE CHARACTERISTICS OF DOMESTIC DOSIMETER GLASS TO RECORDING FISSION TRACKS

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Response characteristics of domestic dosimeter glass to recording fission tracks and the homogeneity of track distribution were studied and compared with dosimeter glass NBS SRM612. The results showed that characteristics of domestic dosimeter glass come up and even better to that of dosimeter glass NBS SRM612. Using a domestic dosimeter glass in fission track dating the relative error is less than 5%.

Radon

M. Balcázar, A. Chávez, L. Tavera and M.E. Camacho
Anomalous indoor radon in a research reactor

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INTS

ANOMALOUS INDOOR RADON IN A RESEARCH REACTOR

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Major repair activities were performed to the Triga Mark III research nuclear reactor at the Nuclear Centre of Mexico, during which the air extraction system was put out of order for several weeks.

Some electronic detection system showed radiation signals well above the expected values. After careful analysis of the problem, it was identified that indoor radon build up was the reason of those radiation signals.

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Climatic and Temporal Variation of Radon Concentration in Malaysia

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Indoor and outdoor radon concentration were measured for diurnal, weekly and seasonal variations. Togeather with these measurements, climatic conditions such as temparature, rainfall, pressure and dust condition were also recorded. Three radon detectors were used viz. surface barrier detector, scintillation detector and nuclear track detector.

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DESIGN OF A PERSONAL RADON DOSEMETER BASED ON THE DIFFUSION PRINCIPLE OF GAS THROUH A FILTER MEMBRANE

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ABSTRACT

A passive intergrating radon personal dosemeter based on the diffusion principle and using a nuclear track detector has been developped for use in atmospheres where high humidity is present such as in mines[1]. This dosemeter consists of an enclosed small sized chamber into which radon gas diffuses through a filter membrane and which contains a nuclear track detector for registration of alpha particle tracks from radon and its decay products present inside the chamber volume. The sensitivity of this passive dosemeter depends on different parameters such as the diffusion chamber geometry and dimensions, the charateristics of the filter membrane and the nature of the track detector.

Theoritical studies were undertaken to determine the optimum dimensions of the diffusion chamber and the membrane thickness which is sufficient to permit the rapid establishment equilibrium betweeen radon concentration outside and inside the chamber volume, using the LR-115 nuclear track detector[2]. The design and the characteristics of the dosemeter as well as the results of the optimisation studies are reported and discussed.

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INTS

Determination of Radon Activity Density in the Soil Gas in Northern Part of Jordan

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Abstract

Radon isotopes occur in the natural radioactive decay series of uranium (^{235}U and ^{238}U) and thorium (^{232}Th), which exist in the earth's crust with varying concentrations in different locations. It is believed that underlying soil is the main source of radon in the atmosphere of dwellings, offices and public places. In view of the risk presented by high concentrations of radon and its progeny indoors, this work was carried out during winter months to measure radon concentration in different types of soil in the northern part of Jordan at different depths (0, 25, 50, 75 and 100 cm). The prepared time-integrated passive dosimeters were distributed among eight stations located in the governorates of Irbid, Jarash and Ajloun. The results of this study show that the radon levels at a given depth vary significantly from one type of soil to another. For example, at 100 cm depth radon levels range from 4000 Bq/m^3 (in limestone) to 4 x 10^5 Bq/m^3 (in chalky marl). Moreover, we found that the radon concentration increases exponentially with depth, which is in a good agreement with the mathematical model of Magro-Campero *et al.* (1980). Therefore, it is strongly recommended that houses should not be constructed on such soil if U/Th-rich bedrock lies underground.

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ESTIMATION OF RADON AND URANIUM TRACE IN BUILDING MATERIALS USING TRACK DETECTORS

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Abstract

Building materials commonly consist of sand, cement, bricks, soil etc. which contain traces of uranium, radium and potassium. Radon-222 is produced by alpha decay of radium-226 which is a member of U-238 decay chain. It means that building materials are potential source of radon emission. The half life of radon-222 is 3.82 days and it is long enough for a part of it to diffuse from the building to the indoor environment of the dwellings. Long exposures of large population to low level of radon is a possible health hazard. It is, therefore, desirable to measure both radon and uranium concentration in building materials. It is possible to measure the radon and uranium concentration in building materials using track etch technique. In the present paper, the use of track etch detectors in the estimation of radon and uranium trace content in building materials shall be presented and results obtained shall be discussed.

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INTS

GROUND WATER RADON AND CHEMICAL SPECIES FLUCTUATIONS ON BASALTIC AQUIFERS

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Surveys of radon, short lived radon daughters and trace elements in ground water belonging to confined and free aquifers located mainly on basaltic bedrock, have been recently performed in Mexico. The studied sites are located along the Pacific coast, where very intense seismic activity occurs, due to the subduction of the Cocos Plate under the North America Plate, and, in opposition, at the Gulf of Mexico Coast where only sporadic low level seismicity is observed.

Radon determinations are performed essentially with track detectors LR 115 type II. Recently, automatic radon probes were also installed at several wells. The two arrays permit to obtain long and short term variation assessment.

The major chemical components of the water samples are determined by conventional chemical analysis while trace concentration levels of several elements are measured with an Inductively Coupled Plasma Mass Spectrometer.

The results indicate differences in the geochemical components behaviour as a function of the characteristics and recharge patterns of each specific aquifer. An analysis concerning the variation of the different species with the local seismicity is intended.

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INDOOR RADON AND ITS PROGENY CONCENTRATION IN ARCHAELOGICAL PLACES IN ALEXANDRIA , EGYPT

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ABSTRACT

Starting from August 1993 until July 1994, continuous radon-222 activity concentrations have been monthly measured in the air of two archaeological places namely, Kom El-Shoqafa Catacombs and Serapis Temple, in Pompy's Pillar area in Alexandria city. The radon activity concetrations were measured using the diffusion cup technique and using LR-115 nuclear track detector inside and out side each cup . Mothly variation of radon acitivity concentrations were observed in the two places. The average monthly value of radon activity concentrations ranged from 34 - 267 $Bq.m^{-3}$ in Kom -El-Shoqafa Catacombs and from 22 - 1234 $Bq.m^{-3}$ in the Serapis Temple. The average inhalled radon dose equivalent for workers and visitors were discussed.

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INDOOR RADON MEASUREMENTS IN SOME INDIAN CITIES

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The detrimental effects of radon exposure on the health of human beings are well known and an appreciable correlation has already been established between radon exposure and various diseases of the lung, skin and the kidney. Radon monitoring in India has however been very sparse, due to its large area and geographical considerations. In the present work, the potential alpha energy exposure (PAEE) due to radon and its progenies has been measured in dwellings of three different cities in India namely Shillong (in north-eastern region), Allahabad (in north-central region) and Vishakapatnam (in south-eastern region). The measurements were carried out by a passive time integrated method, using LR-115 (Type II) detector in bare mode. The detectors were installed for a period ranging between 60-90 days in dwellings of different types of construction. These detectors were dried for one hour in hot air oven maintained at 50°C and then transfered to desiccator. A suitable chemical etching was performed to develop alpha tracks as holes. Both optical microscope and spark counters were used to measure the pore density. The values of PAEE due to radon and its progenies were determined for each location by using a sensitivity factor derived from a separate calibration experiment.

The results obtained for these three locations were compared with national average for India and also discussed under the light of exposure limits set by ICRP.

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INDOOR RADON MEASUREMENTS IN THE TOWN OF PODGORICA - MONTENEGRO

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ABSTRACT

A study of indoor radon in the town of Podgorica, capital of Montenegro, commenced in 1994. For this purpose, the town houses were categorised in 4 distinct types, on basis of their construction characteristics and building material. Selection of the houses for indoor radon measurements was also based on the geological characteristics of the Podgorica region and the results of soil radon measurements in the town area.

Indoor radon concentrations are measured by integral method, with etched track detectors. Passive radiometers of the Research Centre of Spacecraft Radiation Safety, Moscow, are used. The radiometer is a plastic cylinder, with two cellulose nitrate detectors fixed in its central part. Its sensitivity is 2.8 ± 0.8 (track/cm^2)/(kBqh/m^3) for lower detector, and 3.4 ± 0.8 (track/cm^2)/(kBqh/m^3) for upper detector. After exposure, detectors are etched with 5 N NaOH solution at 50°C. Etching time of 90 min was chosen because of a good standard deviation of a spark counter reading (below 20%) and a quite reasonable background (30 ± 15 track/cm^2). Mean error of radon measurement by this method is about 25% for radon concentrations in 20-20000 Bq/m^3 range.

Measurements are performed in 110 dwellings, mainly on ground floors. Detectors are located in living-rooms, and exposed about 90 days in the winter season 1994/95. Results are reported as equivalent equilibrium concentrations (EEC), adopting as equilibrium factor 0.5 value. Obtained radon EEC-values span 4 to 453 Bq/m^3 range, and belong to a log-normal distribution, with geometric mean value 21.8 Bq/m^3 and geometric standard deviation 2.20 Bq/m^3. The median value is 26.4 Bq/m^3. Concentrations higher than 100 Bq/m^3 are found on five measurement sites, and two of them where higher than 200 Bq/m^3.

The highest average radon levels (median value 44.5 Bq/m^3) are found in detached family houses, built of bricks, and the lowest (median value 16.6 Bq/m^3) in multistoried apartment houses, made of concrete and bricks, with mortar on the walls.

The obtained results represent the highest indoor radon concentrations all the year round, because the measurements are performed during winter season, when doors and windows are usually all tightly closed and dwellings are seldom and poorly ventilated.

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INTS

LONG TERM RADON SURVEY IN MEXICO CITY AND OTHER DIFFERENT REGIONS IN THE COUNTRY SITES. (1)

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ABSTRACT

A long-term radon survey is ongoing in Mexico City, (Ciudad Netzahualcoyotl and Tecamachalco) and in the towns of Toluca, Pachuca, Tula, Tlaxcala, Queretaro, Puebla, Tehuacan, Guadalajara, and Zacatecas. Monitoring is done with a passive alpha-track detectors.
Measurement started 6 years ago. We are gathering radon data for a national evaluation of indoor radon problems in the non-tropical regions of Mexico.
Information is also gathered on geology, topography, building materials, architecture and ventilation systems. Each of these factors can have significant effect factors on the indoor radon concentrations.
The passive radon detector is a chip of CR-39 polymer in a closed end cup. This inexpensive devise provides high detection efficiency, easy of handling and does not require highly skilled training for those people engaged in the deployment and retrieval of the devices. The overall costs of a national survey of indoor radon can therefore be kept relatively low.
Some of the results shown radon levels which are of moderate concern for radon related health effects. The fews measurements taken to date are only the first steps in the conduct of a comprehensive survey of mexican indoor radon problems.

KEYWORDS

Indoor Radon, Nuclear Track Detectors, CR-39

(1) Research sponsored by the U.S. Department of Energy under Contract DE-AC05-84or21400 with Lookheed Martin Energy Systems, Inc.

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INTS

Measurement of Radon Concentration Levels in Some Cities of Jordan

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Abstract

Preliminary studies concerning determination of radon concentration levels have been carried out in a number of cities in Jordan. CR-39 detectors were installed in different houses and were allowed to expose to radon for 4 months. The exposed detectors were then etched in 6M NaOH at 70 °C and track densities in each detector were measured under an optical microscope. Measured track densities were then related to the radon working level. These studies showed that radon concentration level ranges from 7.1 to 122.8 Bq/m^3 in the house surveyed.

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MERSUREMENT OF RADON EXHALATION RATE IN CEMENT SAMPLES BY PLASTIC TRACK DETECTORS

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Radon-222, alpha radioactive gas and its daughters are associated with the presence of radium and its ultimate precursor uranium in the ground. Being an almost chemically inert gas, it can move through solid materials such as rocks, clays, gravels, sand, brick and concrete etc. until it reaches the pore space. Macroscopic transport is then possible either by molecular diffussion or by fluid flow in the pore space. Building materials are the main sources of radon inside houses[1]. Cement is one of the main constituents used widely in construction materials as building material, plastering material and in concrete bricks etc. Recently various waste materials produced by Thermal power plants, chemical and metallurgical industry are being used as building materials. Some of them may contain appreciable amount of natural radionuclides from the uranium series. In the present study radon exhalation rates have been measured in different brands of cement samples collected from the market using etch track Can technique[2].

Collected samples were dried and placed in the Cans up to the level such that it leaves a sensitive volume equal to one used in calibration experiment[3] (dia. 7.0 cm. and height 4.5 cm.). Each Can was equipped with a LR-115 type-II plastic track detector (2 cm. x 2 cm.) fixed at the top inside of the Can. Radon and its daughters will reach an equilibrium concentration after a week or more. Samples placed in sealed Cans were left for exposure for 90 days. After exposure the detectors from all Cans were retrieved. For the revelation of the tracks, the detectors were etched in 2.5N NaOH at 60^{o}C for 90 min in a constant temperature water bath. The resulting alpha tracks in the detector were scanned under optical research microscope at 400X magnification. The activity was obtained from the track density using the calibration factor (0.056 Tracks cm.$^{-2}$ d^{-1} /Bq m.$^{-3}$) obtained from the calibration experiment[3]. The exhalation rate has been computed using the expression given in ref.2.

The track density was found to vary from 5.24 to 10.84 Tracks cm.$^{-2}$ d.$^{-1}$, the radon activity was found to vary from 93.57 to 193.57 Bq m^{-3} and the exhalation rate vary from 0.76 to 1.85 m Bq kg^{-1} h^{-1}. The experiments show that the radon exhalation of cement is slightly low as compared to coal and flyash etc.

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Modelling of Solid State Nuclear Track Detector Devices for Radon Measurements

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Theoretical analytical calculations of the Radon registration have been performed for the solid state nuclear track detectors (SSNTD) LR 115 Type II (peliculable) produced by Kodak (France). Known and measured properties of LR 115 together with the well established etching theory using "Huygens" principle were used to carry out these detailed calculations for different types of exposure devices for indoor room and outdoor soil measurements.
The results of these modelling calculations are compared with experimental calibration measurements and show good agreement.

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INTS

New microsystem based monitoring systems SARAD for the measurement of radon and thoron and his progeny in indoor air and soil gas in mining areas

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The natural content and distribution of radon and thoron in rocks and soils and their relations to soil gas and ground water are a very important knowledge understanding some geophysical and geochemical processes in the earths crust. Time series about the ratio between radon isotopes are the basic material for the description of the migration paths of the radioactive noble gases in the deeper parts of the crust.

Also in the case of a secondary contamination of soils with uranium, radium and thorium a good monitoring system is very important to declare an anthropogenic factor in the natural environment.

Therefore we developed a monitorsystem using a alpha spectroscopic microsystem. The monitor SARAD RTM 2010 is a full spectrometric system. A 2 cm^2 PIN-diode for the alpha detection with integrated preamplifier is the heart of the system. An internal pump has a pumping rate of 3 l/min and the measuring chamber has a volume 260 ml. With this equipment we get a detection limit of about 0.3 Bq/m^3 in 10 hours. The efficiency for thoron gas detection is only 10% lower than for radon gas. Concentrations up to 10 MBq/m^3 can be measured. For continuouse measurement the internal intergation time can changed from 6 minutes up to 1 day. In the monitor system can also intergratet up to 8 sensors for meteorological parameters like air pressure, temperature and humidity.

For good description of migration paths in the ground and the interpretation of time series of soil gas measurements the correlation analysis with meteorological parameters may be found geophysical informations.

In an other case the efficiency of the SARAD radon and progeny monitoring systems was further proved in various applications like the quality control of mitigation actions in houses with high radon levels in Germany. In Dresden and Freital, Saxonia, and in some mining areas of the Ore Mountains in the past our epuipments worked in a high radon risk area.

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PARALLEL TRACK ETCH DETECTOR ARRANGEMENT FOR RN MEASUREMENT IN SOIL

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ABSTRACT

A new arrangement using two sheets of parallel track etch detectors in the open metalic holder for Rn measurement in soil is described. The formula for the response of the system was derived and experimentally proved as the linear function of the gap width between the sheets within the limits 0 - 5 mm. The proper choice of the gap width allows to optimise the measuring conditions with respect both to the period of application and the expected radon concentration. The firmness, small size (outer volume less than 5 cm^3), simple and compact construction as well as low costs provide this method as the complementary one to the commonly used *cup-technique*. The preliminary calibrations are described and the results of several pilot field measurements are presented.

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INTS

RADON AS A PRECURSOR OF MICROSEISMIC ACTIVITY IN N-W HIMALAYA

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Radon is established as one of the useful precursors for earthquake studies in India. Radon monitoring work was started in 1989 at Palampur in Kangra valley,Himachal Pradesh in N-W Himalaya using emanometry and track-etch plastic detectors. Time series radon data in soil gas and groundwater show that 60 percent of radon anomalies are correlatable with micro-seismic events of 2-4 M which occurred in the region.The correlation index varies from station to station depending upon the geological conditions, geophysical and meteorological parameters operating at the monitoring site.Uttarkashi earthquake of Ms 7.0 recorded its signals at five stations using track etch method and at Palampur using emanometry,almost a week before the event.

During 1992, six more stations viz. Kotla, Pathankot, Jawalamukhi, Dharamsala,Dalhousie and Chamba were set up under Himalayan Seismicity Programme of N-W Himalaya to monitor the seismicity along the main boundary fault (MBF) of Himalaya. Radon was monitored continuously in soil-gas using alpha logger probes and discrete measurements were recorded in soil-gas and groundwater at Palampur and Dalhousie using emanometry.Chamba earthquake of Ms 5.1 which occurred on 24th March 1995 was recorded in at both the Chamba and Dalhousie stations. Analysis of radon data shows the rising trend in seismicity along the MBF of N-W Himalaya.It is observed that radon emanation shows spike-like phenomenon corresponding to seismic events. Postdiction of several microseismic events in N-W Himalaya puts a premier on radon as a useful precursor of earthquakes.

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INTS

Radon Concentration-determination in some Dwelling of Doha city of Qatar

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Yearly average exposure levels from radon and its airborne daughters have not been reported yet in Qatar. Only few surveys on indoor radon concentrations have been conducted by one (W. A.) of us during the Autumn season in 1992. In this context, a determination of radon concentration in some chosen houses of various locations has been carried out over the whole year. Charcoal canisters were installed at different places of the houses under investigation and a check for reproducibility was performed. Results show that the indoor radon concentration in some dwellings of Doha city varies from 11 to 23 Bq/m^3. Data is compared with our previously preliminary radon concentration measurements and led to the conclusion that the radon concentration in Doha is relativily low not to be shared in any serious environmental radiation problem

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RADON CONCENTRATIONS IN GROUND WATER IN SWAZILAND

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ABSTRACT

WELL water can be a significant source of ^{222}Rn in room air. Ground water carries Rn from its ^{226}Ra precursor in soil and rock into the home, where the radon gas escapes into the air, especially when the water is heated, sprayed or agitated. Examination of exposure pathways indicates that the radiation dose to the lungs due to inhaling ^{222}Rn that escaped from the water used in a home generally is much higher than the dose to the GI tract due to drinking the Rn-containing water. Currently, the ^{222}Rn concentration in drinking water is not yet regulated, but the U.S. Environmental Protection Agency (EPA) has proposed a maximum contaminant level (MCL) of 11 Bq L^{-1} (300 pCi L^{-1}).

Several methods have been developed over the years for measuring dissolved ^{222}Rn in water. Bubbling air through water and subsequent measurement of the radon concentration in the gas phase by SSNTD is an easy way to determine radon in water. CR-39 plastic track detector was employed to measure the concentration of ^{222}Rn in ground water in Swaziland. A total of 100 water samples were collected from wells at 10 different towns. Following the procedure available in literature, the CR-39 detector samples were exposed for 15 days. After exposure all the detectors were etched in 6M NaOH solution at 70° C for 8 hrs and were scanned under an optical microscope for recording the alpha track density. The track density (tr/cm^2) was converted into radon activity in BqL^{-1} by using a calibration constant (1 Bq L^{-1} corresponds to 66.8 tracks/cm^2.d) which was experimentally determined in our laboratory. The radon values in water samples are found to vary from 1.8 ± 0.1 to 152.9 ± 4.8 BqL^{-1}. The water samples from Mbabane area have shown maximum radon content. The arithmetic mean ^{222}Rn concentration in ground water is 25.2 Bq L^{-1} and the geometric mean is 13.5 Bq L^{-1}. The data shows that 54% of the wells has ^{222}Rn water concentration in excess of the EPA's limit of 11 Bq L^{-1}. Fifteen percent of the well water concentrations are above 37 Bq L^{-1} while none exceeds 370BqL^{-1}.

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RADON CONCENTRATIONS IN THE TEOTIHUACAN SUN PYRAMID (1)

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ABSTRACT

Measurements of radon were taken inside the Sun Pyramid and in adjoining tunnels, of Teotihuacan site in Mexico. There are no burial chambers inside the Teotihuacan Pyramids. Beneath the Sun Pyramid however, there is a prehispanic tunnel that was used for ritual ceremonies. We evaluated the radon levels inside this prehispanic tunnel below the Pyramid as well as in tunnels excavated for research purposes by archeologists and in some locations at the eastern end of its site. Passive Nuclear Track detectors were used to monitor radon. Measurements were made in winter away from the rain season that will not allow measurements to be made.

The Pyramids and surrounding buildings are open to the public for the exhibitions of murals and paintings. Access to the tunnels and chambers is restricted to the arqueological staff.

KEYWORDS

Radon exhalation, Radon Concentration, Solid State Nuclear Track Methodology, Teotihuacan Pyramids.

(1) Research sponsored by the U.S. Department of Energy under contract DE-AC05-84OR21400 with Lockheed Martin Energy Systems, Inc.

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RADON DIFUSSION EXPERIMENTS IN A CONTROLED CHAMBER

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Radon difussion experiments were performed in a controlled radon chamber. Radon and its radon decay products were registered as a function of time by means of a surface barrier detector.

The predicted performance by a model match with the experimental results.

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RADON IN MINES AND DWELLINGS IN KOSOVO AND METOHIA

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The first systematic indoor radon survey in Kosovo and Metohia, Yugoslavia, was performed with a passive radon dosimeter of the J. Stefan Institute utilizing CR-39 detector. Some regions (village of Gornja Stubla) could be classified as radon prone areas (Table below).

Town/village	Radon concentration Arithmetic mean (Bq/m^3)	Radon concentration Maximum (Bq/m^3)
Priština	54	119
Brezovica	56	111
Gušterica	137	180
Gračanica	278	472
Kosovo Polje	292	511
Dobrotin	446	652
Gornja Stubla*	806 (250)	1010

* The results relate to houses built from stone with a relatively high uranium concentration (of the order of 10^{-5} g/g) and of concrete or bricks (in brackets), respectively.

With the same dosimeter the radon concentration was measured in various levels of the Trepča lead and zinc mines (Table below). In general the average radon concentration was found to be relatively low (200 – 800 Bq/m^3), and practically independent of the depth (level) in the mine.

Mine	Radon concentration Arithmetic mean (Bq/m^3)	Radon concentration Maximum (Bq/m^3)
Trepča (Stari Trg)	330	1360
Novo Brdo	767	2815
Ajvalija	526	602
Badivac	230	360
Kišnica	210	345

The main results of this study are presented and correlated with local enviromental and geological conditions.

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INTS

Radon levels measured at building sites and in sub-soil in Delta

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Abstract

The concentration of radon in the open air and interiors and in sub-soil of west Delta sites was determined by using the solid state nuclear track detectors (SSNTDs). Radon concentration measurements in air in west Delta, north Cairo, were performed by open and filtered detectors, with volume of 8.6 cm^3 and CR-39 plastic film. The equilibrium factor F and the dose equivalent were calculate by using the track densities of open and filtered SSNTDs.

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RADON MEASUREMENTS IN SOILS OF SOME REGIONS OF TADJIKISTAN AND EUROPEAN RUSSIA

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The measurements of Rn concentrations in some seismically active regions of Tadjikistan and more quiet platform in European Russia were performed during 1995 year.

The alpha-sensitive CR-39 plastics were exposed during 30 days in standard Rn collectors-100mm high and 60mm in diameter. The organic membranes, wich prevents the regisration of short-lived alpha-decaying nuclei of Th row of radioactive decay were placed at the open sides of Rn collectors.

The preliminary data on Rn measurements are presented.

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Radon Migration Study in Venezuelan Caves Using SSNTDs

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ABSTRACT

Venezuelan karstic caves of the Andes have been studied to determine the radon concentrations using LR115 (Kodak-Pathé, France) and CR-39 (TASTRAK, Bristol, U.K.) passive track-etch detectors.
The detectors were exposed to the cave environment for a month in different seasons covering a period of several years.
The results indicated a wide range of values between 40 and 80 kBq/m^3. The highest radon concentration was observed in the Guaramacal Cave (Trujillo State), and in the Guacharo Cave (Monagas State) a concentration gradient of a factor of 10 was measured. In this cave there are large rooms, halls, where the ventilation rates are quite different. An attempt has been made to correlate between the concentration gradient and the ventilation.
The detector calibrations were made in the radon chamber of the National Air and Radiation Environmental Laboratory and the following conversion factors were obtained: 0.434 and 60 Bq/m^3 per month of exposition per track/m^2 for the CR-39 and LR115, respectively.
To conclude this study the dose for a typical journey of a speleologycal expedition was calculated to determine the possible risk for a person. Values varying between 5.7 and 100 mSv/year were obtained depending on the caves, the maximum is roughly equivalent, in term of respiratory cancer, to a probability of $16*10^{-6}$.

This work was supported by the Venezuelan Council for Science, CONICIT, project RPVII 260076 and IAEA-VEN/9/005.

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Radon Monitoring for Health Studies in the Caracas Subway Using SSNTDs

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ABSTRACT

The underground transportation system (Metro) of Caracas City has been monitored for radon concentration by use of passive track detectors and the radon concentration gradient has been determined. It is possible to establish a correlation between the depth of the metro station and the radon concentration for a particular geological boundary condition.

The radon monitoring method used is a well known technique which consist of the exposure of an LR-115 type detector (Kodak-Pathé) in a cup for a given period of time. This type of passive dosimeter has a low detection limit and an adequate time stability. In addition, this detector is relatively inexpensive to be used for long term radon monitoring.

The radon concentration was measured at the most of the underground stations of Caracas obtaining a mean value of 43 Bq/m^3.
The maximum effective doses for the metro workers and the passengers were determined to be 1 mSv/year and 10 μSv/year, respectively.

This work was supported by the Venezuelan Council for Science, project RPVII 260076.

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Rn-222 Measurements in Different Types of Natural Water in Jordan

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Abstract

In this work, the results of Rn-222 concentration for different natural water resources (cold and hot spring; well and sea water), are presented. Sites were chosen from different aquifers, namely, Irbid - Ramtha, Madaba-Ma'in, Dead Sea and Aqaba gulf, which represent different hydrogeological areas in Jordan. The measurements were carried out using time-integrated passive sealed dosimeters containing supergrade quality CR-39 plastic detectors. The activity concentration of Rn-222 ranges from 3.3-10.7 Bq/l (cold spring water), 3.2-5.5 Bq/l (hot spring water), 3.1-5.7 Bq/l (well water), 2.5-4.7 Bq/l (home drinking water) and 4.3-6.3 Bq/l (sea water). The average concentration in all different types of water was 4.5 Bq/l. No unusual radon levels in Jordanian water were, therefore, observed.

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Sensitivity Computation of Solid State Nuclear Track Detectors Using Variable Etch-Rate Ratio

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Previous work (Sima, 1995 a; Sima, 1995 b) aiming at modelling the SSNTD measurements applied in environmental studies are extended in this paper. A rather general Monte Carlo simulation package, intended to supplement the experimental calibration procedures of the SSNT detectors, has been developed. All routine measurement arrangements used in environmental studies can be described (filtered or unfiltered LR-115 or CR-39 detectors; bare detectors, cup type monitors, etc.). Various etching and counting conditions can be simulated.

Latent track parameters are computed on the basis of the ASTAR program (Berger, 1992). Variable etch-rate ratio is used, either in the parametric form of the type proposed by Somogyi (Somogyi 1990), or in the form of a numerical function given in the input. The case of perforated tracks in LR-115 detectors — etched on the exposed side or on both sides —, as well as the case of observable tracks, developed after etching out a detector layer of a given thickness, are explicitly described. In the last case, various criteria required for track counting can be applied.

The following alpha particle sources are considered: ^{222}Rn and ^{220}Rn, together with their progenies, measured in free air or inside of a measuring cup; alpha emitting nuclides in solid matrices; surface contamination. In the case of ^{222}Rn, the source distribution is assumed to be uniform, but in the case of the daughters, the plate-out phenomenon is taken into account. For ^{220}Rn, a distorted spatial distribution can be used, which in turn affects the distribution of the daughter nuclides. In the case of radioactive nuclides distributed in solid matrices, a uniform distribution is assumed.

The equilibrium factor and the fractions of the activity deposited on surfaces, required for the analysis of radon measurements, can be given in the input of the program or can be estimated independently, using a model relying on the values of the deposition velocity and attachment rate.

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Cairo, Egypt, September 1996

SENSITIVITY OF LR 115 DETECTOR FOR RADON MEASUREMENTS -AN EXPERIMENTAL STUDY-

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ABSTRACT

Recently, a theoretical analyses of LR 115 detector sensitivity was published[1]. This analyses, performed for a detector in cylindrical diffusion chamber, was done by using Monte Carlo Method. In the present work an experimental study was performed in order to verify the theoretical predictions. The experiments were conducted in the following manner. Cylindrical diffusion chambers by radii 1, 2, 3, and 4 cm and heights 1, 2, 3, 4, 5, and 6 cm, with SSNTD LR 115 type II on the bottom, were irradiated in the box with high radon concentration. Five chambers of each type were used (totally 120 samples). After the irradiation, the detectors were etched in the standard etching conditions 10 % solution of NaOH, T=60^{0}C, t=120 min. An optical microscope was used for track density determination. Sensitivity dependence on the chamber radius and height was studied in this way.

The results of this experiment confirmed the theoretical prediction of sensitivity behaving with the chamber dimensions. The sensitivity increases with the chamber radius and height, and achieves the saturation.

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SOME PERFORMANCES OF A LR115 DETECTOR RELEVANT FOR RADON MEASUREMENT

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ABSTRACT

In this paper some relevant performances of an strippable LR115 detector for radon and its short lived progeny were investigated. The thickness of removed layer by etching was measured with high quality device and data acquired are presented in the paper. The removed layer increases linearly with the time of the etching; the slopes of these lines depend on the temperature of the etchant. The bulk etch rate of LR115 detector is as follows:

Temperature degrees	Etching rate μm/hour
T=50	1.74
T=60	3.38
T=70	8.22

Before the etching the detectors were irradiated in the box with high radon concentration. Track density increases linearly with the removed layer; for 2 micro meters of removed layer the track density increases approximately 100 %.

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Spatial distribution of radon content of soil gases and well waters measured with etched track radon monitors.

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Enhanced geogas (containing mostly CO_2) upflows were reported in the beginning of 1992 at Mátraderecske, a village situated at the northern foreground of the Mátra mountain, in Hungary, where a few km wide seismically active zone crosses the North Hungarian Central Range. Since the upflowing CO_2 is expected to have higher yields along geological faults, and it carries with itself the radon accumulated in the soil pore space, radon level of soil gases may be an indicator of high CO_2 exhalation sites, and of faults in the underlaying geological structure.

In our survey during the summers of 1993 and 1994 we have measured spatial distribution of radon in the ground water and in soil gas at Mátraderecske. We have used small volume etched track radon monitors, placed 80 cm beneath the water level in draw wells, and in 30 cm deep holes drilled in the vicinity of the wells. The 200 sampling sites were chosen within an area of approximately 1.5 km^2, selecting houses where draw wells were found. Results for the two investigated years indicate no significant change of radon levels from 1993 to 1994. The faults revealed by elevated radon zones in the maps of radon in well water and in soil gas match well the geological structure of the area. The two maps are in good agreement with each other, as well as with the carbon dioxide exhalation rate map and also with elevated indoor radon levels measured by other authors.

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STUDY OF RADON CONCENTRATION WITH SOIL DEPTH

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Abstract

The spatial variation of radon concentration is controlled strongly by geological conditions. However, our recent radon survey near to Biggin in Debyshire on a single lithological unit indicated that there was spatial correlation in the radon values, and when mapped there was a strong pattern in its variation. Hence there must be factors other than underlying geology that affect the variation of radon concentration in the soil. One possibility is that radon concentration is related to the thickness of soil, and another is that it is related to its bulk density. To gain further insight into this, radon and other soil properties were measured along a 2 km transect in the same area but at a more intensive sampling interval of 20 m. Soil thickness and composition were determined by measuring the electrical resistivity and electromagnetic characteristics of the soil. A systematic variation was observed in the depth to the bedrock in relation to elevation, and this also showed a relation with radon concentration, albeit weak.

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STUDY OF RADON LEVELS IN THE DWELLINGS OF HIMACHAL PRADESH USING TRACK ETCH TECHNIQUE.

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Radon is naturally occuring radioactive gas in our environment. igher incidences of lung cancer in various mining populations have been bserved due to high concentration of radon in uranium and other mines. In he open, radon is readily diluted due to large volume of atmosphere where s the dwellings have restricted ventilation and thus its oncentration may build up to many times more than in the open. Recently, t has also become clear that high levels of radon may occur in dwellings.

LR-115 type-II detectors in 'Bare' mode were exposed in the ellings of the cities of Palampur and Baijnath in Himachal Pradesh H.P.). These places are supposed to be high background areas[1] situated in he hills of the northern Indian state of H.P.which are close to Himalaya. he life style and building construction of this part is much different rom the other part of the country. The measurements were carried ut in living rooms as well as in bedrooms in about 30 dwellings. In some ouses, the detectors were also fixed in kitchens. The houses selected n the present study were the typical houses of the region. The detectors ere exposed for a period of 3 to 4 months. The exposed detectors ere etched in 2.5N NaOH at 60°C for 90 minutes in a constant temperature ater bath. For obtaining the radon activity from the track density etectors were calibrated[2] in controlled conditions simulating the tmosphere as found in from which the estimation of Potential Apha nergy Concentration (PAEC) in working level (WL) was made. Assuming the quilibrium factor (F) as 0.45 for a typical Indian bdwellings[3], radon oncentration was estimated..

The radon concentrations in living rooms vary from 94 $Bq.m^{-3}$ to 360 $Bq.m^{-3}$ and in bedrooms from 77 $Bq.m^{-3}$ to 271 $Bq.m^{-3}$. In kitchens, the adon concentrations are found to vary from 123 $Bq.m^{-3}$ to 272 $Bq.m^{-3}$. he radon concentrations found in these dwellings seem high as compared o the other parts of the Country. The results will be discussed in etail.

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Study of Radon-222 Concentration Levels inside Kindergartens in Amman

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Abstract

In this work, measurements of the indoor radon concentration levels were carried out for 74 kindergartens in Amman (the capital of Jordan). The number of children (4 to 6 years old) attending these kindergartens are nearly 15,000. This study was performed during winter season by using time-integrated passive dosimeters, containing CR-39 solid state nuclear track detectors of supergrade quality. We found that the radon concentrations were below 50 Bq/m³ in 16 kindergartens (21.6%), range between 50-100 Bq/m³ in 42 kindergartens (56.8%), range between 100-150 Bq/m³ in 13 kindergartens (17.6%), and over 150 Bq/m³ in 3 kindergartens (4%). The variation of radon concentrations among the kindergartens under study can be attributed to many aspects such as heating system and ventilation, geological structure of the sites, the various types of building materials used for the construction of the kindergartens and aging effect on the buildings. Overall, the results ranged from 40.7 to 193.5 Bq/m³ with an average of 76.79 Bq/m³. This average is relatively higher than the radon concentration average in Amman's dwellings (about 40 Bq/m³) found in a previous study (Abumurad et al., 1994). This is because the studied kindergartens are closed most of the time (75%) for the purposes of children's safety and conservation of heating energy, which allow the radon level to build up. Better ventilation is therefore recommended.

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THE DETERMINATION OF THE QUANTITY OF RADON GAS IN THE RADIOACTIVE DEPOSIT AREAS

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Tajikistan was a main supplier of Uranium for the first atomic units of the former USSR. In post-war years the uranium deposits here were exploited intensely. It resulted in the increasing of the radionuclide contamination at places of ore mining, at the road edges and the territory around the corresponding industrial areas. Besides there appeared the places of interment with solid and fluid radioactive agents. Some interments are just within the boundaries of the towns, Khujand, for example, others are in settlements. In summer time, when the soil full of fluid radioactive agents dries up, radioactive dust is carried away by wind along considerable distances. The dusty storm is vividly seen from the windows of our houses, causing worry, trouble and apprehensions for nature, biosphere and the inhabitants of the nearest space. There have been formed a lot of "dangerous" places of this sort about Northern Tajikistan.

That's why we conduct the jobs on registration of α -particles from radon gas, β and γ rays. For the registration of α - particles we used the film of CR- 39 mark. The detector was etched in the 6,25 N NaOH solituon at temperature 60^0 C during 30 - 90 minutes.

According to the results of measurements one can say that around fluid radioactive agents, behind the protected zone, the quantity of radon gas exceeds the normal one by factor two times. And in some places, for instance, the right bank territory of Khujand, the excees reach five and even more times the normal level.

The Measurement of Radon Levels in the Environs of Himachal Pradesh India. An Application of Solid State Nuclear Track Detectors.

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LR-115 plastic track detector has been used to record alpha activity due to radon in dwellings and building materials of some areas in Himachal Pradesh. The radon values recorded in some dwellings are quite high compared to the action level recommended by various radiation protection agencies. The seasonal variations of radon have also been observed in the area. The high radon values in dwellings may be due to the enrichment of uranium in the soil and rocks of the area. The presence of uranium deposits in some areas in Himachal Pradesh have already been reported by some workers.

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INTS

The nuclear track detector - a tool in radon measurements

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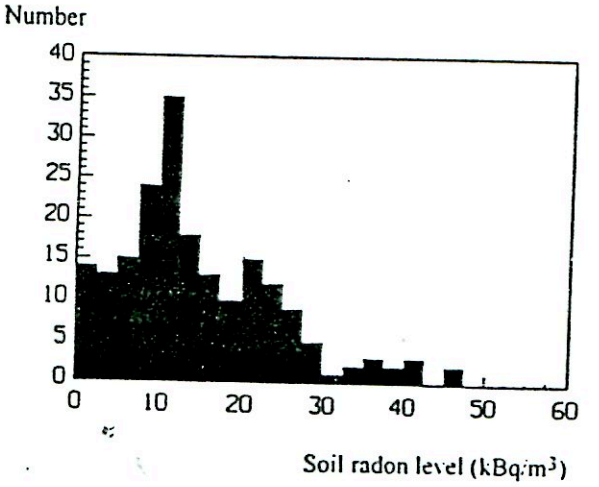
The nuclear track detector is an excellent tool as well in large scale radon surveys as in single measurements indoors or in soil.

In this report there is a discussion concerning radon measurements, where the detectors are based on the plastic film LR 115-II. The detectors have been used in radon measurements indoors and in soil by the Physics Department at Lund University since about 1970. The laboratory is accredited for indoor radon measurements by SWEDAC (The Swedish Board for technical accreditation) according to SS-EN 45001.

There are discussions concerning the following items in this report:
* the properties of the detectors
* the calibration of the detectors
* the use of the detectors and interpretation of measured radon levels



The Figure shows the distribution of soil radon levels from 196 points of measurements in a south Swedish community. The measurements are included in a large scale survey in order to classify the soil from the point of view of soil radon risk. The radon detectors are based on LR115-II plastic film.

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INTS

USING PASSIVE DETECTORS IN SOIL AND INDOORS IN TWO MEDITERRANEAN LOCATIONS FOR RADON CONCENTRATION MEASUREMENTS

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In the frame of an European Project, measurements of radon in the soil and indoors have been carried out using SSNTD's detectors. Two of the involved laboratories have the same climatic conditions and are geographically close: Barcelona (Spain) and Montpellier (France). Montpellier group uses an open-type dosimeter for soil measurements and an closed-type for indoor measurements, both based on LR-115 detector material, while Barcelona group uses a LR-115 based closed-type dosimeter for soil measurements and a Makrofol based closed-type for indoors. The dosimeters have been calibrated respectively in the SRPI (Swedish Radiation Protection Institute, Stockholm) and the ENEA (Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Roma) radon rooms, and a description of the dosimeters (geometry, sensitivity, background and detection limit) is given. Some results of these measurements are presented with the comparison of the calculation of the ratio indoor / soil radon concentration for the two regions.

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INTS

Variation of Radon Concentration in Different Sites in Syrian Typical House

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Abstract :

The concentrations of radon and radon daughter in Syrian homes were studied science 1994 . The data obtained of this study indicated that the radon and radon daughters concentrations depend strongly on the geological characteristic of the soil , indoor radon characteristics , home design , the inhabitant life style, ventilation, ...and Radium content in building materials

We tried in this work to study the relationship between the house parameters and radon ,radon daughters concentration . For this work the Syrian homes were classified into five types depending mainly on the homes design , building material and inhabitant culture . The radon concentrations measurements were carried out in different places of the homes (sleeping room, guest room , sitting room , kitchen and bathroom) using solid state nuclear track detectors. The measurement period was about four months the lower limit of detection was about 5 Bq/m3 .

On the other hand , the scintillation technique was applied for grab samples in some typical homes , Sampling were carried out between 06:00 morning and next 04:00 morning . The personnel were asked to do their daily habit during taking the measurements , the equilibrium factor was calculated by measuring radon and radon daughters by mean of filter paper , also at the same time the electret detectors (short term) were used to confirm the other results .The results of long term NTD showed that the highest radon concentration was in the guest room , while the lowest concentration was in sleeping room .

The time table measurement indicate that the highest radon concentration was at 23:00 , and the calculated average equilibrium factor was 0.57 . The total dose of inhabitants was calculated.

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THE INVESTIGATION OF SUBSOIL RADON DYNAMICS IN THE KOPETDAG REGION OF TURKMENISTAN

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As it is known, natural radon actively reacts to geological and geodynamical processes in bowels of the earth. Besides, changes in radon content of the subsoil atmosphere in area can reflect heterogeneousness of rock's physical properties and its concentrations changes in time can reflect the dynamics of tektonical processes in the region.

The present paper is devoted to the analysis of the dynamics of subsoil radon in the Kopetdag seismic active region of Turkmenistan characterized by complicated geological and tektonical structure and high seismic activity of bowels of the earth.

For subsoil radon's activity registration we use track detectors LR-115-11. Results of our investigation shows the unevenness of disribution of radon concentrations in area and also extreme non-stability of its content in time. Besides, over zones of tectonical disturbances and geodynamical active structures increased concentrations of radon are observed. Intensification of geodynamic activity causes great changes its concentrations in time, besides,grantity and duration of anomalous variations dependon invensity of geodynamical processes in the region.

Filters & Other Applications

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INTS

Application of CR-39 detectors in spent reactor fuel assay

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Fast neutron emission from spent reactor fuel was studied as a possible nondestructive tool by means of CR-39 etched track detectors. The detectors were irradiated in a steel container placed on the top of fuel assemblies vertically stored under water in a spent fuel pond. Hanging on a steel wire, the container was lowered down to the headpiece of assemblies of various burnup and cooling time. The easy-to-use method allows close access to fuel assemblies. In-field tests were carried out in a VVER-440 type nuclear power plant.

Exposure times were optimized for providing acceptable statistics in number of tracks, and keeping gamma-dose low enough to prevent the material from drastic changes in bulk etch rate due to the huge intensity gamma-background. A kind of energy discrimination performed by means of shape selection - with etching time dependent threshold level - allowed reduction of disturbing events. The effect of the adjacent assemblies in a hexagonal lattice of 160 or 225 mm storage distance proved to be 70-80 % or 10-20 %, respectively. The method seems to be a promising tool in nondestructive assay of nuclear material.

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INTS

APPLICATION OF CR-39 DETECTORS IN STUDYING THE RADIATION DAMAGE OF CCD CAMERAS ON BOARD THE MIR SPACE STATION

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A CCD-based TV camera for broadcasting was modified for space use and successfully operated in the MIR Space Station by T. Akiyama of TBS in 1990. Later on it was found that the number of white defects in CCD pixels due to the radiation was increasing with time.

To investigate radiation effects on CCD imagers we exposed test samples of CCD to several kinds of ion beams from the SF cyclotron at the ICRR. We also designed test stacks of CCD sandwiched between sheets of CR-39 and exposed them to the radiation in the MIR space station.

Results from the analysis of these stacks will be presented at the time of the conference.

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INTS

DOPING OF POLYETHYLENE-TEREPHTALATE MODIFIED BY 150 keV Ar^+ BOMBARDEMENT WITH ANORGANIC AGENTS

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Polyethylene-terephatalate (PET) foils, 10 μm thick, were irradiated with 150 keV Ar^+ ions to the fluences from 5×10^{11} - 1×10^{15} cm^{-2} and after several days they were exposed to (the temperature and the time of treating are given in brackets): 0.5 M $(CH_3COO)_2Pb$ water solution (24, 80°C, 20min -30 d), 5 M LiCl water solution (100 °C, 15 s - 8 h), iodine vapour (90 °C, 3h) and mercury vapour (24 °C, 7-30 d). The depth profiles of the incorporated dopant atoms were determined using Rutherford back-scattering technique (Pb, I and Hg) and neutron depth profiling technique based on the $^6Li(n_{th}, ^4He)^3H$ nuclear reaction.

Preliminary results can be summarized as follows:

a) The irradiated PET exhibits enhanced permeability for all dopants with the amount of incorporated atoms being an increasing function of the Ar^+ ion fluence and the time of doping.

b) The depth profiles of Li, I and Hg atoms exhibit anomalous shapes with most atoms being trapped in the radiation damaged surface layer, whose thickness is close to the TRIM estimated projected range of the 150 keV Ar^+ ions (R_p=215 nm). With increasing ion fluence the profiles evolve from those copying the depth profile of the total energy losses of the Ar^+ ions to those characterized by a surface depletion. These findings are in general agreement with our previous results obtained in similar experiments on PE and PP [1].

c) The Pb depth profiles exhibit structureless nearly Fickian form in most cases and after long treatment they extent well behind the radiation damaged surface layer.

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HEAVY ION TRACK SENSIBILIZATION IN POLYPROPYLENE

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The process of sensibilization (of increasing etching selectivity) of high energy ion tracks in polypropylene by way of treatment of the solvents dissolving the products of radiolysis in a track zone has been investigated. The biaxially oriented polypropylene films "Torayfan" of types T2372 and T2400 (Japan) thickness 10.0 and 10.2 μm accordingly were used in experiments. Film samples were irradiated in vacuum by accelerated xenon ions with the energy 1 MeV/a.u.m. Ion fluence varied in the range of 10^7 and 10^8 cm^{-2}. The irradiation was performed on the cyclotron U-300 of Flerov Laboratory of Nuclear Reactions (JINR). The chemical etching was carried out in chromium-VI solution [1].

A variety of organic solvents the influence of which leads to the ion track sensibilization in polypropylene has been determined. It was found that the next necessary stage of the process is the additional thermal treatment aimed to remove the adsorbed solvent out from a polymer matrix which causes its swelling. The optimal procedures were determined for each stage of the process.

The sensibilization method with solvents for production of the polypropylene track membranes was used. The results of the performed investigations show that the present sensibilization method results in substantial increase of selectivity of ion track etching. This allows to produce the microfiltration membranes with cylindrical pores of 0.1−0.2 μm in diameter. The advantage of the developed sensibilization method is that the membranes obtained are characterized by insignificant variations of the pore diameters in size.

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NUCLEAR TRACK MEMBRANES AND THEIR CLINICAL PRACTICE

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Nuclear track membrane (NTM) is a noble-one in the membrane family. NTM possesses some particular properties such as regular and uniform shape of pores, smooth surface, transparency, light weight, negligible moisture absorption, etc. Considering the unique properties, NTMs have been widely used in a variety of technological applications. Recently, we have successfully applied NTMs in the clinical practice. They are made of PET plastic foil irradiated at H1-13 Tandem (CIAE, Beijing) and subsequently etched in NaOH solution. As a part of an infusion set, these NTMs are used to retain granules, tiny fibres, etc., that would cause many diseases if entering the human body through infusion. The results acquired in practice are much better than those with filters based on fibre membranes. The filtration rate of the NTM is about 98% for particles sized >0.5μm in the ward air and more than 95% for particles larger than (15±5)μm in medical liquids. The throughput is about 1500 ml/10 min that is large enough to fit various requirements of intravenous infusion.

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INTS

ON THE TECHNIQUE OF TEMPLATE GROWTH OF NANO/MICRO ENSEMBLES

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A B S T R A C T

Nano/micro materials have extensive range of applications in a variety of fields of science and technology including material science, electrochemistry , micromechanics, microengineering, electronic and optoelectronic devices, drug delivery and bioencapsulation , conducting polymeric fibrils etc. /1/. In general,there exist a variety of techniques for the production of nano/microstructures viz., electron and ion-beam micro-lithography, optical and x-ray methods, selective electroless method /2/. The technique of electrodeposition got recognition eversince Possin/3/ demonstrated successfully its use in production of 300 - 400 Å thick metallic wires. Basically this is a membrane-based synthetic approach and is also called as "template synthesis" involving the synthesis of required material within the pores of the membrane. This method is adorned with simplicity, ease of operation, can generate monodispersice nano/microstructures with high aspect ratio and different geometrical shapes of not only of metals but also of semiconductors, metal-semiconductor junctions/4/, polymeric fibrils down to 3 nm size (lithographic techniques would probably fail here).

The basic instrumentation and related aspects involve the use of membranes (ion-track filter based or porous alumina,nano-channel array glass, xeolites and other nanoporous solids),electrolyte of the desired material with its optimum chemical requirements , constant current / voltage power supplies , properly designed electrodeposition cell , SEM/TEM for revelation of topological and morphological details.

This paper describes in detail the various aspects of this technique and the related problems , factors affecting growth of the desired structures, besides other relevant information based upon the experience of the authors gathered in their labs.

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PROFILE CHARACTERIZATION OF TRACK-FILTER-GROWN COPPER-SELENIUM MICROSTRUCTURES

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A B S T R A C T

One of the most potential and technological applications of Nuclear Track Filters (NTFs) lies in their use in the manufacturing of nano / micro-elemental ensembles structures,whiskers , fibrils,tubules, quantum wires and dots through electrodeposition of the required metal or semiconductors in the etched openings or pores of NTFs as templates for growth. The fabrication of these nano/microstructures is being considered significant not only for their use in microelectronics and micromechanics but also in analytical investigations pertaining to behavioural aspects of materials at nano or submicroscopic scale where tunneling has its realm and scope. Inspite of the fact that there exist variety of techniques like electron/ion beam lithigraphy, photolithography, selective electroless metallic deposition techniques etc for growing such ensembles, the technique of electrodeposition is adorned with simplicity and ease.

It is known that in all electrodeposited metals, the initial layer on the substrates normally forms as submicroscopic crystallites which grows by accertion of the incoming atoms both horizontally and vertically untill a continuous coating is formed. The number and distribution of the crystallites in the initial nucleation of the surface is strongly affected by the surface preparation. However, electroplating process is quite complex in nature. In general, the condition describing the rate of formation of nuclei from which subsequent crystallites grow, would yield the finer grade deposits.

We have used this technique of electrodeposition involving template growth of micro(homo as well as hetero) structures of metal and metal-semiconductor (Cu -Se) throught the pores of NTFs of Makrofol. The details of the method actually used are given elsewhere /1/.

The profile characterization of these microstructures involving metal-semiconductor junctions or interfaces was studied using XRD (Rigaku, Miniflex Japan). The SEM microphotograpgs and XR-Diffraction peak data indicate the presence of both Cu and Se in the crystalline form in the microstructures. However, efforts are on for using other techniques for ascertaining finer profile distribution.

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INTS

RADIATION-INDUCED GRAFT POLYMERIZATION TRACK MEMBRANES WITH SMALL PORES

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Radiation-induced graft polymerization from liquid phase is a unique method for the modification of polymeric materials. After such a modification the physico-chemical properties of the polymer used change significantly. Modification of track membranes with the aim of improving their flow performance is one of the interesting applications of radiation-induced graft polymerization for the preparation of novel types of micro- and ultrafiltration membranes on the basis of known ones[1-3]. It was known that the modification of the surface properties of ultrafiltration membranes, leading to the appearence $-SO_3-$, $-COO-$, $-C=O$ and NH_2 groups, results in a dramatic increase both in water flow rates and in the rejection level of poly(ethylene glycoles).

In this work grafting of a hydrophilic polymer onto poly(ethylen terephthalate) (PET) track membranes with pore size 0.05 μm has been used for preparation of the modified ones. Grafting was carried out by the method of preirradiation in air. The membrane was irradiated by γ–rays from ^{137}Cs. Influence of conditions of modification of track membranes with hydrophilic monomers on the morphology of PET, topochemistry of grafting (on external surface or inside membranes pores) and surface properties of graft membranes has been studied. The thickness of PET membranes grows linearly with grafting yield. Water contact angle on the original and modified membranes has been measured and it was found that it decreases with increasing grafting yield. Gas flow rate decreases during grafting but only for grafting yield higher than 2%. It was shown that the modification of PET membrane with hydrophilic polymer results in growth of water flow rates. The optimal conditions of modification of PET membranes are obtained when the wetting capacity of their surface is increased, while the porosity and filtrating capacity remain unchanged. It is noteworthy that the properties of graft PET membranes were unhanged during their storage under ambient conditions for more than a year.

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SOLUTE CONCENTRATION DETERMINATION USING ION TRACK FILTERS

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There exist a variety of techniques for understanding the solute-solvent interaction. We have made microhydrodynamical flow studies on various fluids (water, alcohol,acetone) using ion track filters (ITFs) for the estimation of solute concentrations in different mixtures with water as the base. The variation of the derivative of volume with respect to time (dV/dt) versus concentration of the solutes in water at constant pressure difference has been studied. It is observed that dV/dt decreases with the increase of solute concentration.

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SOME CHEMICAL APPLICATIONS OF NUCLEAR TRACK MICROFILTERS

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Nuclear track micro-filters were prepared from Bisphenol-A-polycarbonate (Makrofol-N) plastic films. The latent tracks were created by exposing the films to a well collimated beam of ^{129}Xe and ^{161}Dy of 13.0 MeV/A. Optimum etching conditions were determined and the pores were developed by etching the irradiated films in 5N NaOH at 55°C. The diameter and density of the pores were measured using optical and scanning electron microscope. Seven filters were then developed with pore diameters ranging between 1.7 μm to 13.1 μm. The filters were then characterised in terms of various parameters like length of pores, tapering angle, pore shape, and porosity. Rate of filtration and throughput were also determined. The filters were used for the following chemical applications

(a) determination of viscosity of some liquids.
(b) determination of concentration of ethylene diglycol.

Further, an attempt was made to demonstrate their possible applications in newer areas by studying the surfactant solvent interactions leading to the determination of critical micelle concentration (cmc) of the surfactants both with and without the presence of a dye.

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VARIATION OF U.V. SOLAR ABSORPTION WITH DRESSING

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Abstract

Nuclear track detectors type CR-39 irradiated with Cf-252, were fixed on two personnel phantoms and exposured to U.V. Solar radiation for 40 days in Dhahran, Saudi Arabia in the period starting from 1st August. One phantom was rotating continuously and the other was stationary. Both phantoms had different dressing. The U.V. Solar radiation was measured using Epply Sensor. The effect of dressing and its color on the absorption of U.V. Solar radiation was studied by the measurements of alpha and fission fragments tracks diameters on the nuclear track detectors. Absorption on bare phantom was found higher than with dressing. More analysis about colour dressing effect and shadow will be reported.

Etched heavy ion track membranes as templates for metallic microstructures

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Transmission electron images of tracks induced by high energy ion irradiation in organic foils show damaged areas of 6 to 7 nm diameter. By using different etching technics and etching conditions channels with different shapes can be obtained. The channels can be filled with metals by electrochemical deposition. After galvanic filling, the membrane matrix is separated from the replica by an organic solvent. The metal needles replicate the shape of the channels in the membrane. In this way it is possible to generate large random whisker arrays with almost identical individual whiskers with length up to several 100 µm and diameters down to tenths of µm. A systematic local arrangement of the columns can be reached by using an ion beam microprobe. Various shapes as small tubules, pointed needles or different column shapes can be produced. By suitable choice of electrolyte and working conditions it is possible to grow metal whiskers on areas of several square cm.

Track Observation and Measurement

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A COMPUTER APPLICATION FOR QUANTITATIVE EVALUATION OF BETA RADIOGRAPHY IMAGES

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The treatment of autoradiograph images is very important for quantitative evaluation of radionuclide distribution in rocks and minerals. Special equipment such as "Densitron", microphotometr a.o. are required for autoradiograph study. A computation technique and program ensuring make possible to obtain the quantitative information about a radioisotope distribution without equipment.

Autoradiographs on the photoemulsion film and nuclear emulsion plate were used under radioisotopes of ^{195}Au, $^{110+110m}Ag$, ^{63}Ni, ^{3}H distribution study in geological experiments. Autoradiograph were introduced into computer 486DX by a "Mustek Paragon 1200" scanner with transparency adapter. A resolution of scanning is 600 dpi with 256 gray scale.

The "Radiograph" program worked out in Buryat Geological institute and "Aldus Photostyler" standard program were used for a radiograph analysing with the construction of profile blackening plots, equal radioisotope contents charts and a calculation of radioisotopes concentration in any point of autoradiograph using standard samples.

The distribution of gold (^{195}Au) and silver ($^{110+110m}Ag$) in sulfide minerals (pyrite, sphalerite, galena and others) were studied by such method. It was established the mechanism of "unvisible" gold formation. The mapping of the radioisotopes distribution in glass samples was also obtained by beta radiography computing evaluation.

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A COMPUTER PROGRAM FOR SEMIAUTOMATIC MEASUREMENT OF GEOMETRICAL PARAMETERS OF NUCLEAR TRACKS

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From experience we learned that the analysis of skewed tracks in CR-39 detector resulting, for instance, from target fragmentation, hot particle decay, neutron-induced charged particles, or simple calibration experiments with accelerated heavy ions is difficult if not impossible by fully automatic measuring systems. This was the motivation to develop an interactive computer program capable of measuring not only the track coordinates on the detector foil surface, minor/major track axes and azimuthal track angle, but also projected track length, diameter of a rounding at the end of a track hole and track depth (the distance from the foil surface to the track bottom end).

The entire system consists of an optical microscope, a manually controlled moving stage, focusing system, CCD camera, video digitizer and a personal computer. After completing the measurements, besides all the above mentioned track parameters, the number of analyzed individual tracks and/or number of so-called "stars" of tracks as well as other auxiliary data are written in an ASCII output file which can then be processed with some other suitable software, e.g. electronic tables. From this processing the distribution of etch rate ratio vs particle residual range (important for particle identification), event multiplicities and the reconstructed point of interaction in the case of target fragmentation, and the size and activity of the hot particle can be obtained. In this contribution the program is briefly described and its utilization illustrated by some selected examples.

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INTS

A TEST TO ANALYSE THE UNIFORMITY OF TRACKS IN SSNTDs

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In this work, a suitable statistical test for analysis of spatial distributions is presented. This te which is based on the Legendre Polynomials, has some advantages over the Pearson's χ^2 test an the least square fit to a polynomial. The application of this test in the analysis of the homogenei of thin uranium films is showed and its generic reliability is discussed.

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DIGITAL AUTORADIOGRAPHY

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Application of the fast-acting digital computers and the technical means of signals treatment allowed to spread the possibilities and the resolution of autoradiography.

Analysis of autoradigraphic features is connected with the elucidation of the optical density distribution of the exposed and treated photoemulsion used as of detector of the secondary beta-irradiation.

In this report the possibilities of the digital image processing (DIP) by the autoradiographic investigations of impurity and component distributions in the grynat crystals are shown.

Identification of radionuclides and the qualitative evaluation of their contents was conducted by gamma-spectrum of specimens irradiated by neutrons.

The treatment of autoradiograms was conducted with the help of the dialogue system, having matrix in 512x512 elements.

For the interpretation of the experimental data clustering analysis methodology was used.

Classification of zones on the minimum of the square mistake was conducted according to the data of histograms of the optical densities of the studying autoradiograms.

It was proposed algorithm of digital treatment for visualisation of autoradiographic features.

The resolution of autoradiography at minimal contrast has been enhanced on degree by adaptation of methods and digital processing algorithms.

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INVESTIGATIONS OF THE USE OF ELECTRON SPIN RESONANCE FOR NUCLEAR TRACK COUNTING AND GAMMA-RAY DOSIMETRY IN CR-39

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ABSTRACT

CR-39 plastic detectors were exposed to (i) α-particles from an ^{241}Am source, (ii) fast neutrons from an accelerator ((d, D) reaction), and (iii) gamma-rays from a ^{60}Co source. The α-particles and neutron-recoils produce "latent tracks" in the CR-39, which are thought to be accompanied by long-lived free radicals. After irradiation, all the CR-39 samples were subjected to electron spin resonance (ESR) analysis- even though gamma-rays are known not to produce latent tracks

Exposure to neutrons of ~ 5.8 MeV with a fluence of ~ 7.6×10^{11} failed to yield an observable ESR signal. The samples were then etched in 6 M NaOH at 70 °C for different lengths of time (up to 14 h) and a high track density from recoil protons was revealed. These samples, too, did not show an ESR signal. The samples that had been exposed to the ^{241}Am α-particles with different fluences (up to ~ 8.1×10^6) also failed to produce an observable ESR signal. It is suggested that either the polymer chain dissociation by ionising particles (i.e. protons, alphas, etc.) does not end up with long-lived free radicals, or the minimum detectable dose for ESR requires a higher fluence- and hence a greater concentration of free radicals- than used in these experiments. Such high doses, however, have little relevance to normal environmental dosimetry.

In the case of the ^{60}Co-irradiated samples, an ESR signal (3 scans accumulated at room temperature) was observed at doses ≥ 100 Gy. The dose response curve exhibits good linearity between ~ 100 Gy and the maximum dose used of ~ 1.3×10^4 Gy. It was also found that the ESR signal decays to unobservable intensities in ~ 6 days if the irradiated samples are stored at room temperature, but in ~ 20 days if stored in a refrigerator at ~ 4 °C.

Our original hope that it might be possible to use ESR in place of track counting as a means of detecting and measuring moderate doses of both alphas and fast neutrons in CR-39 must obviously be abandoned. Consequently, these results suggest that nuclear etched-track counting in CR-39 remains the only feasible method, at present, in these fields.

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Lyoluminescence Of Common Salt and Sugar

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Abstract

Lyoluminescence of the above chemicals after exposure to gamma dose of up to 45 kGray were studied. The solvent used was distilled water. The lyoluminescence(LL) response for sugar was linear with dose up to 0.5kGray and then started to saturate up to the dose of 2kGray after which the response drop rapidly. For salt, the LL response was linear up ~10 kGray, after which the response drop. The effect of bleaching with UV light and annealing immediately after irradiation were also studied.

Keywords

Lyoluminencence,salt,sugar,annealing

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1 - 5 Sept 1996 Cairo - Egypt

INTS

TRACK REPLICA METHOD APPLIED TO CR-39

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ABSTRACT

The replica method has been applied previously to detector materials which can be easily removed by specific solvents. Taking into account that CR-39, one of the most sensitive ion track detectors, can not be removed by any solvent without altering the replica materials, the technique had to be adapted for using with this material. Replicas for normal and grazing angle ion incidence on CR-39 were obtained and observed with a transmission electron microscope.

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