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Banin shakeri jooybari

Highlight of Results from ATLAS at LHC

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Physics results of the ATLAS experiment at the Large Hadron Collider (LHC) at CERN will be reviewed based on data collected during proton-proton collisions at center-of-mass energy of 7 TeV and 8 TeV. This talk presents Standard Model measurements, recent studies of the Higgs boson and searches for processes beyond Standard Model. In addition, we will mention about semiconductor trackers used for ATLAS inner tracking detectors.

FNTD TECHNOLOGY - LATEST AD VANCES IN INSTRUMENTATION AND NEUTRON-PHOTON DISCRIMINATION

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Introduction: The next technological breakthrough in tools for medical dosimetry, radiobiology and radiation protection was done with Fluorescent Nuclear Track detectors (FNTD) that has some important advantages in measuring fast neutron, high energy heavy charge particles (HCP) and photon fields. New detectors made of luminescent aluminum oxide single crystals Mg-doped and novel type of high resolution imaging instrumentation will be discussed. This new technology was developed primarily for neutron and ion dosimetry, and applications in radiobiology and high resolution imaging of photon radiation [1]. The results of latest experiments in LET spectroscopy of HCPs, fragmentation, 2D and 3D imaging of particles and photon microbeams, and alpha emitting nuclides identification will be presented. Special attention will be dedicated to the possible use of FNTDs as a radiobiology research tool and QA tool in proton and carbon-ion radiotherapy.

Detectors: Fluorescent Nuclear Track Detector (FNTD) technology based on aluminium oxide crystals and fluorescent laser scanning confocal microscopy. FNTDs are made of Al₂O₃:C,Mg having high concentration of single and double oxygen vacancies associated with impurities and forming aggregate defects with unique optical properties. These color centers undergo radiochromic transformation which remains thermally stable up to 600°C and are insensitive to ambient light that does not have a UV component. Unlike Plastic Nuclear Track Detectors (PNTDs) FNTDs do not require chemical etching before imaging. Images of tracks are obtained in fluorescent contrast and the readout can be repeated multiple times without erasure. If needed FNTDs can be erased and reused after bleaching with pulsed UV light.

Radiological characteristics: The main advantage of FNTDs is their ability to image individual charged particle tracks with diffraction limited resolution and to discriminate particle tracks against fluorescent signal caused by photons and electrons. At low doses (below 50 mSv) track counting mode is utilized. At higher doses a proprietary image processing algorithm is applied for discriminating neutron- and photon-induced signals. The low limit of detection (LLD) is estimated to be 0.1 mSv for neutrons and 3 mSv for photons. The saturation of photon-induced signal happens at around 100 Gy. Energy dependence for neutrons was characterized in monoenergetic and broad energy fields.

FNTD reader: The fully automatic compact table-top FNTD reader (Model FXR-700N) was designed for small and large dosimetry services. The reader allows one to load 216 detectors on a

tray, their engraved IDs are automatically recognized and fluorescent images are scanned and processed The reader is characterized by robust and compact optical design, fast data acquistion electronics and a user-friendly software interface designed for three level of access: technician, senior dosimetrist and technical support engineer.

FNTD annealer (bleaching system): FNTD detectors are reusable after optical bleaching with pulse UV laser light. To perfrom high fidelity bleaching automatic instrument was developed that allows bleaching scan of up to 1000 detectors on four trays loaded with 250 FNTDs each. The annealer is equiped with imaging CMOS camera head working in dual mode (green fluorescence and IR imaging) for both reading the engraved ID and measuring crystal coloration for QA and radiation senstivity assignment.

Performance in mixed neutron-photon fields: The FNTD performance was successfully "blind-tested" against US-ANSI N13.11-2009 standard for measurements of mixed neutron-photon fields with different ratios of AmBe and ²⁵²Cf neutrons (bare and moderated) and photons (¹³⁷Cs and X-rays) with total dose up to 50 mSv. Expansion of the dose range from 0.2 mSv to 30 Sv for both neutron and gamma doses is achieved by using three radiation converters (⁶Li-glass, polyethylene, TeflonTM) and new, proprietary image processing techniques.

Reference

[1] Akselrod, M.S., Sykora, G.J., **2011**, Fluorescent Nuclear Track Detector technology - a new way to do passive solid state dosimetry, Radiat. Meas., 46 1671-1679.

Latest Developments in Nuclear Emulsion Technology

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Nuclear emulsion is high sensitive photographic film used for detection of three-dimensional trajectory of minimum ionizing charged particles. These trajectories are recorded as tracks consist of a lot of silver grains. The size of silver grain is about 1 micron, so that nuclear emulsion has very high three-dimensional spatial resolution (sub micron), which gives us the very high three-dimensional angular resolution (a few mrad).

The important technical progress was speed-up of the read-out system of nuclear emulsions built with optical microscope system. We succeeded in developing a high-speed three-dimensional read-out system "Super Ultra Track Selector, called S-UTS" with the speed of about 100 cm² per hour. Furthermore, new scanning system "Hyper Track Selector, called HTS", which speed is one hundred times faster than S-UTS, is under development.

We are developing the nuclear emulsion itself in our laboratory at Nagoya University by using emulsion gel production machine. We can control the silver bromide crystal size and its sensitivity in order to optimize for various purposes. We are also developing nuclear emulsion production techniques (gel production, poring and drying).

By developing these new technologies, our nuclear emulsions are applied for cosmic-ray muon radiography, fusion plasma diagnostics, laser ion acceleration experiment, gamma-ray telescope, neutrino experiment, darkmatter experiment and so on. Especially, latest nuclear emulsions produced in Nagoya University are already used for the muon radiography experiment.

In this presentation, I will talk about the status of latest developments of nuclear emulsion technologies focused on my studies.

Functional Nanopores Based on Nuclear Track

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Nanopore or nanochannel is very important for life, that is called ion channel, which is responsible for the transport of electrolyte ions. Swift heavy ions are powerful in fabrication of nanopore in polymer film. The inner surface of the track-etched nanopore is negative charged since there exist carboxyl groups. A charged conical nanopore exhibits asymmetric properties of ion transport that resemble those in biological ion channels, such as current rectification and ionic selectivity. The asymmetric properties were studied with continuum theory and were contributed to ion-enrichment and ion-depletion when an external voltage was applied. Based on these knowledges of polymer nanopores, a variety of nanopores with different shapes, different charge sign and distribution were fabricated controllably and were found their potential applications as energy converters or pulse generator. By modifying the inner surface with some DNA or polymer molecules, which opening or closing the nanopores at special conditions, several functional synthetic ion-channels were realized. Recently, we found that without chemical etching, after UV radiaton and when an external voltage is applied, there exists novel ion permeation across the PET membrane with latent tracks and the amount of the transported ions is in proportion to the ion fluence. The most interesting things with this new type of nanopore are that it shows dual ionic selectivity, i.e., cation ions and some some dehydrated ions. From SAXS and positron annihilation spectroscopy (PAS) measurements, the diameter of the nanopore is estimated to be about 0.7 nm. We think this new type of nanopore system will find its applications in seperation or filtration of electrolyte ions.

The use of CR-39 Plastic Nuclear Track Detector in quantifying the contribution to dose in healthy tissue from Secondary Neutrons in Proton and Photon Radiotherapy

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The use of ionizing radiation to treat cancer is one of the most commonly used modalities in cancer therapy. Photon radiotherapy using MVp x-rays is the most common form of radiotherapy, while throughout the world, the number of proton radiotherapy facilities is growing rapidly. In both proton and photon radiotherapy, secondary neutrons produced in nuclear interactions of the primary protons or x-rays with target nuclei can deliver dose to healthy tissue surrounding the tumor being treated. However, secondary neutrons are not considered in treatment planning in either proton or photon radiotherapy. CR-39 Plastic Nuclear Track Detector (PNTD) is an ideal detector for quantifying the contribution from secondary neutrons to dose in healthy tissue in both proton and photon radiotherapy. In this presentation, the use of CR-39 PNTD in detection and measurement of secondary neutrons is described and illustrated with results from recent studies measuring secondary neutron dose equivalent in both proton and x-ray radiotherapy carried out by the OSU Radiation Physics Laboratory.

Proof of principle experiment of Laser-driven Exotic Nuclei extraction-acceleration method

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The contemporary radiofrequency accelerator technology have provided radio-isotope beams for the research in fundamental nuclear physics. However, the existing technology now faces difficulties in exploring the further frontiers in the nuclear chart. One of the promising solution might be brought by the combination of the state of the art high intensity short pulse laser system and the nuclear measurement technique. Recent progress of the laser technology brought table-top lasers with focused intensity up to 10²¹ Wcm⁻² with only less than 10 J of energy on target. By the interaction with the solid density target, the state-of-the-art laser technology can extract heavy ion beams in multi-charged state and low emittance, independently on the chemical properties of the target material.

We propose Laser-driven Exotic Nuclei extraction-acceleration methods (LENex), in which the exotic nuclei which are the products in the target by the bombardment of the external ion beam, are extracted away by a femtosecond petawatt laser pulse in the form of highly-charged and high energy beam. As a proof-of-experiment of the LENex scheme, we demonstrate the extraction of the almost fully stripped iron ions with the energies of 0.9GeV out of the Al bulk target which contains iron impurities simulating the nuclear products. In the experiment, the short pulse high contrast high intensity laser pulses from J-KAREN laser system at JAEA is focused on the target with the intensity of 10²¹Wcm⁻². The detection of the iron ions are conducted by the calibrated solid state nuclear detector, Kapton film. The ionization condition of the ions is monitored by the X-ray crystal spectrometer.

Together with the experimental results and the numerical simulations we conducted, we show that the short-lived, heavy exotic nuclei, with a much larger charge-to-mass ratio than in conventional technology can be obtained in a form of an energetic, low-emittance, high current beam.

Nuclear Tracks in Students Laboratory: Some Simple Experiments

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Since their very inception, Solid State Nuclear Track detectors (SSNTDs) have found various applications in myriad of fields of science and technology - from high energy particle physics to generation of nano-/micro structures and nano-particles encompassing nano-technology in to their folds. Being adorned with simplicity, ease in handling, versatility, low cost and independence from complicated electronic processing and circuitry intricacies; they have been primarily used as particle detectors, and in understanding and investigating some basic nuclear laboratory experiments.

However, these have not been able to attract the attention of the students and teachers as well for their exploitation and possible inclusion in undergraduate laboratory curriculum.

This talk presents some of the possible undergraduate low cost and simple experiments like range and half-life measurements; nuclear statistics; alpha, fission fragments recording and auto-radiography techniques; template synthesis of nano-/micro structures, filtration characteristics and pore size measurement via electrical conduction measurements etc- all involving the use of SSNTDs. Some interesting experiments for the students of botany and zoology have also been suggested.

Calibration for the Fission-Track Dating using LA-ICP-MS

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The Fission-Track Dating (FTD) is based on the spontaneous fission of the ²³⁸U, present in trace amounts in natural minerals. The emitted fission fragments interact with the crystal structure of the host mineral, leaving a trail of modified structure that is more reactive to appropriate chemical treatments than the bulk material. In this way, a channel, which is visible under the optical microscope, is formed. These channels are the fission tracks and their densities are proportional to the number of decays occurring since the mineral cooled down its closure temperature. To date the mineral, besides spontaneous fission-track density, the volume concentration of the parent nuclide has to be determined. The usual way to determine uranium concentration is to induce fission by irradiating the mineral with neutrons in a nuclear reactor. The induced-fission tracks are detected in an external detector and have their densities determined by counting under the microscopy after proper etching. While this is a well tested and reliable method, the irradiation and lowering of neutron-activated activity to safe levels may take several months and make FTD a very time expensive technique. Other issue is the need to implement radiological protection demands in FTD labs. To overcome the complications arising from the neutron irradiation, researchers are working on the direct determination of mineral uranium content using spectrometric techniques. The laser ablation induced coupled plasma mass spectrometer (LA-ICP-MS) is the most used equipment for this purpose. Uranium determination by LA-ICP-MS is a faster and cleaner (from the radiological point-of-view) technique, although still much more expensive than neutron activation techniques. The main issues to be dealt with are related to age calibration: search for uranium standards and absolute values of etching and counting efficiencies in the determination of spontaneous-fission track densities that used to be determined relatively to the induced track ones. In this work, a review of attempts to calibrate this technique is presented. We present some promising results regarding uranium standards and efficiency determination mainly for apatite, the most used mineral in FTD. We also discuss the possibility of using the electron microprobe for the determination of uranium content in zircon, mineral widely used for FTD and that presents higher uranium contents than apatite.

Chemical structure of heavy ion tracks in polymers

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Some polymers, known as nuclear track detectors have been used for more than 50 years. An important work has been conducted on the ion's parameters (charge, energy, incidence angle) that lead to the formation of an etched track using appropriate chemical agents. In comparison with this work on etching, the radiation chemistry of the ion latent track is poorly studied. Consequently a large gap of incomprehension still remains between the primary process of energy deposition and the consequent chemical modification induced.

We will review the literature both on the physical parameters proposed to describe the etching process (LET, REL, dose from secondary electrons) and on the radiation chemistry of polymers. Even if the main results for radiation chemistry are coming from electrons beams, X-rays or γ -rays irradiations. We will then discuss the ability to describe the ion track radiation chemistry with an approach based on the dose deposited by the secondary electrons removed by the incoming ion. This discussion will be illustrated with the experimental bonds-scission cross sections induced by different ions having LET ranging from 10 to 10^4 KeV. μ m⁻¹ in four organic detectors; the LR115 cellulose nitrate based detector, polycarbonate, polyethylene terephthalate, and PADC (poly-allyl-diglycol carbonate). The effective track core radius, directly related to the experimental cross section, could be the most suitable parameter to understand the chemical modification along nuclear tracks in polymers. Limitation of this approach based only on the dose will be emphasized. We will end proposing to mix this dose approach with kinetic model used in radiation chemistry for instance to understand radio-oxidation. This new approach could then bring new insights of the oxygen role on the ion track registration in PADC.

Low energy electrons and swift ion track structure in PADC

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In passing through a medium, primary ionizing radiation (IR) gives raise to secondary particles (delta rays) that are for their most part responsible of the damages produced along the primary particle track. Indeed, radiation-induced low energy electrons (LEEs), namely, below 15 eV, are produced in large number along the ion track. And even if such LEEs have impact energies significantly lower than the ionization energies of the molecules of interest, they can nevertheless induce crucial physical mechanisms among which the resonant electron attachment appears as one of the most important processes since potentially involved in the chemical bond break induction.

In this context, the present paper aims at using an up-to-date Monte-Carlo code - called TILDA-V (an acronym for Transport d'Ions Lourds Dans l'Aqua & Vivo) - which provides an accurate description of the ion-track in PADC. All the ion- and secondary electron-induced interactions are described by means of a complete set of multi-differential and total cross sections for a large range of ion energies (10 keV-100 MeV) and electron energies (7.4 eV-100 keV). The ion track structure in PADC is here mainly described in terms of "ionization" processes and "energetic" delta-rays effects allowing a fine analysis of the role of LEEs in the creation of a latent track.

After a brief remind of the most important channels through which LEEs are prone to break a chemical bond, we will report on the simulated energetic distributions of LEEs along an ion track in PADC; in particular on both sides of the Bragg-peak position. Finally, based on the rare data dealing with LEEs interaction with polymers or organic molecules, we will emphasise on the role played by the LEEs in the formation of a latent track in PADC, notably that induced by the sub ionization electrons.

The-State-of-the-art Development of Electrochemical Etching of Charged Particle Tracks in Polycarbonate Track Detectors

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Polycarbonate track detectors (PCTD) provide a number of advantageous characteristics such as simplicity, low cost, high spatial resolution, uniformity, sensitivity to low-LET ions such as fast-neutron-induced recoils, alpha particles (depending on etching process applied) and heavier ions, insensitive to low LET ionizing radiations (e.g. x, γ and electrons), insensitive to non-ionizing radiation (e.g. light, UV, IR, microwave), insensitive to environmental conditions (e.g. ambient temperatures, moisture, etc.), easy to be cut from large sheets, usually masked on both sides, etc. for some applications. In particular, charged particle tracks in PCTDs when processed by electrochemical etching (ECE) method are large enough to be directly observed, analyzed and diagnosed by the unaided eyes at a glance.

The ECE method has promoted the PCTDs use in applications such as fast neutron dosimetry, albedo neutron individual dosimetry, neutron dosimetry in high-energy intense x-ray beams, radon monitoring indoors and outdoors, radon mapping, ion detection, etc. The ECE process may be now classified into two general methodologies; high frequency-high voltage (HF-HV) and 50 Hz-HV methods. The HF-HV method has been under development and use since 1970. The 50 Hz-HV method has been once studied about 40 years ago and then some recent studies in our laboratory which seem to have promoted some applications based on its simplicity, availability and low cost in of using thick PCTDs and 50 Hz-HV generators to apply very high voltages to thick PCTDs, if necessary. Each ECE method depends on a large number of physical and chemical parameters; they can be optimized for any particular applications. The ECE chambers developed can process one to even 100 or more small detectors (2 cm x 2 cm) at a time or detector sizes from small to large sizes (e.g. 40 cm diameter with 1256 cm² area) desired for certain applications. The PCTDs with thicknesses from thin (e.g. 100 μ m) to thick (e.g. 1mm) can be processed. It is the purpose of this paper to provide a brief historical review of the ECE methodologies in terms of detectors, equipment, processing parameters, and applications of the PCTDs and the state-of-the-art development of ECE process and some applications with particular regards to alpha particles; ions such as helium, nitrogen, neon, etc.; using 50 Hz-HV methodology.

High Sensitive Palmtop Sensor with Etched Tracks on a Sensor-Plate

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We developed a highly sensitive and palmtop sensor based on optical waveguide mode. A TE-polarized beam is directed onto the base of a glass prism at an angle necessary for total internal reflection. The configuration was named as Kretschmann configuration which is frequently employed for excitation of surface plasmon resonance. When a dielectric layer was fabricated on a reflection layer as a waveguide, an incident light excites weakly guided modes in the wave-guiding structure. Refractive index change by surface reaction on the waveguide can be detected with the waveguide mode. It was found that the maximum of electronic field was located in the middle of the wave-guiding structure calculated with Mie theory. If surface reaction can be observed in the middle of waveguide via nano holes, high sensitivity will be expected. Mono-crystalline silicon film on a silica glass substrate was thermally oxidized for fabrication of a sensor chip. Amorphous SiO₂ layer on a silicon layer on a silica substrate was obtained as the waveguide. 137 MeV Au²⁰⁺ irradiation at a fluence of 5×10^9 cm⁻² was performed with the 12 UD Pelletron tandem accelerator at University of Tsukuba followed by etching with a vapor from a 20% hydrofluoric acid for 30 min. Etched tracks penetrated into silica layer until a silicon layer and the diameter of the etched track was determined by etching time as well as temperature. It was found that sensitivity on the perforated waveguide is much higher than sensitivity on the normal waveguide.

Space radiation dosimetry by PADLES in the ISS Russian segment to evaluate the effects of polyethylene shielding and different tissue equivalent materials

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The ALTCRISS project has been conducted in order to evaluate the effect of the polyethylene pads 4π or 2π shielding (PE, thickness of 5 g/cm²) used for an active detector (sileye/alteino cosmic ray detectors) and passive dosimeter packages in International Space Station (ISS) Russian segment (PIRS and ZVEZDA). The PE was equivalent to the crew-cabin shielding of a US module.

Our passive dosimeters 'PADLES' were installed in three conditions: between PEs, in a zip bag on the surface of the wall without the PE and at ground (Baikonur Cosmodrome). With relocating the sileye/alteino active detector, the passive dosimeters between polyethylene block and in zip bag without the polyethylene were also relocated in ISS.

The PADLES package usually consists of two types of passive and integrating dosimeters, a CR-39 plastic nuclear track detector (HARTZLAS TD-1 PNTD: Fukivi Chemical Industry) and a thermoluminescence dosimeter (TLD-MSO-S: Kasei Optonics, LTD.). In the ALTCRISS experiments, both tissue-equivalent material CR-39 PNTDs and NAN-JAERI (Tsuda et.al, 2005) were enclosed in the PADLES packages as radiators for CR-39 to precisely measure a personal exposed doses. The NAN-JAERI is improved in both hydrogen and oxygen elemental composition to be optimized for neutron personal dosimetry. We compared the doses obtained by PADLESs with or without the PEs, and with or difference of the two tissue-equivalent materials.

The results of space radiation measurements of the ALTCRISS project Phase 1 to 4 using the PADLES system will be reported in this time: Phase 1 experiments was 108 days from December 2005 to April 2006, Phase 2 was 158 days from April to September 2006, phase 3 was 215 days Sep 2006 to April 2007, and Phase 4 was conducted from May to October 2007.

Fading and ageing effects of CR-39 PNTDs during ISS space experiments evaluated using reference sample pre-exposed C/Fe heavy ions

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Passive Dosimeter for Lifescience Experiments in Space 'PADLES' have been using for various experiments onboard the International Space Station (ISS) since Japanese Pressurized module 'KIBO' has launched and installed part of the ISS in June, 2008. It consists of two types of passive and integrating dosimeters, a CR-39 plastic nuclear track detector (HARTZLAS TD-1 PNTD: Fukivi Chemical Industry) and a thermoluminescence dosimeter (TLD-MSO-S: Kasei Optonics, LTD.). So far the PADLESs has allied to area space radiation monitoring inside the KIBO at fix locations every half a year, dosimetry for bio-specimen under various temperature between -80 to 36°C and personal dosimeters for astronauts dose management throughout their careers, end so on.

Each PADLES package includes a reference CR-39 PNTD plate exposed to heavy ions (390 MeV/n 12 C, 427 MeV/n 56 Fe) from the HIMAC heavy ion accelerator of the NIRS, Japan in 2005, which in order to check the sensitivity stability of the CR-39 PNTDs during space experiment.

We evaluated the fading and aging effects for the sensitivities during the flight using the reference plates in a same lot included in 150 PADLESs used for space experiments in ISS KIBO and the control ones over last 5 years since 2008. Also, has long-term ground performance test being conducted that the reference CR-39 PNTD plate kept under -80, 4 and 20 degrees over 10 years. The detail results of the sensitivity under each temperature and long-term fading effects will be presented at the meeting.

Projectile fragment emission in the fragmentation of silicon on carbon and polyethylene targets at 800 A MeV

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The emission angle and the transverse momentum distributions of projectile fragments (PFs) produced in fragmentation of silicon on carbon and polyethylene targets at 800 A MeV are measured. It is found that the angular and transverse distribution of PFs do not evidently depend on the mass of target nucleus, the average value and width of angular distribution decrease with increase of the charge of PF for the same target, and no obvious dependence of angular distribution of PF can be explained by a single Gaussian distribution and the averaged transverse momentum decreases with the increase of the charge of PF. The cumulated squared transverse momentum distribution of PF can be well explained by a single Rayleigh distribution. The temperature parameter of PF emission source decreases with the increase of the size of PF.

Gamma radiation induced modifications on physico- chemical properties of Makrofol (KG & N) polycarbonate

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Gamma-ray irradiation is a very useful tool to improve the physicochemical properties of various polymers without the use of any heating and crosslinking agent. This technique is widely used in many applications. Solid State Nuclear Track Detectors (SSNTDs), being threshold-type detectors are applied for ionographic registration and are well studied for heavy ion research [1]. Makrofol (KG & N) polymers are the most versatile solid SSNTDs. The Makrofol (KG & N) polymers samples were exposed to gamma radiation up to the dose level of 1000 kGy. The pristine and exposed samples were characterized by X- ray diffraction, UV- visible and FTIR for the structural, optical and chemical studies respectively. The gamma exposure experiment and the characterizations were carried out at Inter University Accelerator Centre (IUAC), New Delhi, India. The crystallite size and band gap energy values were calculated using Scherrer formula [2,3] and Tauc's relation [4] respectively. The values of both quantities were found to vary after gamma exposure. The intensity of the various absorption bands of the infrared spectra were found to change in their wave numbers indicating the changes in the chemical properties of the exposed samples. The results will be discussed during the presentation.

Keywords: Track detector polymers, gamma exposure, X- ray diffraction, UV- visible, FTIR.

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An improved FT-TIMS method of measuring uranium isotope ratios in the uranium-bearing particles

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An improved method of FT-TIMS was established in order to determine uranium-bearing particle. Working standard of uranium oxide particles with a defined diameter and isotopic composition were prepared and used to review the method. Results showed an excellent agreement with certified values. The developed method was used to analyze isotope ratio of single uranium-bearing particle in swipe samples successfully. The analysis result of uranium-bearing particles in swipe sample accorded with the operation history of the origin.

Copper Nano- and Micro wires Electrodeposited in Etched Cellulose Nitrate and Makrofol KG Nuclear Track Detector

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Ion tracks (or nuclear tracks) have found many applications in different branches of science. In recent years, ion-track technologies have found application in design of track-etch templates for micro- and nano-fabrication, hole engineering and track membrane technology, etc. The replication of ion track templates opens up the possibility of accessing electrical properties of micro- and nanowires. This method consists of filling a nanoporous membrane with a material of choice, resulting in large arrays of wires with uniform diameter down to a few micrometer and a high aspect ratios. Cellulose Nitrate and Makrofol KG nuclear track detector foils of 96 µm and 20 µm thicknesses were irradiated with ²³⁸U ions (kinetic energy 17.7 MeV/u, fluence 10⁵ ion/cm²) and 208 Pd (kinetic energy 14.0 MeV/u, fluence 10⁵ ion/cm²), respectively. By etching of damage trail caused by the ion, templates containing conical pore were prepared. By electrochemical deposition of copper in homemade design electrolytic cell, conical wires were obtained. The electric current recorded during electrodeposition reflects the geometry of the pore. The length of wires were 96 µm and 20 µm, corresponding to the thickness of membranes. The influence of deposition parameter such as applied Voltage, geometry of cathodes and distance between anode and cathode on Cu wire structure (single and/or polycrystalline structure) and electric current recorded during electrodeposition were studied. The texture and orientation of Cu wires under different conditions were analysed using x-ray diffraction. Current -Voltage (I-V) characteristics of copper wire arrays also was studied.

Spallation and BURST - two paths of high-energy heavy ion interactions

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A new approach to solve the observation of "enhanced neutron production" in high energy heavy ion induced reactions in thick targets is presented: Two different reaction mechanisms are considered. 1.) Limited fragmentation of the projectile, called SPALLATION and 2.) Complete nuclear fragmentation of the projectile fragment into single hadrons only, called BURST. This second path is increasing with the charge and energy of the heavy ion and may be responsible for "enhanced neutron production" observed with radiochemical methods in 44 GeV ¹²C and 72 GeV ⁴⁰Ar irradiations. Interactions of 72 GeV ²²Ne in nuclear emulsions show, that SPALLATION and BURST have strongly different interaction signatures, including the rate of BURSTS is increasing from (26±3)% in the 1st generation of all interactions to (70±8)% in the 2nd generation. The theoretical understanding of BURSTS is not discussed, but this effect may have practical consequences for neutron safety considerations in the construction of advanced heavy ion accelerators.

Fragmentation cross-section of 800 A MeV silicon ions on carbon and polyethylene targets

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The total charge-changing cross sections and the partial cross sections of projectile fragment production of the fragmentation of silicon ions on carbon and polyethylene targets at 800 A MeV are measured using CR-39 plastic nuclear track detector. The total charge-changing cross sections of silicon ions on carbon and polyethylene targets at 800 A MeV are 893 ± 196 and 770 ± 99 mb, respectively, which agree well with other experimental results at different energies and the prediction of Bradt-Peters semi-empirical formula using parameter $r_0 = 1.31$ fm and b = 0.96 within experimental errors and less than prediction of NUCFRAG2 model. The partial cross sections for fragmentation of silicon ions on carbon and polyethylene targets at 800 A MeV are consistent with other results at close energy. The obvious even-odd effect is observed in present investigation.

Forward-backward emission of target evaporated fragments at high energy nucleus-nucleus collisions

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The multiplicity distribution, multiplicity moment, scaled variance, entropy and reduced entropy of target evaporated fragment emitted in forward hemisphere (emission angle >90) and backward hemisphere (emission angle >90) in 12 A GeV He, 3.7 A GeV O, 60 A GeV O, 1.7 A GeV Kr and 10.7 A GeV Au induced emulsion heavy targets (AgBr) interactions are investigated. It is found that the multiplicity distribution of target evaporated fragment emitted in forward and backward hemispheres can be fitted by a Gaussian distribution, the Gaussian fitting parameters are different between the forward and backward hemispheres for all the interactions which may be commented that the nature of multiplicity distribution during the emission of target evaporated particles differs between the two hemispheres. The multiplicity moments of target evaporated particles emitted in forward and backward hemispheres increase with the order of the moment q, and second-order multiplicity moment are energy independent over the entire energy for all the interactions. The scaled variance, a direct measure of multiplicity fluctuations, is close to one for all the interactions which may be said that there is a feeble correlation among the produced particles. The entropy and the reduced entropy of target evaporated fragment emitted in forward and backward hemispheres are the same within experimental errors, respectively.

Multiplicity fluctuation analysis of target recoiled protons in nucleus-emulsion collisions at a few hundred MeV/nucleon

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Multiplicity fluctuation of target recoiled protons emitted in 290 A MeV C-AgBr, 400 A MeV C-AgBr, 400 A MeV Ne-AgBr and 500 A MeV Fe-AgBr interactions is investigated using scaled factorial moment method in two-dimensional normal phase space and cumulative variable space, respectively. It is found that in normal phase space the scaled factorial moment (ln) increases linearly with increase of the divided number of phase space (lnM) for lower q-value and increases linearly and then becomes saturated or decreased with increase of lnM for higher q-value, and in cumulative variable space ln decreases linearly with increase of lnM, which indicate that no evidence of non-statistical multiplicity fluctuation is observed in our data sets. So any fluctuation indicated in the results of normal variable space analysis is totally caused by non-uniformity of single-particle density distribution.

Determination of deuteron characteristic channeling parameters by simulation of channeling spectrum along Si <100>

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In this paper, deuteron beam with energy of 1.4 MeV was channeled along the <100> axis of Silicon wafer cut normal to the plane (110). The characteristics channeling parameters (the channeling energy loss, the depth in which dechanneling starts and the dechanneling rate and range) were deduced by the simulation of the experimental channeling Rutherford backscattering spectrum. These parameters explain the behavior of deuterons in the <100> channel of Si.

Simulation was based on the basic concept of channeling in solids. It is known that the surface of solids cannot distinguish the channeled ions from the random ones. So, some part of the ion beam always enters the target as the random component due to ion scattering from the surface rows of atoms. Further, The dechanneling of channeled part of the beam takes place at the greater penetration depths and increases the yield of RBS/c spectrum. The minimum random component is measured by the minimum normalized yield χ min in the channeling spectrum, and the depth at which dechanneling starts was deduced by simulation.

To simulate the channeling Rutherford backscattering spectrum, the target was divided into slices of thickness dx=0.02 µm. The beam was split into two parts, a random part and a channeled part. For the random part, by considering χ min, the backscattering probability and detected energy for each particle history were evaluated. Then, the contribution of the channeled part was calculated by considering that the channeled particles suffer only a portion energy loss of the random part. It was assumed that dechanneling starting at the deeper peneteration depth follows the Gompertz sigmoidal function with two parameters, the dechanneling rate and range. The part of the beam that has been dechanneled was considered as the random one. Subsequently, the backscattering probability of the dechanneled part in the next slices and its energy when it left the target were calculated. The energy resolution of the detector was also included in this simulation. To take the beam straggling and multiple scattering into account, the energy dependence of the elastic cross-section of the reaction ²⁸Si (d, d)²⁸Si was obtained by the excitation function extracted from the experimental random spectrum. The simulation program was written in standard language C++. The set of characteristic channeling parameters in which the least squares were achieved by using Levenberg-Marquardt Method, was picked as the best. The result shows the ratio of channeling to the random energy loss of deuteron along <100>axis of Si is 0.7. The dechanneling process starts after ions penetrating 0.2 μ m along the channel. The dechanneling rate is 0.28 per μ m and the dechanneling range is 2.9 µm. The simulation and experimental RBS/c spectra are in a remarkable agreement with each other. This consistency confirms our method of simulation and validity of determined characteristic channeling parameters.

Tomographic study of ion tracks by energy-loss analysis with a MeV-ion microprobe

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A nondestructive tomographic approach (i.e., microprobe ion energy loss spectroscopy) for the study of density inhomogeneities (e.g., etched nuclear tracks) in thin solid films (e.g., polymer foils) is introduced. In the method, the tomographic data are obtained by analysis of the energy loss of ions passing through the spatial micro-inhomogeneities (vacancies or densifications) and registering by solid state detector placed behind the target foil. The energy spectra from the scanning areas (with the size of ~ 1 or more micrometers) are subjected to the MC simulation - analysis by a set of codes corresponding to the various shape patterns. The optimal fit of the experimental data is obtained by gradual variation of the microobject spatial parameters. The method enables determination of the 3D form of the pore, study of dynamic processes, such as pore gradual evolution in the etching procedure, or filling of the pore hollow with materials of different densities. For randomly-shape material inhomogeneities, the method has to carry out a set of energy loss tomographic scans from different inclining angles. Here, an application of ion microprobe in tomographic examination of ion tracks (process of their evolution and filling) is presented and discussed.
Effect of Temperature on Growth of Cu wires and Tubes in Etched Cellulose Nitrate and Makrofol KG Nuclear Track Detector

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Porous membranes were prepared by etching the ion tracks contained in cellulose nitrate (96 mm thickness, irradiated by ²³⁸U ions kinetic energy 17.7 MeV/u, fluence 10⁵ ion/cm²) and Makrofol KG (20 mm thickness, irradiated by ²³⁸Pd ions kinetic energy 14.0 MeV/u, fluence 10⁵ ion/cm²).

By electrochemical deposition method, growths of micro and nano conical Cu wires in porous membranes were performed. The influence of temperature on recorded electric current during electrodeposition and wire structure were studied.

Micro- and nano Cu tubes were prepared in porous membranes by electroless method. Electoless methods include a three-step process: pre-activation, activation and copper deposition. Influences of temperature in deposition step on growth of cu tube were studied.

Using X-ray diffraction and SEM, the crystalline structures, morphology and orientation of Cu wires and tubes under different temperatures were analysed.

Characterization of solid state nuclear track detectors of the CR-39/PM-355 type for light charged particle spectroscopy

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Solid state nuclear track detectors (SSNTDs) are a very useful diagnostic tool in various physical investigations including high-temperature experiments. However, to use such detectors in an optimal way and to take full advantage of their properties they should be precisely tested before using in any experiment. Our group has been performing such test measurements of the CR-39/PM-355 type detectors for many years and we collected a large number of data concerning track dimensions as a function of projectile energy and etching time. This paper presents a method which uses the characteristics of the etch pits induced in the CR-39/PM-355 detector to estimate particle energy. This method is based on the data provided by a semiautomatic system that select tracks according to two parameters, crater diameters and mean gray level values. In this paper we used the results of the calibration measurements that were obtained in our laboratory in the period 1995 - 2012. Combining the information on the two parameters it is possible to determine unambiguously the incident projectile energy values. The paper presents the results of an attempt which was made to estimate the energy resolution of the method when analyzing the tracks produced in the CR-39/PM-355 detector by energetic ions like alpha particles protons and deuterons. We discuss the energy resolution of the measurement of light charged particle energy which is based on parameters of tracks induced in solid state nuclear track detectors of the CR-39/PM-355 type. The irradiated samples are chemically etched in our laboratory in a 6.25 N water solution of NaOH at a temperature of $70.0 \pm 10^{\circ}$ C. The etching procedure is interrupter every 2 h and track parameters are measured. The track detector read-out is made using a semiautomatic system composed of an optical microscope connected to a PC by means of a CCD camera and suitable software. To analysis etching tracks we used also another programs such as ImageJ.

GEOCHEMICAL INVESTIGATIONS FOR URANIUM IN SOME AREAS OF JHARKHAND STATE USING FISSION TRACK TECHNIQUE

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Naturally occurring heaviest radioactive toxic element uranium is found in traces in almost all types of rock, soils, sands etc. Due to its property to get dissolved in aqueous solution in hexavalent (U^{6^+}) form and to precipitate as a discrete mineral in tetravalent (U^{4^+}) form Uranium forms deposits in the earth's crust where the geological conditions become favourable.

Human population is always exposed to ionizing radiations from natural sources present in the earth crust. Hence the analysis of uranium in soil sample has great significance due to health hazards to human beings. For the purpose, soil & some samples collected from some area of Jharkhand have been analysed for trace uranium concentration using the fission track technique. Lexan polycarbonate was used as detector for recording fission tracks. As reactor neutron spectra is associated with both thermal and fast neutron fluxes; correction to the present uranium data due to fast neutron fission of ²³²Th was also applied. The Uranium in the soil samples were found to vary from 311ng/g to 998 ng/g. The aim of study is the possible health risk assessment due to presence of uranium in soil samples.

Influence of UV-irradiation on latent tracks in PET films

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Latent tracks in 12 μ m thick polyethylene terephthalate (PET) films irradiated by Xe and Au ions at the energy around 10 MeV/u and with the ion fluence from 1×10^9 cm⁻² to 5×10^{13} cm⁻² were investigated in this presentation. After irradiation Ultra-violet lights were used to treat on the samples at the wavelength of 365 nm with flux density of about 4.2 mW/cm². The physical and chemical changes of latent tracks under UV irradiation were studied by flourier transform infrared (FTIR) absorption spectroscopy in the total attenuation reflection mode, small angle X-ray scattering (SAXS) and positron annihilation lifetime spectroscopy (PALS).

The FTIR spectrums demonstrated that after UV irradiation, the oxygen-containing groups increased gradually. In contrast, under the same condition, the non-UV irradiated PET membranes didn't show the same change, which indicated the photo-oxidation happened in latent tracks. From orthopositronium (o-Ps) lifetime of PALS, free volume hole radius, free volume of micro voids and fractional free volume of polymer can be computed. Our PALS results indicated the occurrence of chain scission when ultra-violet light irradiated on latent tracks. In addition, studied by SAXS, it was found that the exposure of the sample with latent tracks to ultraviolet light induced a tiny increase of radius of track core which resulted in the transformation of radiolysis products.

We think these studies would help to make a better understanding about the structure and chemical mechanism of UV irradiation on polymer latent tracks.

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Parameters of 500 MeV/u ⁵⁶Fe tracks in bubble detector of the T-15

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Extra length and big sized bubble detectors of type T-15 have been irradiated with 500 MeV/u ⁵⁶Fe ions at HIMAC accelerator in the National Institute of Radiological Science (NIRS), Chiba, Japan. Linear tracks composed of regular arrays of tiny bubbles are visible by the naked eyes. The total length of each track is longer than 5 cm. In each track there are more than 40 bubbles. The gap distance between two neighboring bubbles in a track has been measured and analyzed, which is related to the percentage of the superheated liquid (Freon-115) in the sensitive volume of the detector and to the sizes of the droplets of the superheated liquid. Details of the analysis of the track parameters are presented in the article.

Keywords: Bubble detector; High-energy heavy ion tracks in bubble detector; Track formation mechanisms of bubble detector; Gap distance between two neighboring bubbles in a track

Design and Construction of Optimized Electrochemical Cell and Data Analysis System for Etching of Ion Tracks and Electrodepsition of Nano - and Micro Wires in Porous Ion Tracks Foils

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In this work, an optimized computer controlled electrolytic cell were designed and constructed. Electrolytic cell used for etching latent ion tracks and electro replication in porous ion tracks foils. The applied voltage and current during the etching and electrodeposition were measured in real time by a Data Analysis system. Monitoring of current during the electro replication lead to one can terminated growth of micro and nano wire in the present length or at the present bud that forms after filling the porous ion tracks.

An electrolytic cell is consisting of two half-cell and two electrodes. In this work design and construction of a sealed electrolytic cell was done in a manner that one can change distance between electrodes and geometry of cathodes.

Data analysis system includes three parts: Amplifier, Data acquisition system and software. A current amplifier that used in Data analysis system is a log Ratio amplifier, the log ratio amplifier provides an output voltage proportional to the log base 10 of the ratio input current I1 (current during the electodeposition of wire in cell) and Input current I2 (flexible current of current supply), a DAQ reading output voltage of amplifier and send to Computer. With lab view software analyzed the voltage and converted to the current corresponding to the electrodepsition of wires. A current amplifier is designed and constructed is a noise suppression that can measure small currents with sufficient precision. Advantage of proposed log ratio amplifier is that we can used this amplifier in the case of different track density that means it can measured wide spread range of current during the electro deposition, especially in very small current.

Track overlapping probability and counting statistics for reliable track counting in high density track images

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In the solid state nuclear track detectors of chemically etched type, nuclear tracks with center-to-center neighborhood of distance shorter than two times the radius of tracks will emerge as overlapping tracks. Track overlapping in this type of detector resemble the dead time (pulse overlapping) in paralyzable response model of active detectors which causes miscounting statistics. It can be stated that in case of overlapping the minimum spatial separation of nuclear tracks is smaller than two times the tracks radius and also overlapping losses becomes rather severe when high track densities are encountered. As a result, a number of true events may be lost though they expand further the overlapping area. Therefore, counting measurements in these conditions should include a correction factor for count losses. In this paper statistical errors of count losses in track counting of intensely irradiated solid state nuclear track detectors are studied. Track counting statistics for the chemically etched solid state nuclear track detectors as one of the most commonly used passive detectors are studied in this paper for the counting errors occurred in high densities of nuclear tracks which are resulted from high accumulative doses of heavy ions, e.g. environmental Alphas of Radon and its daughters. Co-occurrences of two or more particles in close spatial positions cause overlapping of nuclear tracks after the etching process and this issue influences the accuracy of counting process. Analysis of the counting statistics for both single-object-assumed overlapping tracks and the probability of tracks overlapping yield us estimation on how many tracks are overlapped. This estimation is then used to approximate the count losses and uncertainty of true counts of tracks in the measurement system. It is shown that in high and ultrahigh track densities statistical correction of track overlapping cases is mandatory to achieve a reliable and accurate track counting measurements.

Emulsion scanning system for double-strangeness nuclei

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Nuclear emulsion is the best detector to study double-lambda hypernucleus, a nucleus made up of two A baryons in addition to nucleons, very short-lived. Two types of scanning system are being developed to search for more events of double -lambda hypernucleus in nuclear emulsion rapidly. One is an automated Xi- following system. The other is "Overall-scanning", a dedicated image process picks out hypernucleus-like shapes which have characteristic topology of multi tracks and vertices from microscopic images.

Fading of Nuclear Tracks in Polycarbonate by UV C light irradiation

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The methodology to obtain neutron autoradiographies of tissue samples containing ¹⁰B atoms in polycarbonate detectors was fully developed in our laboratory. It is actually being applied to qualitatively and quantitatively analyze boron distribution and concentration in different experimental models used in BNCT (Boron Neutron Capture Therapy) research.

A decrease in the density of tracks produced by alpha ions and Li recoils coming from the neutron capture reaction $({}^{10}B(n, \alpha){}^{7}Li)$, was observed after chemical etching, when the detector foils had been exposed to UV C light (254 nm wave length). A series of experiments has been carried out with different samples on polycarbonate foils, in order to determine the factors that make this fading effect to occur: exposure time, lamp irradiance, foil temperature, etc.

It was found that under certain conditions 75 to 90 % of the tracks per unit surface area disappeared. A comparison with foils exposed to UV A (360 nm wave length) light was also realized. In this case the fading effect was not observed. Wave length dependant photodegradation mechanisms of polycarbonate could be interfering with latent tracks development.

CP-11

Influence of intense soft X-ray radiation on parameters of tracks induced in CR-39 and PM-355 solid state detector

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Solid state nuclear track detectors (SSNTDs) have found wide spread applications in various disciplines of science and technology including high-temperature plasma experiments. To measure energetic ions escaping from hot plasmas very often SSNTD samples are located inside the vacuum vessel of a plasma facility, where they encounter harsh conditions of high temperature, heat impacts, intense plasma streams etc. These samples are also irradiated with energetic electrons, electromagnetic radiation (UV, X-rays and γ - quanta) and fast neutrons emitted from the plasma. All these factors can influence parameters of the craters (diameters, lengths, shape) induced in the solid state detector by investigated ions. Such influence can change characteristics of the detector, which makes it impossible to perform a precise analysis of these ions. Therefore, we decided to study separately the effects of all these contributions on the craters produced in the tested detectors by mono-energetic ions (protons, deuterons, ⁴He-ions). This paper presents the results of soft X-ray radiation influence on craters induced in SSNTDs by mono-energetic α particles of energy in the MeV range. We checked two detectors of the PM-355 and CR-39 types in order to verify and compare their resistance to harsh conditions of high-temperature plasma experiments. To determine this effect some detector samples were irradiated first with mono-energetic α particles emitted from natural a-particle sources. After that these samples were exposed to soft X-ray radiation emitted from an X-ray tube and also from the PF-1000 Plasma Focus facility. Doses during X-ray irradiations varied from 0 up to tens kGy. The irradiated samples were etched then in steps and track diameters and bulk etching rate values were determined versus the absorbed dose and etching time and compared with those measured for non irradiated samples.

Effect of phosphate fertilizers on soil to plant transfer of alpha activity in potato plants

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Natural radionuclides are found in diverse environmental compartments such as oceans, rivers, soils, rocks, vegetables and animal as well as in human body tissues. The radionuclide present in soil have strong tendency to transfer from soil to plant through root and then ecosystem. Consumption of potato roots in vegetables and fast food as a delicacy has been high throughout the world. Thus, it is necessary to study the alpha activity in potato plants due to radionuclide present in soil due to use of fertilizers in term of transfer factor. Present work deals with the alpha activity in the different parts of the potato (Solanum Tuberosum) plants grown under controlled pots experiment using different amounts of phosphate fertilizers and urea. Alpha activities have been measured by track etch technique using the solid-state nuclear track detectors (LR-115). The results revealed that the alpha activity in the potato plants was found to be higher in case of the plants grown with the use of phosphate fertilizers than with other fertilizers. Translocation factor for the fruit (edible Part) varied from 0.13 (for DAP) to 0.73 (for PF) with an average of 0.40±0.26 for the plant grown with 20 g of fertilizers. Translocation factors increased with the increase in amount of fertilizers having value 0.51±0.31 for the plant grown with 50 g of fertilizers. The transfer factor (TF's) for the potato plants varied from 1.5×10^{-2} to 1.03×10^{-1} for root, from 1.3×10^{-2} to 1.23×10^{-1} for stem, from 2.1×10^{-3} to 4.5×10^{-2} for fruit and from 5.4×10^{-3} to 5.8×10^{-3} for lower part of the leaf after 105 days of the plantation.

Alpha Particle Energy Response of 250 μm Polycarbonate Track Detectors by 50 Hz - HV ECE Method

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Electrochemical etching (ECE) of polycarbonate track detectors (PNTDs) has been commonly based on the use of high frequency - high voltage (HF-HV) processing of 250 µm thick PNTDs applying a HF-HV generator. Recent studies in our laboratory on the detection of alpha particles as well as nitrogen and helium ions in 1 mm thick PCTDs processed by 50 Hz-HV ECE method under 10 hours ECE duration in PEW solution at 26°C have provided promising results. The alpha particle track energy registration characteristic responses of 250 µm PNTDs by the 50 Hz-HV method were also investigated to optimize ECE processing conditions in particular to reduce ECE duration. Alpha particle track registration efficiency versus energy, energy range, lower and upper alpha energy registration thresholds, track shapes and diameters as well as background track density and diameter were studied. Alpha track registration efficiency versus alpha energy follows Bragg-type responses. The efficiency, registration energy range, track shapes and diameters depend on alpha energy, high voltage applied and ECE duration when other parameters are kept constant. The energy registration ranges of 50Hz-HV methodology are wider and tracks are much smaller than those obtained by using 2 kHz-800V ECE method. These are advantageous characteristics for some applications. However under higher voltages applied, background track densities are higher than that of 2 kHz-800V field conditions which is considered a drawback for some applications. Efforts are being made to reduce the background by layer removal methods we developed. The results are presented and discussed.

Surface modification of PET films irradiated by keV to GeV ions

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Polyethylene terephthalate (PET) films were irradiated at room temperature with different ion energies ranging between 200 keV and 1.6 GeV, and the ion fluences are between 1×10^9 cm⁻² and 5×10^{13} cm⁻². UV lights were used to treat on the samples at the wavelength of 365 nm with flux density of about 4.2 mW/cm-2.The treated films were investigated by X-ray photoelectron spectroscopy (XPS), flourier transform infrared absorption spectroscopy (FTIR) and contact angle (CA).

The XPS results indicated that after ion irradiation, there is a decrease of C1s and O1s. And after UV irradiation, the oxygen-containing groups increased gradually. In contrast, under the same condition, the pristine PET with latent tracks didn't show the same change. The same phenomenon has also been demonstrated in the FTIR measurements.

The surface hydrophobicity was measured by water contact angle. And the results shows that with the increase of ion fluencies, the contact angles on the surface of latent track films become larger, while after UV treatment, it become smaller. It has been reported that the oxygen were depleted preferentially at the PET surface because its lower strength of chemical bonds with other constituent element than other bonds and this can explain well the decrease of surface hydrophobicity.

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Feature of radiation damage formed along the nuclear tracks in bisphenol A polycarbonate films

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A series of FT-IR spectrometric studies has been carried out on bisphenol A polycarbonate (PC) films exposed to protons and heavy ions, as well as low LET radiations like gamma rays from an intense Co-60 source and high energy electron beams. It has been confirmed that the radiation chemical yields, G value, for the loss of carbonate ester bonds in PC hardly depends on the stopping power among protons and heavy ions. The G value for gamma rays is also equivalent to that of heavy ions. In order to make clear the role of the low energy electrons to from the latent tracks, we conducted the experiments using a focused 28 MeV electron beams with 3 mm in a diameter. Because the gamma irradiations have been carried out keeping the electron equilibrium condition, not only the the secondary electrons produced through the photoelectric effect and the Compton scattering, but also low energy electrons will act to breake the PC polymeric network. Utilizing a microscopic infrared spectrometric system, the damage caused by the high energy electron beams were examined, excluding the effects of low energy electrons as much as possible. On the other hand, the effects of Xe ions were also evaluated, which has the highest stopping power in this study. Chemical damage parameters, including G value and track core radius, have been assessed for some typical functional groups forming PC chains, based on the fluence or absorbed dose dependence on the relative absorbance for each group. The G value of 28 MeV electron beams is about half of that of the gamma rays for the loss of carbonyls.

A study on polyimide films as an etched track detector with higher registration threshold

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It is well known that different polymeric etched track detectors have their own track registration properties. The polymeric Kapton is known for its ability to maintain excellent physical, electrical, and mechanical properties in wide temperature regions from 4 K to 673 K. It works as an etched track detector with a higher threshold for etch pit formation.

In this study, the track registration property in Kapton has been examined for heavy ions, during chemical etching in sodium hypochlorite aqueous solution kept at 55°C. Its initial content of active chlorine was between 8.5 and 13.5%. Heavy ion irradiations were performed in air at the ports of the medium-energy experiment course (MEXP) and at the Biology Experimental Room (BIO) of the HIMAC of NIRS, Japan. At the MEXP, samples were exposed to Ne, Al, Si, Fe, Kr, and Xe ions at energy less than 6 MeV/n. To know the track registration property for high energy ion beams, samples were exposed to Fe (<56 MeV/n), Kr (<320 MeV/n), and Xe (<190 MeV/n) at the BIO. The examined stopping power covers ranges from 1800 to 12000 keV/ μ m.

The threshold of etch pit formation depends on the ion charge. The thresholds of etch pit formation for Al was 2552 keV/ μ m. That for Si is between 2206 and 2324 keV/ μ m. 56 MeV/n Fe ion cannot form any etchable ones (1290 keV/ μ m). Threshold for Kr and Xe ions were 2830 - 3140 keV/ μ m and 3290 - 3980 keV/ μ m, respectively.

Effective track core radius for the loss of C=O and C-N-C composing imide bonds, and diphenyl ethers of C-O-C have been evaluated by means of FT-IR. The effective core radius for the loss of diphenyl ether is 1.5 nm at the threshold for Si ion, which is almost eqivalent to distance between the adjacent diphenyl ether bonds. A possible damage structure formed at the higher stopping powers in Kapton is more than two breakings at adjacent diphenyl ethers in the vicinity of the ion's trajectory.

Quantum yields for loss of carbonate ester bonds in polymeric nuclear track detectors under 222 nm UV radiations

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The effects of ultraviolet (UV) photons on bisphenol-A polycarbonate (PC), polyethylene telephtalate (PET), and poly(allyl diglycol carbonate) (PADC), at a wavelength of 222 nm has been examined by means of FT-IR spectrometry, which have been applied for polymeric nuclear track detectors. The progress of photo-Fries reaction has been found in PC, as well as de-carbonyl reaction forming CO or CO₂ gases. The quantum yield for the de-carbonyl reaction is about 2×10^{-3} , which is almost equivalent to that of simple shift of carbonyl due to hydroxyl group on the neighboring polymer chains. Norrish I and II type reactions have been found in PET. The de-carbonyl reaction is hardly observed in the early stage of the UV irradiations. The de-carbonyl reaction in PADC is hardly enhanced in the early stage of the exposure. On the other hand, breaking of ether bonds in PADC progressed effectively under the UV ray. Only above a fluence of 3.9×10^{19} photons/cm², the de-carbonyl reaction will start in PADC.

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Optimization of track etched Makrofol etching conditions for short-term exposure duration

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When nuclear track detectors are exposed with a filter to protect detectors of high humidity environments, the duration of the exposure is normally limited to a few weeks because the filter is not completely waterproof and after several months some parts of detector start to degrade. Additionally, in really extreme measurement conditions, like high aerosol content, temperature, and humidity, we must reduce the exposure time but then detector detection limit becomes a problem, unless buildings have high radon concentrations. In those cases where radon levels are not high enough we need to use passive detectors with better detection efficiencies. In our laboratory we use passive detectors based on the track etched Makrofol DE foil covered with aluminized Mylar and we also analyse them by means of an electrochemical etching. Our standard etching conditions allow analysing detectors generally exposed for periods between three and six months. We have optimised our etching conditions to reduce the exposure time down to a month for common radon concentration values. A total number of 100 detectors has been exposed in a small radon chamber and different sets have been etched changing some influent parameters on detectors response, like temperature, duration, electric field strength and frequency, with the aim to obtain those parameters values that maximize relative efficiency value, which does not depend on exposure.

Measuring the gravitational acceleration for antihydrogen with emulsion detectors

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The motivation of the AEgIS experiment at CERN is to test the universality of free fall with antimatter. The goal is to reach a relative uncertainty of 1% for the measurement of the Earth's gravitational acceleration gbar on an antihydrogen beam. High vertex position resolution is required for a position detector and an emulsion based detector has been chosen for its unbeatable spatial resolution. In AEgIS, the detector will operate in vacuum and at cryogenic temperatures of around 77 K. Accordingly, an intensive R&D program on emulsion detectors is ongoing to cope with such challenging conditions.

While we already established the operation condition in vacuum without worsening the performances of emulsions in terms of background and efficiency, the properties of emulsion detectors at cryogenic temperatures are still not well known and we are presently working on that.

In parallel, 4pi track reconstruction has been implemented to detect antimatter annihilation products and further upgrades are in progress. In addition, antiproton annihilations on thin metal foils of varying compositions and on the emulsion surface have been studied. The status of the developments and achievements on emulsion detectors for the AEgIS experiment will be presented in this talk.

Study of double-strangeness nuclear systems with nuclear emulsion

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Our knowledge on nuclei with double strangeness, S = -2, nuclear systems has so far been very limited, we will carry out the E07 experiment at J-PARC which would provide us $\sim 10^2$ or more double-hypernuclear events in nuclear emulsion. To record such number of the event, we prepared huge amount of the emulsion gel, i.e. weight of 2.1 t, and the building to handle its gel.

The nuclear emulsion plates are perpendicularly exposed to the beams of 1.8 GeV/c K- mesons. At the beam exposure, many plates are stacked in a hard box made of stainless steel. If many thin plates are stacked, it is necessary for much time to change plates for scanning. Therefore the thickness of the plate becomes thick, e.g. \sim 1 mm, to save time for scanning. To make their plates, it was necessary for much R&D about;

- 1) Surface reformulation of thin film to support the emulsion on both sides of the film,
- 2) Selection of chemicals and optimization of its content to keep soft the plate,
- 3) Uniform pouring over the area of $700x710 \text{ mm}^2$ with a flat base,
- 4) Surface coating with gelatin to avoid adhesive silver after photographic development,
- 5) Keeping fresh condition of the plates from cosmic and gamma rays from environment.

We have succeeded to make such thick plates over six months. The number of the plates with the size of $345x350 \text{ mm}^2$ was $\sim 1.5x10^3$.

In this report, it is discussed on the result of above developments and output for nuclear physics.

Development of nuclear emulsion detector for muon radiography

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Muon radiography is the non-destructive testing technique of large-scale constructions with cosmic ray muon. Cosmic ray muon has high penetrating power and it always comes from the whole sky. In the same way of taking a X-ray photograph, we can obtain integrated density of constructions which thickness are several tens to several hundreds. We had ever applied this technique to nuclear reactors, ancient tombs and volcanos, tested the principle.

At now, in order to more widely deployed this technology, we are developing it from both sides of the data-processing system and the detector. Our detector, nuclear emulsion, is high resolution three dimensional track detector. This detector has mrad angular resolution. In Nagoya University, we launched emulsion manufacturing equipment at 2010. It has become possible to flexible development of our detector. An important factor is the temperature characteristic to withstand the outdoor observation as a detector to be used in the muon radiography. In addition, the features which requires no power supply and can observe in a large area suitable for muon radiography. In this talk, I talk about basic characteristics (especially sensitivity and thermal properties) of nuclear emulsion and detector structure.

Nuclear Emulsion Readout System, HTS

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Nuclear emulsion, as a solid track detector, has several distinctive features, which are submicron spatial resolution, lightweight, compact and without a need for power. The crucial problem is the fact that we need to readout nuclear emulsion in order to use up the recorded phenomenon. The readout system has to be an automated system and the readout time is required to be comparable with the exposure time or less. We have developed nuclear emulsion readout system Hyper Track Selector (HTS), evaluated the performance and came to be for practical use.

Previous readout system has a limit to the number of views can be processed per second. Since the 3-dimension motion of the optics for the nuclear emulsion, readout is not only X-Y plane but also along Z-axis. Even if we used the piezo actuators to achieve high frequency motion, the limit was 50Hz of ""S-UTS"", which we developed in 2005. In this situation, a major breakthrough to overcome the speed limit is to enlarge the field of view (FOV) to 5mm square. The repetition frequency became one-seventh due to larger motion, but overall readout speed has been achieved up to 90 times faster than the previous one.

We use 72 sensors which is the frequency of 300Hz and resolution of 2MP to cover the wide FOV. 36 high-end consumer computers were installed in order to handle the images of 30 GB/s. We made it possible to process images at real time using 72 GPU boards.

The difficulty which we have to solve is to understand a wide FOV optical system. First, we need to consider that the aberration effect when the images are reconstructed because the wider FOV makes more aberration. Thus we developed the method to calibrate the position of multiple image sensors automatically. By this method, HTS can achieve submicron spatial resolution which is comparable to nuclear emulsion itself. Second, we developed a multi-processing method for the real-time processing since it is too huge to preserve raw image data on hard drives. Finally, we investigated the efficiency of track recognition and measurement accuracy which are almost same as ones of the previous system at condition of the same signal-noise ratio.

HTS is not only emulsion readout system but also huge microscope system. We are considering the possibility as a framework for multipurpose 3D microscope. HTS can get tomographic images with 5mm square and a thickness of 1mm at once.

In this talk, we present a short history of the nuclear emulsion readout system, technology for developing HTS, these equivocation results and future plans.

Fine grained nuclear emulsion and new readout system for dark matter search

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The nuclear emulsion has contributed for physical discovery by its high spatial resolution.

We are trying dark matter detection. The emulsion might provide new knowledge about directional distribution of dark matter. However, this experiment requires further performance of the emulsion because nuclei recoiled by dark matter fly only submicron in the emulsion. Therefore we improve the nuclear emulsion and new readout system, and we implement the detection system for submicron tracks.

The emulsion detects tracks as line of silver grains which came from silver bromide crystals. So the detection limit depends on the crystals quality.

We micronized crystals less than 40nm, and improved sensitivity of each crystal. They enable to detect tracks less than 200 nm.

Then new readout system was also required. The length of such tracks is shorter than the optical resolution of usual microscope. We developed new signal candidate selection method which detects small deformation of optical image, and we also combined X-ray microscope confirmation method which allows non-destructive survey and 70 nm spatial resolution.

This hybrid method gives high speed and high resolution readout.

We basically established submicron track detection method. We are planning directional dark matter search experiment with this which is quite important for conclusion of dark matter problem.

New Experimental Project for Study of Neutrino with Nuclear Emulsion Detector at J-PARC

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We are planning a new experiment to measure the cross sections of neutrino-nucleus interactions at a low energy region with nuclear emulsion detector at the near detector hall of the J-PARC neutrino beam line. The original neutrino detector is so called Emulsion Cloud Chamber (ECC) and consists of nuclear emulsion films, acting as high precision tracking detectors, interleaved with various material plates providing a massive target for neutrino interactions. The ECC has contributed to particle physics (charm, double hypernucleus, tau neutrino and so on) by its unique capability to observe short lived particles. Thanks to its high spatial resolution, it can also identify an electron neutrino, with small background from π^0 misidentified as electron, by observing the electromagnetic shower or by studying the scattering behavior of the electron. We will use iron and carbon plates as target material so that we can study neutrino-iron and neutrino-carbon interactions. We also intend to insert the packed emulsion films in water to study neutrino-water interactions. First, we will check the quality of new high sensitivity emulsion gel and films. Then we will optimize the thickness of material plates and other conditions. We will study the performance of the detector by analyzing real data. Assuming 10^{21} p.o.t. data taking with a 100kg detector (corresponding to 12 standard ECC bricks), 17,000 neutrino interactions are expected to be accumulated in the target. We will report the detail of this plan and status of its preparations.

GRAINE project: Gamma-ray Astro Imager with Nuclear Emlsion

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We are promoting the cosmic gamma-ray observation project using balloon-borne telescope with nuclear emulsion. It can provide world finest gamma-ray image in GeV/sub-GeV range. We describe overall road map of the project and the next balloon experiment planed to be launched Nov. 2104 at Alice Springs, Australia.

Development of cosmic-ray muon radiography analysis system with nuclear emulsions

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Cosmic ray muon radiography is the non-destructive inspection technique using cosmic ray muons. The principle of this technique is the measurement of absorption of muon in matter. Cosmic-ray muon comes from all direction in the sky. Thus, in order to measure matter density by cosmic-ray muon radiography technique, it is needed to measure incoming angles of each muons and compare between expected number of incoming muons and detected muons.

Nuclear emulsion is high sensitive photographic film and record the detection of three-dimensional trajectory of each minimum ionizing particle like cosmic-ray muon. Recently, automated nuclear emulsion scanning system ""S-UTS"", which readout tracks recorded in emulsion layer at the speed of about 100 square cm per hour, was developed and new system is under development to achieve 100 times faster scanning speed than S-UTS. For usage of muon radiography observation outdoors, nuclear emulsion has these following advantages, No requirement of electric power supply, compact, and lightweight ($<1kg/m^2$).

We are developing the muon radiography analysis system with nuclear emulsion detectors. In this presentation, we will present the details of the system and its performances.

Test experiments on muon radiography with emulsion track detectors in Russia

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Lebedev Physical Institute and Skobeltsyn Institute of Nuclear Physics MSU open the series of pilot muon radiography experiments starting in Russia. The experiments aim to study peculiarities of the method and to develop on its basis the monitoring systems for natural and technological objects. The track detectors on base of nuclear emulsions are used, the choice of which was determined, in addition to a good spatial and angular resolution, by large information capacity, else of transportation and utilization, no energy supply and electronic reading system required.

Automatic analysis of microscopic photo-pictures of undeveloped nuclear emulsions.

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Computer analysis was applied to the two cases. In the first case it was investigated a single microscopic photograph containing a large number of nuclear emulsion microcrystals AgBr. In the second case considered monolayers of diluted emulsion microcrystals and large statistics of measurements were achieved by simultaneous consideration of a large number of micrographs. Some fraction of microcrystals gave overlapping images looked like ellipses. During computer analysis of these regions there were automatically inscribed ellipses in each region and the distributions over sizes of the large and small axes of the ellipses were found. For the sample of undeveloped nuclear emulsion with granulometric characteristics, which had characteristics similar to the characteristics of nuclear emulsion type-R2, the distribution over microcrystal sizes AgBr of undeveloped emulsion was recalculated for a distribution over sizes of developed grains. Also it was automatically analyzed micrographs of developed nuclear emulsion type-R2 and it was shown that predicted and experimental distributions over grain sizes in developed emulsion turned out to be close to each other. There some aspects of dependence of emulsion sensitivity on geometric factors of microcrystal were studied.

Application of advanced nuclear emulsion technique to fusion plasma neutron diagnostics

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In magnetically confined deuterium plasma, 2.5 MeV neutron (DD fusion neutron) is generated by DD fusion reaction. Since DD reaction rate depends on energy of deuterium ion, DD neutron measurement is useful for energetic-ion diagnostics in deuterium plasmas. Recently, nuclear emulsion technique with automatic nuclear emulsion scanning system [1] was applied to neutron emission profile diagnostics in the National Spherical Torus Experiment [2]. In addition, it is also expected to apply to detection of 14 MeV neutrons caused by DT fusion reaction [3]. We have developed a compact fusion neutron detector based on nuclear emulsion which serves as energy spectrometer and neutron camera at the same time [4,5]. The detector consists of a nuclear emulsion plate and a pinhole collimator covering the plate. Using the pinhole collimator, most of neutrons pass through a pinhole and then incident onto the emulsion layer. The incident 2.5 MeV DD neutron makes elastic scattering with a hydrogen atom in the emulsion layer. Along track of recoiled proton caused by elastic scattering of fast neutron, grains in the emulsion are developed and these are recognized by optical microscope. Because track length of recoiled proton depends on its energy, the recoiled proton energy Erp can be derived from the track length. The scattered angle of neutron elastic scattering θ can be derived from the angle between the vector from the pinhole to the start point of the track and the vector of the recoil proton track. Thus, the incident neutron energy En = Erpcos 2θ can be estimated. In addition, combination of the pinhole collimator and the nuclear emulsion also works as a pinhole camera of fast neutron.

We evaluated the response of the detector to accelerator-based DD neutron source, fusion neutron source (FNS) at Japan Atomic Energy Agency. The response function obtained by experiment showed good agreement with the Monte Carlo calculation based on PHITS code.

The detector was installed at a fusion experimental device, Korea Superconducting Tokamak

Advanced Research (KSTAR) at National Fusion Research Institute, Republic of Korea, to check the applicability to fusion plasma neutron diagnostics. The measured number density of recoiled proton tracks in nuclear emulsion was proportional to the irradiated neutron fluence. In addition, the peak position of measured spectrum could be roughly identified with DD neutron energy. Detailed analyses of measured spectra and images of fast neutron are ongoing. The expected performance on the present nuclear emulsion technique as the fusion neutron detector will be discussed in this presentation.

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Development of nuclear emulsion for fast neutron measurement

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Nuclear emulsion is high sensitive photographic film used for detection of three-dimensional trajectory of charged particles. The principle of the measurement of fast neutron with nuclear emulsion is the detection of proton recoiled by neutron. The whole image of 3D track of recoiled proton is recorded with the spatial resolution of about 1 micron, which is the silver grain size. The energy of each neutron is estimated by measuring the 3D track length of recoiled proton. The detector size is very flexible and no need of power supply. From these features, nuclear emulsion can be very powerful detector applied to the dosimetry, spectrometry and imaging in various fields (fusion plasma diagnostics, medical application, space radiation measurement, fundamental physics, radiography, ...) by analyzing statistically 3D tracks. In order to evaluate performance as a neutron detector, I measured energy resolution, detection sensitivity and gamma ray rejection power of nuclear emulsion. For measure energy resolution and detection sensitivity, irradiated nuclear emulsion with monochromatic neutron at FNS (neutron energy 2.8MeV) and AIST (4.9MeV). In 2.8MeV and 4.9MeV, energy resolution is 16% and 11% FWHM. Compared with Geant4 simulation, these were consistent. Most background events are compton electron tracks. We are developing the nuclear emulsion itself in our laboratory by using nuclear emulsion gel production machine, so we can control the sensitivity for various purposes. By using this machine, we developed a new nuclear emulsion gel (crystal size is 220nm) optimized for the detection of recoil protons by fast neutrons without recording electrons by gamma rays. Energy loss is different between electrons by gamma rays and recoil protons. Number of electron hole pair generated are also different when it pass the silver halide crystal. Rhodium can capture an Ionization electron. By added it into silver halide crystals, only electron tracks are rejected and recoil proton tracks remain high developing probability. Moreover by adjusting the method of developing, the same effect is expected. Then nuclear emulsion can use under 3×10^{13} gamma ray/m² (Am-241 gamma ray source) maximum. This new nuclear emulsion is applicable under high gamma ray environment like a nuclear fusion experiment for plasma diagnostics. Furthermore, we are developing emulsion which have higher gamma ray rejection power and can detect fast neutron signal. In this time, I will report nuclear emulsion performances and future prospect.

Electron identification and energy measurement with Emulsion Cloud Chamber

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Emulsion Cloud Chamber (ECC) is composed of emulsion films, three dimensional tracking detector for charged particles, interleaved with metal sheets. Generally, a charged particle is scatted by the Multiple Coulomb Scattering (MCS) when passing through the material and the scattering angle depends on its momentum. So the momentum can be estimated from the distribution of the scattering angle directly. While, the angle of an electron (or positron) largely changes because of the energy loss by bremsstrahlung. An electron is distinguished from other charged particles by making use of its feature. When measuring the energy of an electron from the scattering angle, the correction of the energy loss is needed.

A general energy measurement method of an electron in ECC is the count of electromagnetic shower (em shower) tracks in each emulsion layer. This method is effective to fully developed em shower in analyzable volume in ECC; it needs the material equivalent for more than 3 radiation length. However, in the range of sub-GeV to a few GeV, an electron doesn't develop its shower so much within 3 radiation length. In order to estimate the energy of electrons in this range, we established the new method which is estimated from the scattering angle considering the energy loss by bremsstrahlung. The systematic error is estimated by Monte Carlo simulation (MC). We report the evaluation of the validity of this method in several kinds of energy by MC and the result of the measurement of 1GeV electron beam sample.

In case of electron track, the variance of scattering angle distribution would become bigger as mentioned above. From the MC data, 0.5GeV, 1GeV, 2GeV electron beam are exposed to ECC, we understood the correlation between energy and scattering angle in each layer. And then we estimated the error to be set and the best number of layer to minimize the systematic error. We tried a several approaches for the energy measurement and evaluate the energy resolution in the best method by the MC. In addition, we re-evaluated the validation of measuring method by using the 1GeV electron beam sample (about 10% contamination of pion). We applied the new method to this data sample and evaluate the ratio of the pion contamination. Then we measured the energy of selected electron tracks and estimated the energy resolution.

Application of Emulsion Cloud Chamber to cosmic-ray muon radiography

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We report current improvements on cosmic-ray muon radiography using nuclear emulsion films. Muon radiography is a noninvasive inspection method that exploits the high penetration power of cosmic-ray muons. This technique measures an absorption rate of cosmic-ray muons inside the target material. The attenuation of muon intensity can be used to derive the amount of matter present along the muon trajectories, since the energy spectrum of cosmic-ray muons and their interaction with matter have been extensively investigated. Use of this technique has spread to a variety of fields in geophysics, such as volcanology, hydrology, and mineral exploration. Several types of particle detectors have been used for this technique, such as plastic scintillation detectors [1,2], gas chamber detectors [3,4], and nuclear emulsion films [5].

One advantage of the nuclear emulsion films is that they weigh light and do not require electricity for operation. These features are feasible for experiments in remote places. Another advantage is that microscopic analysis of emulsion films enables us to trace the incident particles with very high spatial resolutions, which other detection techniques cannot attain. The position and angular resolutions of the microscopic analysis are a few micrometers and a few milliradians, respectively.

The high spatial resolutions of emulsion films enable us to measure small deflection of tracks caused by multiple Coulomb scattering inside a detector, and make it possible to measure momenta of incident particles. This kind of analysis is possible by using Emulsion Cloud Chamber, which is a repeated structure of emulsion films and passive materials with high Z number [6]. We applied this technique to muon radiography in order to reduce the background noise caused by low-momentum electromagnetic particles induced from air-shower [7].

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Large Angle Tracking and High Discriminating Tracking in Nuclear Emulsion

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Nuclear emulsion is a tracking detector with sub-micrometer resolution. We can analyse particle reactions recorded in emulsion with different methods repeatedly because it keeps charged particle tracks permanently. The emulsion detector has contributed to progress of charm and tau-neutrino physics. Currently we are using high speed automatic emulsion scanning system, so called Track Selector (TS).

TS takes 16 images for each emulsion layer and then recognises tracks by fitting silver grains linearly. To process large amount of emulsion rapidly and keep efficiency of true tracks, the angle acceptance is limited to $|\tan \theta| < 0.6$ and many recognised fake tracks are allowed in conventional TS. We have developed a new automatic emulsion scanning system "Fine Track Selector (FTS)" to improve these limitations and fakes. FTS is used for reduction of human eye check and scanning of large angle tracks.

The new system detects particle tracks to $|\tan \theta| < 3.5$ with at least 90% efficiency and takes a series of 32 layers of emulsion image. Thanks to the features and new track reconstruction algorithm running on powerful GPU, we reduced number of noise tracks by a factor of 1/20. We plan to scan emulsion films by very high speed automatic track selector "Hyper Track Selector (HTS)" coarsely at first and then remeasure recognised tracks in detail by FTS in a new experiment at J-PARC.

We present current status of FTS improvement for the new experiment, compatibility between the FTS and conventional TS data and preparation of the new experiment.

Silica-Nanocapsule-Doped CR-39 Fluorescence Detector for X-rays

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CR-39 (PADC) is a solid-state nuclear track detector, and a nuclear track has been visualized using CR-39 after etching with an alkali solution [1]. In this study, a fluorescence image of an X-ray-irradiated area on CR-39 was observed upon controlling the doping content of a UV absorber and stabilizing it by doping with silica nanocapsules without alkali treatment. Various amounts of the UV absorber from 600 to 4000 ppm were doped during the synthesis of CR-39. The UV-absorber-doped X-ray-irradiated CR-39 emitted fluorescence and the irradiated area was also observed using a polarizer through light.

X-rays (30 kV, 15 mA) generated using a X-ray diffractometer (Rigaku MiniFlex II) were detected as a fluorescence image using the UV-absorber-doped CR-39 when the X-ray dose exceeded 1 Gy. The optimal content of the UV absorber was 4000 ppm. The fluorescence image was easily obtained using an FLA-9000 image analyzer. The excitation wavelength dependence of the intensity was observed and the optimal excitation wavelength in the imager for obtaining the highest fluorescence intensity was 555 nm. The surface excitation spectrum of the X-ray -irradiated UV-absorbed CR-39 obtained using a Shimadzu RF5300PC spectrometer showed a peak at 559 nm and a surface fluorescence peak at 578 nm. This wavelength was similar to the excitation wavelength of 555 nm in the image analyzer. However, the observed fluorescence intensity of the image decreased with time and the image disappeared within 1 h at room temperature. X-ray irradiation of the UV-absorber-doped CR-39 generates fluorescence centers by charge separation. Therefore, to stabilize the fluorescence image, we attempted to prevent the recombination of the electrons and positive holes generated by X-ray irradiation by doping methylviologen (MV)-encapsulated silica nanocapsules into the CR-39 during its synthesis. MV is an electron acceptor and it was encapsulated in the nanocapsules using an adsorption and core-shell method [2]. It was found that the fluorescent intensity of the image remained constant for almost 120 min when more than 0.5 g of MV-encapsulated nanocapsules were doped in CR-39. A new solid-state fluorescence detector for X-rays was thus realized using MV-encapsulated silica-nanocapsule-doped CR-39.

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CHARACTERIZATION OF DAP THROUGH MATERIAL SCIENCE TECHNIQUES

E-2

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The polymer Diallyl Phthalate (DAP), commonly used as solid state nuclear track detector (SSNTD), has been characterized via optical microscopy and Raman and FT-IR spectroscopies in three distinct processes :i) without irradiation; ii) irradiated by induced nuclear fission fragments and iii) in function of the chemical etching time. The detectors were exposed to fissionable isotopes of uranium nucleus by thermal neutron induction, with nominal fluency similar to those used in fission track dating. For the track revelation it was used a standard chemical etching with a solution of 15% KOH, 20% water and 65% ethanol at 60 °C for time periods from 2 to 30 minutes. Through gradual chemical etching, i.e., decreasing sequentially the etching time, the aim is to study the latent track structure ("nano-track") without major physical-chemical changes happened in the detector surface. For this reason, the detectors were analyzed by optical microscopy and Raman and FT-IR spectroscopies. While optical microscopy provides information about the morphological changes, the spectroscopic techniques provide physical and chemical information over the detector molecular structure. This information is important because according to the literature it is said that the occurring ionization and excitation in the material atomic structure due to irradiation lead to the breaking of carbon and hydrogen and carbon and oxygen chemical bonds. This breaking implies in the decreasing of the density of the respective functional organic groups in the initial structure of the polymer, leading to the rearrangement of the same, as it can be observed in this work.

Two- and three-dimensional X-ray image reconstruction from a disk-type Ag-activated phosphate glass plate

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Novel disk-type two-dimensional (2D) image detectors for measuring large areas were proposed and demonstrated using nano-scale defects as minimum luminescent units such as radiation-induced Ag-related species in Ag-activated phosphate glass [1] and F-aggregate F_2 and F_3^+ colour centres (CCs) in lithium fluoride (LiF) thin films deposited on glass [2]. Such luminescent detectors are based on the radiophotoluminescence (RPL) and photoluminescence (PL) phenomena, respectively.

In this presentation, firstly, the blue at 470 nm and orange at 600 nm RPL [3] intensities as a function of three-dimensional (3D) location within the X-ray-irradiated Ag-activated phosphate glass are systematically investigated by means of a time-resolved spectral technique. Secondly, a non-destructive readout of 3D image reconstruction using the blue RPL with a short, 4.7 ns, and orange RPL with a long, 2400 ns, fluorescene lifetime in Ag-activated glass is successfully demonstrated for the first time.

The high-efficiency RPL glass detector, which was used a commercially available Ag-activated glass, was a disk-type plate with a diameter of 100 mm and a thickness of 1 mm. The detector was rotated at a rate of 2400 rpm (40 Hz) and controlled to translate a laser spot having a diameter of ~500 nm with a wavelength at 371 nm from the outer disk to the inner disk in the radial direction [1, 2]. A confocal detection system having a 0.90 numerical aperture (NA) objective lens and a working distance of 1 mm enables the reconstruction of 3D image within the transparent detector by combing area images at different depths from the vicinity of the surface to ~700 μ m. This non-destructive readout detector should be suitable for a wide range of applications, particularly, in clinical radiotherapy and particle trajectories as well as in outdoor environments, e.g., in structural health monitoring for buildings, tunnels and bridges.

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Acceleration of background gas ions due to Coulomb explosion of clusters triggered by irradiation of ultrashort intense laser pulses

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The laser-driven ion acceleration via the interaction of ultrashort, intense laser pulses with matter, known as laser-plasma acceleration, is featured by its high accelerating electric fields and short pulse length compared to conventional rf-accelerators. Recently, substantial enhancement of the accelerated ion energies up to 50 MeV/u has been demonstrated by utilizing a unique property of a cluster-gas target, where submicron-size clusters are embedded in a background gas [1,2]. In such highly nonlinear interactions between ultrashort, intense laser pulses and cluster-gas targets, acceleration mechanism becomes complicated and consists of different processes such as, (a) acceleration of ions due to Coulomb explosion of individual clusters, (b) compression and acceleration and associated pinching near the rear surface, and (d) sheath acceleration at the interface between the medium and vacuum.

In this study, to understand the synergetic interplay between the processes (a) and (b), we have conducted ion acceleration experiments using CO₂ clusters embedded in background H₂ gas with the J-KAREN laser (1 J, 40 fs) at JAEA-KPSI [3]. In order to characterize the accelerated ions, we used a combination of a magnetic energy spectrometer (0.75 T) and CR-39 detectors covered by a 6 μ m Al filter. By a careful analysis of etch pit positions on CR-39 and their structures including the etch pit growth behavior analysis with the multi-step etching technique [4], energy spectra for protons (from background gas) and carbon/oxygen ions (from clusters) are obtained separately for the first time. We found that the maximum energies of protons and carbon/oxygen ions are almost identical as ~2 MeV and ~2 MeV/u, respectively. Based on the experimental results, the acceleration mechanism of background gas ions induced by Coulomb explosion of clusters will be discussed with the help from numerical simulations which employ a particle-in-cell (PIC) method including relaxation and ionization processes of plasma particles (EPIC3D) [5].

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A novel method based on Digital Image Correlation to investigate by CR-39 detectors the occurrence of fusion reactions in a laser produced plasma

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CR-39 is extensively used to assess the fluence of heavy ion particles in different fields, as neutron dosimetry, radon measurements and also advanced fusion research. To investigate the reaction rates of p-B11 fusion in laser plasma produced at ENEA ABC facility, our Radon Service has developed an original procedure to readout these special exposed detectors. Having realized that standard pattern tools were unfit to reduce the background to the required very low level, a new score has been devised, by combining both Normalized Cross-Correlation (NCC) and Zero-mean Normalized Cross-Correlation (ZNCC) indexes. Alpha track templates can be obtained both experimentally and by simulating their optical rendering by an appropriate code of calculus provided by Nikezic et al. (TRACK_VISION). Some parts of his source program were modified to our needs, so to build under LabVIEW 10.0 f2 a library of virtual instruments (VI), each one representing the vector of the pixels forming an alpha track, entering the detector at 90° and of determined energy and removed layer, as it appears at our light microscope.

The robustness and the figure of merit of the new score was assessed by analyzing with the proper track VI library a set of fields of view (FOV) previously exposed to almost mono-energetic alpha particles, produced by a source of ²⁴⁴Cm.

Two sets of detectors exposed to plasma in the course of different test performed at ABC were readout with the same specifications used for the detectors exposed to radon, except for the number of FOVs, which was increased to 806, for a total of 3.63 cm² scanned surface. All the images were finally analyzed with a dedicated LabVIEW VI, whose core is represented by our pattern recognition virtual instrument: to improve the computational efficiency pre-etching techniques as such as the use of track dimension windows have been adopted.

A very significant number of alpha tracks with high scores were detected in many of the analyzed detectors, with an energy resolution of 250 keV. Many other clusters of pixels were found and attributed to other kinds of particles, mainly protons.

Actually the same procedure to achieve the alpha templates is on progress to generate similar libraries for protons.

Effect of laser polarization on proton energy at laser plasma accelerators

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In this paper, proton acceleration via interaction of an ultra-short intense laser with over-dense plasma is simulated using 1D-LPIC code. The parameters of laser and plasma have been chosen as following: laser intensity, $I = 1.37 \times 10^{20}$ W/cm², laser pulse duration, 80fs, and plasma density $n = 9n_c$ ($n_c = \omega^2 m_e \epsilon_0/e^2$) and laser polarization both of linear (p type) and circular polarization. Effect of target's thickness on proton's energy spectrum was studied. The results indicate that proton energy has been increased when laser with circular polarization was used instead of laser with linear polarization. In linear polarization mode spreading of electron by fluctuating field leads to distortion of accelerating electrostatic field. This field results in broadening of the protons energy spectrum. On the other hand, when laser with circular polarization is used there is not oscillating component force in direction of laser propagation and therefore, process of electron heating and spreading is eliminated. This effect results in effective acceleration and produces quasi- mono-energetic bunch of proton about tens of MeV. Reduction of target's thickness, just in the case of circular polarization, leads to increasing the proton's energy and improves the width of energy spectrum.

Fragmentation studies of 290 A MeV ¹²C ions with ²⁷Al Target with CR-39 Ion Track Detector

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The reaction products or fragmentations of +6C ions with ¹³Al target have not been studied for all projectile energies. This research will be a step to add knowledge for the fragmentations of 290 A MeV +6C ions with Al target. The +6C ions of 290 A MeV were allowed to interact with aluminum target. The incoming flux of incident particles and reactions products have been measured using thermoset plastic Ion Track Detector (ITD) placed before and after the target material.

The incident flux of +6C ions and the reaction products were revealed through successive etching technique. Optimum etching conditions were obtained. Then CR-39 NTDs were scanned using the auto-scanning system installed at the Radiation Physics Laboratory (RPL). For the analysis of the scanned images, image processing software "ImageJ" has been used.

Fragmented and un-fragmented parts of the primary beam have been identified from the area distributions of the respective charges. The nuclear parameters such as partial and total charge-changing cross sections have been determined. Experimentally determined cross sections in this research have been found in comparisons with the values computed using theoretical models. The results have also been compared with the experimental results reported by others researchers.

The results of this research are useful for astrophysics like shielding design for spaceship, radiobiology and therapeutic treatment of deep seated cancer in human tissues.

The fluence of high energy neutrons emitted from surface of QUINTA setup irradiated by deuteron beams of energies of 4 and 8 GeV

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Experiments with a natural Uranium setup "QUINTA" using 4 and 8 GeV deuteron beams of the Nuclotron accelerator at the Joint Institute for Nuclear Research (Dubna) are analyzed. The ¹²⁹I, ²³²Th, ²³³U, ²³⁵U, ^{nat}U, ²³⁷Np, ²³⁸Pu, ²³⁹Pu and ²⁴¹Am radioactive samples were installed on the surface of the "QUINTA" setup and irradiated with secondary neutrons. The neutron flux through the RA samples was monitored by Al foils. The reaction rates of ²⁷Al(n,y1) ²⁴Na, ²⁷Al(n,y2) ²²Na and ²⁷Al(n,y3) ⁷Be reactions with the effective threshold energies of 5, 27, and 119 MeV are measured at both 4 GeV and 8 GeV deuteron beam energies. The average neutron fluxes between the effective threshold energy and the effective end of the neutron spectra (which is 800 for 4 GeV energy and 1000 MeV for 8 GeV deuteron energy) are determined. The evidence of intensity shift of the neutron spectrum to higher neutron energies with the increase of the deuteron beam energy from 4 GeV to 8 GeV is obtained from the ratio of the average neutron fluxes. The reaction rates and the average neutron fluxes at different energies are calculated with MCNPX2.7 and MARS15 code also for comparison with the experimental flux.

THE USE OF SSNTD TECHNIQUE FOR THE EVALUATION OF PHOTO-NEUTRON FLUENCES IN RADIOTHERAPY FACILITIES

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It is well known that neutrons represent an undesired dose component in radiotherapy facility with high energy Linacs. A review was given for our recent studies on the evaluation of neutron fluences generated from the Varian Clinac 2100C and the Siemens Primus accelerators in Algerian radiotherapy facilities [1-4]. The neutron source strength (Q), the peripheral doses, the in-beam dose and the neutron head leakage from these medical accelerators have been experimentally determined using active methods (dose rate meters) and passive methods by the use of activation detectors (P₂O₅), thermoluminescent dosimeters (TLDs), Solid State Nuclear Track Detectors (CR-39 with and without bore converter (BE10) and LR-115 type 1B), and bubble detectors. In this communication, we present a comparative study between these different techniques. Results confirm that SSNTD technique is the most appropriate method to be used for the evaluation of the neutron source strength (Q) and the peripheral dose measurements regarding many considerations such pulsed nature of the neutron field, the low peripheral doses which needs integrating measurements. Peripheral doses lying between 0.40 and 1.61 mSv/Gy have been estimated on patient plane using CR-39 detectors. Values of Q, determined for Varian Clinac 2100C using CR-39, and Siemens Primus accelerators using LR-115 type 1B, have been found about 0.98 1012 and 0.36 1012 n/Gy, respectively. These results are in good agreement with published data.

Study of sub-actinide (²⁰⁹Bi, ^{nat}Pb, ¹⁹⁷Au) fission in the Quinta assembly of JINR

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Accelerator Driven Systems (ADS) consist of a spallation neutron source coupled to a sub-critical nuclear assembly and are a proposed technology for transmutation of nuclear waste. The Quinta assembly of the Joint Institute for Nuclear Research (JINR) in Dubna, Russia is composed of 512 kg of natural uranium surrounded by a lead reflector and is designed for neutronic studies of fast ADS. The Quinta assembly was irradiated with 1 and 4 GeV deuterons and the fission rate of several sub-actinides (²⁰⁹Bi, ^{nat}Pb, ¹⁹⁷Au) mooted as potential target materials was measured using mica SSNTD's placed inside the assembly. The experimentally measured fission rates were compared to those calculated using MCNPX and INCL4-ABLA physics models. Fission due to neutron, proton, deuteron, charged pion and photon reactions were all calculated using cross sections retrieved from the literature or calculated using the XSEX3 code. Good agreement was found for samples located away from the beam axis whereas samples placed within the beam shadow resulted in significantly higher experimental rate than could not be accounted for in the calculations. The significant amount of pion fission for the 4 GeV irradiation highlights the need for improved cross sections.

CR-39 detector for determination of equivalent dose and energy spectrum of Am-Be source

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CR-39 detectors are widely used for {neutronic purposes such as detection and dosimetry}or (neutron detection and dosimetry). The aim of this work is determination of equivalent dose in different distances from neutron source. Fast neutrons are detected via tracks produced by secondary charged particles from interaction of fast neutron with CR-39 constituent atoms. In order to increase detection efficiency of fast neutrons, Plexiglas radiators were used in front of the CR-39 detectors. For detector of thermal neutron, the CR-39 detectors were mounted with ¹⁰B convertor. CR-39 detector registers α -particles and ⁷Li ions emerging from ¹⁰B(n, α)⁷Li reaction. In this work boric acid (H₃BO₃)disc was selected as a suitable convertor. The designed assembly were exposed to a 15 Ci ²⁴¹Am-Be cylindrical neutron source. After irradiation the CR-39 detectors were etched chemically. Through obtained information from latent tracks, fast neutron spectrum and equivalent dose of ²⁴¹Am-Be neutron source were evaluated. The measured fast neutron spectrum of ²⁴¹Am-Be source showed that the CR-39 detector doesn't have adequate accuracy for neutron spectrometry. The equivalent dose for fast and thermal neutrons were simulated by MCNP-4C code. The results of measurements and simulation show a good agreement.

Measurement of the secondary neutron field inside a water phantom exposed to scanning proton radiotherapy using PADC track detectors

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One relevant advantage of proton therapy for cancer treatment, as compared to photon therapy, is that proton beams may be tuned to deposit most of their energy at specific depths inside the patient, thus minimizing unwanted exposure of healthy tissue and organs around the treated volume. Nevertheless, interaction of protons with materials in or around the beam line, inside the treatment room and with patient's tissue, results in the production of secondary neutrons with energies up to several tens or hundreds of MeV. Unwanted neutron doses outside the clinical target volume increase the risk of developing radiation-induced secondary cancers in healthy organs.

An experimental measurement campaign investigating secondary radiation generated by a scanning proton beam was undertaken by the EURADOS WG9 (the European Radiation Dosimetry Group, Working Group 9 - Radiation protection dosimetry in medicine). Irradiations took place at the IBA (230 MeV) active-scanning proton beam therapy facility in Trento, Italy. A volume of $10 \times 10 \times 10$ cm³ inside a $60 \times 30 \times 30$ cm³ water phantom was uniformly irradiated to an experiment-specific absorbed dose, which varied between 40 and 100 Gy. The water phantom was filled, among other dosimeters, with Poly-Allyl-Diglycol-Carbonate (PADC) track detectors to evaluate neutron dose equivalents at several points outside the clinical target volume.

Dose measurement variation with depth inside the phantom and its lateral distribution will be presented, together with the procedure that allows converting the detector readings (tracks·cm⁻²) to dose equivalent. This procedure uses Monte Carlo simulation to determine the neutron spectra at the measurement points in order to apply the correct calibration factor for each PADC. Preliminary results indicate that neutron dose equivalent values outside the clinical target volume are of the

same order of magnitude than those found in previous photon irradiations performed in conventional hospital linacs.

HP-6

Research Reactor Operating Power Study with Nuclear Track Metodology

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Nuclear Track Methodology (NTM) is one often employed as alternatives for neutron flux measurements and dosimetry using neutron-proton interaction. In this paper the Triga Mark III research reactor operating power and neutron flux, are studied using Nuclear Track Detectors (NTD). The facility of the "Instituto Nacional de Investigaciones Nucleares (ININ)", Salazar, Mexico operate with a core load of 74 elements Low Enriched Uranium (LEU) 30/20 plus three followers enriched to 20% U and a density of 30% of the Moderator-Fuel. The fuel mixture has a total load of 165 g of U-235 plus 12,612 g of U-235 in an elongated pool filled with demineralized water, providing a neutron flux around 2 x 10^{12} n cm⁻²s⁻¹ at the irradiation channel. The latter were employed to expose CR-39 (allyl diglycol policarbonate) Landauer® to neutrons; the detector was covered with 3 mm acrylic sheet as moderator. Etching conditions were: 6.25M-KOH solution at 60±1°C for 6 hours. The track density was determined by a custom made Digital Image Analysis System (DIAS). Results show a linear response between the reactor power in the range 0.1-7 kW and the average nuclear track density with data reproducibility and relatively low uncertainty (+/-7%). The method is a simple technique, fast and reliable procedure to monitor research reactor operating power level. The NTM open the possibility for neutron flux density calibration to deerminet an unknown low reactor power.

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Computer simulation of neutron-induced recoil proton tracks developed on etched PADC films

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Solid-state nuclear track detectors (SSNTDs) such as polyallyldiglycol carbonate (PADC) films have been found useful for neutron dosimetry. In the present work, a relatively small-sized computer program (when compared to those large-scale computer codes such as MCNP) was prepared, which could take an arbitrary energy spectrum of neutrons to strike a PADC film, then modeled the physical interactions of the neutrons with the PADC film and finally generated the lengths of the major and minor axes of opening parameters of the recoil proton tracks developed on the PADC film for a specified etched layer thickness. The development of this program built on a published computer program Neutron_CR-39.F90 (Milenkovic et al. 2011). It was expanded based on our experience in developing the programs TRACK_TEST (Nikezic and Yu 2006) and TRACK_VISION (Nikezic and Yu 2008) for calculating alpha-particle track parameters in SSNTDs. The present work was part of our ongoing project to develop a methodology based on analyses of parameters of the tracks from the recoil protons developed on the etched PADC films to reconstruct the incident neutron energy spectra, which would help a realistic neutron dose assessment.

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Research on anisotropy of fusion-produced protons and neutrons emission from high-current plasma-focus discharges

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The paper reports on measurements of fast protons and neutrons emitted from D-D fusion reactions in high-temperature plasma produced within the modernized DPF-1000U facility, which was operated at 23 kV/ 350 kJ and could generate on average 3.5×10^{10} neutrons per shot. The described measurements were performed by means of solid-state nuclear track detectors (SSNTD) arranged as "sandwiches", each composed of an Al-foil of 80 m in thickness, the first PM-355 detector of 500 m in thickness, a polyethylene converter-plate of 250 m in thickness, and the second PM-355 detector of 500 m in thickness. The Al-foil constituted an absorption filter which eliminated almost all primary deuterons escaping from plasma, but was penetrable for fast (about 3 MeV) fusion-produced protons to be recorded by the first PM-355 detector. The first two layers of the "sandwich" were penetrable for fast (about 2.5 MeV) fusion neutrons, which could be partially converted into recoil protons within the polyethylene layer. These secondary protons could subsequently be recorded by the second PM-355 detector. The measurements were carried out with four identical "sandwiches" placed at different angles to the z-axis. There were performed 3 experiments, during which all the "sandwiches" were irradiated by discharges with comparable total neutron yields. The irradiated PM-355 detectors were subsequently etched at the standard conditions, and analyzed with an optical microscope. The analysis of the etched tracks in the PM-355 detectors enabled to determine the recorded numbers of fast protons and neutrons, and to estimate their emission anisotropy. These measurements were supported by computer simulations of behaviour (i.e., penetration and conversion) of the investigated fusion-born particles in the applied "sandwich" detectors.

HP-9

Development of Fast Neutron Detection for Dark Matter Search using Nuclear Emulsion

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Nuclear emulsion is one of fast neutron detectors, which have a distinctive feature of a submicron spatial resolution. It is possible to measure the length and angle of recoiling nucleus precisely. Recently, nuclear emulsion is being used for a fusion reactor experiment or a dark matter search by utilizing this feature. Nuclear emulsion has key advantages of reconstructing the angle and energy distribution of incident neutrons and high rejection power of gamma radiation because the sensitivity to gamma-ray is under control.

It is necessary to readout tracks in nuclear emulsion by a microscope. We developed a new automated tracking method to pick up proton tracks which have a length of less than 100 microns. The conventional tracking method has been developed to detect high energy charged particles for neutrino experiments or cosmic-ray experiments. It is limited to detecting all solid angle tracks and short tracks. Using the new method makes it possible to find all solid angle (4pi sr) tracks and determine the length of tracks. We evaluated the reconstruction efficiency of the emulsion to which we exposed 2.5MeV neutrons by D-D reaction.

We are investigating dark matter search with nuclear emulsion in an underground laboratory. Fast neutron is an intrinsic background for the direct dark matter search. In other words, it is impossible to distinguish the nuclei which are recoiled by neutron and dark matter. So we are using an underground environment where the neutron flux is three orders of magnitude less than the surface. However, the neutron flux in the underground has not been understood well due to the very low flux.

Our plan is to measure neutron flux at 10 percent uncertainties. In addition, we will try to observe an anisotropic and an annual modulation of neutron flux which have not ever been measured.

For this study, what is the most problematic is that nuclear emulsion itself does not have a time resolution. Thus we need to prepare a target mass of 10kg and change it every two months. We will use HTS a new emulsion readout system in order to readout such amount of the emulsion. HTS has a capacity of more than several 10kg per month therefore this plan is feasible.

In this measurement, a background of neutron detection is alpha particles emitted by radioactive nuclei since alpha decay occurs three order of magnitude more than proton recoils. And alpha particle leaves a track the almost same as the proton recoil which has a certain energy. We are planning to reduce the radioactive nucleus and distinguish between alpha particles and proton recoils.

In this talk, we present a development of tracking method to detect fast neutron, its evaluation and future plans.

Using average stopping power of recoiled nuclei in determination of the maximum neutron energy of the ²⁴¹Am-Be source by superheated drop detector

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In this paper, the average stopping power of the recoiled nuclei was employed to determine the maximum neutron energy of the ²⁴¹Am-Be source using the superheated drop detector made of Freon-12. In an elastic collision between neutron and nuclei of Freon-12 liquid, ¹²C, ¹⁹F and ³⁵Cl nuclei can receive different amount of energy depending on their atomic weight. For a given neutron energy, the stopping power of ¹²C, ¹⁹F and ³⁵Cl is different because of differences in their received energy. To calculated average stopping power for a given neutron energy, the stopping power of a given neutron energy, the stopping power of a given neutron energy, the stopping power of all these nuclei corresponding to received energy through elastic head-on collision was determined by SRIM code. These stopping powers were weighted by considering the neutron-nucleus elastic scattering cross section and the number of each nucleus in Freon-12 molecule. Finally, the average stopping powers.

For determination of the maximum neutron energy of the ²⁴¹Am-Be source not only the threshold pressure for nucleation is required but also the thermodynamic efficiency. To estimate the threshold pressure for nucleation, a set of superheated drop detectors operated at different applied pressures was irradiated in a neutron field at a known temperature. The threshold pressure for nucleation was determined using correlation between the applied pressure and the nucleation rate of irradiated detectors. Using this method the threshold pressure of superheated drop detectors irradiated at temperature of 26°C by neutrons with the known energy of 2.89 MeV obtained from d-d neutron generator estimated 4.4 atm.

The thermodynamic efficiency was estimated using the threshold pressure of superheated drop detectors irradiated by 2.89 MeV neutrons. Using the value of 4.4 atm for threshold pressure at temperature 26°C and considering the value of 295 keV/µm for the average stopping power of 2.89 MeV neutrons in Freon-12, the thermodynamic efficiency was determined 0.03. In order to determine the maximum neutron energy of the ²⁴¹Am-Be source, the threshold pressure of superheated drop detectors irradiated at temperature 11°C in neutron field of this sources was estimated about 2.70 atm. Using this value for threshold pressure and knowing the value of 0.03 for thermodynamic efficiency, the average stopping power is 10.8 MeV. It should be mention that, at the threshold pressure only the neutrons with the highest energy take part in nucleation. Thus the determined energy is the highest level in the ²⁴¹Am-Be spectrum. The consistency between

the determined highest energy and the other reported values confirms the validity of using the average stopping power for determination of neutron energy by superheated drop detectors.

HP-11

Measurement of Thermal Neutron Flux Density at the neutron beam exit of In-hospital Neutron Irradiator

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Abstract: In-hospital Neutron Irradiator(IHNI) is an especially designed nuclear device based on Miniature Neutron Source Reactor(MNSR) for Boron Neutron Capture Therapy(BNCT). IHNI with the rated power of 30kW is an undermoderated reactor of pool-tank type, and UO₂ with enrichment of 12.5% as fuel, light water as coolant and moderator, and metallic beryllium as reflector. There are a thermal neutron beam and an epithermal neutron beam used for patient treatment on the both sides of the reactor core. The absolute neutron flux density at the exit of the thermal and epithermal neutron beam are measured by SSNTD, Mica with ²³⁵U fissile target is put at the center of the exit of neutron beam, and is irradiated at the 30kW, the tracks can be measured by optical microscope system, the neutron flux density can be gotten according to the nuclear number of ²³⁵U fissile target, tracks number, irradiation time and other parameters. The thermal neutron flux densities at the exits of thermal and epithermal beams are 1.67×10^9 n/cm² · s and 2.44×10^7 n/cm² · s respectively when the IHNI operates at 30kW. The thermal neutron flux density at the exit of thermal beam can meet the requirement of BNCT.

Keywords: In-hospital neutron irradiator; thermal neutron flux density, SSNTD.

Outline of new "wide-energy range personal neutron dosemeter (WNP)" using CR-39 nuclear track detector

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The wide-energy range personal neutron dosemeter (WNP) [1] is an individual passive neutron dosemeter that was developed by Chiyoda Technol Corporation (CTC) using its TechnoTrak CR-39 nuclear track detector. About 40,000 radiation workers throughout Japan use the WNP for neutron dose control at nuclear facilities and laboratories per month.

The WNP is designed to separately detect slow and fast neutrons using CR-39 attached to a high-density polyethylene filter and a boron nitride (BN) filter to achieve neutron dosimetry over a wide energy range (thermal to 15 MeV). The WNP is used with a radiophotoluminescence glass [2] dosemeter that measures photon and beta radiation as the Glass Badge whole-body dosemeter [3] developed by CTC. CR-39 measures only neutron dose in the mixed field of neutron and gamma radiation since it is non-sensitive to photon radiation. In the 2014 version of the Glass Badge, the concentration of BN in the filter was adjusted. As a result, the measurable upper dose limit for thermal neutrons has been extended from 2 mSv to 8 mSv.

The energy response of the WNP, etch-pit radii distributions on the CR-39 surface irradiated by monoenergetic and RI source neutrons, and other product characteristics will be shown in our conference presentation.

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Determination of photoneutron dose received by patient from LINAC by CR-39 detector

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Linear accelerator of energies higher than 8 MV in additional to electron and photon beams can produce secondary particles such as photoneutrons that these photoneutron cause unwanted dose to patient and hospital staff. Due to high magnetic fields, high frequency and high photon flux measurements by active detectors very complicated.

Therefore CR-39 detector could be very suitable detector for neutron dosimetry in high gamma and x-ray fields. The CR-39 samples were calibrated by ²⁵²Cf source, then for higher efficiency the Plexiglas used as a radiator for fast neutrons and boric acid for convertor of thermal neutron to charge particles. Two Linac machines of 18 MV Varian an 15 MV of Siemens were used in this study.

With increasing x-ray dose, photoneutron also will increase. The highest dose for neutrons in isocenter of $40*40 \text{ cm}^2$ filed achieved to be 5.97 mSv. For one Gy photon dose the minimum neutron dose in isocenter of $5*5 \text{ cm}^2$ measured to be 3.64 mSv. In this work also the effect of wedge fillter on photoneutron production and its dose distribution also investigated.

Preliminary results of neutron surveillance at LNF with PADC track detectors

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A neutron surveillance campaign was performed at the Laboratori Nazionali di Frascati (LNF) from the Istituto Nazionale di Fisica Nucleare (INFN). Stray neutron radiation is originated in the e $- e+ DA\Phi NE$ collider, from the nuclear interaction of the beam particles with the elements of the accelerator such as collimators and bending magnets, as well as with the shielding material. Poly - Allyl - Diglycol - Carbonate (PADC) based neutron dosimeters from different laboratories were placed at the same positions and during the same periods than those used for routine ambient monitoring, with the purpose of comparing their performance under realistic workplace neutron high energy field irradiation. One of the PADC dosimeter types used in this campaign is that developed by the Radiation Physics Group of Universitat Autònoma de Barcelona (UAB), able to record neutrons with energies ranging from the thermal regime up to about 10 MeV. The UAB dosimeters were electrochemically etched after several months' exposure and read with a semi - automated device. Neutron ambient dose equivalent H*(10) values are assigned using appropriate calibration factors for the neutron fields present in the premises. Results from the UAB dosimeters will be reported in this work.

Neutron ambient dose equivalent measurements using PADC detectors around charged particle accelerator workplaces

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This work reports the use of Poly - Allyl - Diglycol - Carbonate (PADC) based neutron dosimeters for the evaluation of ambient dose equivalent $H^*(10)$ in workplaces, namely, the Tandem Van der Graaf linear accelerator and cyclotron of the Centro Nacional de Aceleradores (CNA) in Seville (Spain). In particle accelerators, a parasitic neutron field is produced due to nuclear interactions of the beam particles with the elements of the accelerator, such as collimators and bending magnets, as well as the shielding material. Therefore, from the point of view of radiological protection, it is worth to evaluate the neutron ambient dose equivalent around the accelerator, especially in places where workers are expected to stay. Several PADC neutron dosimeters, able to record neutrons with energies ranging from the thermal regime up to about 10 MeV, were distributed in selected locations around the particle accelerators, inside and outside the irradiation rooms. Dosimeters are electrochemically etched using our standard procedure [1] and tracks are semi - automatically counted. H*(10) is evaluated from track densities, using a calibration factor previously determined from Am - Be source irradiations. In addition, neutron spectrometry was carried out using a Bonner Sphere Spectometer (BSS) with a ³He proportional counter as thermal neutron detector. Comparison of the H*(10) values obtained using the BSS and PADC detectors is performed.

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Study of a new neutron dosimeter incorporating RPL detectors

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The recently introduced radiophotoluminescent (RPL) detectors offer a unique combination of advantages for radiation monitoring that include rapid exploitation, stability to fading, reusability, and insensitivity to light, temperature and humidity. RPL detectors register X, γ and β radiations well but have low sensitivity for neutrons. After having designed and tested an RPL-based thermal neutron dosimeter with H*(10) and Hp(10) thresholds of < 0.5 mSv in a mixed n- γ field, we now look at the behavior of an RPL-based fast neutron dosimeter capable of measuring neutrons in an $n-\gamma$ field. The fast neutron dosimeter tested consists of an ordered assembly of Al foil, RPL detector(I), Al foil, polyethylene converter, RPL detector(II) and Al foil, all encased together in a polyethylene container. RPL detector(I) registers γ -rays incident from the mixed field. RPL detector(II) registers the same γ -rays as the other detector plus protons from energetic (n,p) collisions in the hydrogen-rich converter. The difference between the two RPL readings represents (n,p) protons and is related to the fast neutron dose. The response of the dosimeter is linear and shows an acceptable angular dependence. However the detection threshold turns out to be about 2 mSv, which is too high a value for routine monitoring. This threshold could be lowered to a more practicable value if next generation improvements in RPL detectors and in the reader could be made. The main shortcomings we encountered are (i) a 1.7 µm thick dead layer at the surface of the detectors that render them insensitive to part of the recoil protons, and (ii) an intrinsic detector background that could be reduced if the reader were able to pick out individual densely ionized zones created by the recoil protons.

On the modified structure around the latent tracks in PADC films exposed to protons and heavy ions

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A series of FT-IR measurements has been performed to understand the modified structure of latent tracks in poly(allyl diglycol carbonate) (PADC) films exposed to protons and heavy ions, He, C, Ne, Ar, Fe, Kr and Xe, in air or in vacuum. The examined stopping power ranged from 10 to 12000 keV/µm. For every examined ions, the effective track core radius for CH₂ group is almost equivalent for those of ether and carbonate ester bonds which are more radio-sensitive. This indicates that the frame of PADC with branched polyethylene like structure is also lost as well as the sensitive parts in each repeat unit. Hydroxyl groups are formed during the exposure, as new end-points of the network. Recombination of free radicals resulted in modified polymeric network is a compatible process with the hydroxyl formation. The latent tracks in PADC has inner surface decorated by the hydroxyl groups and the recombined molecule chains with altered structures, accompanying the significant amounts of excess waters.

Influence of SHI upon nanohole free volume and micro scale level surface modifications of polyethyleneterephthalate polymer films

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Topographic micro and in-depth nanoscale level modifications of polymeric materials play an important role in engineering their physical and chemical properties. Investigation of free volume (nanoscale level) and surface (microscale level) properties of polyethyleneterephthalate (PET) polymeric thin films after SHI treatment were employed by means of positron annihilation lifetime spectroscopy (PALS) and atomic force microscopy (AFM) respectively. The PET thin films were irradiated by 50 MeV lithium ions to the fluences of 1×10^{11} , 5×10^{11} , 1×10^{12} and 5×10^{12} ions/cm² at Inter University Accelerator Center (IUAC), New Delhi, India. The PAL spectra of PET indicated the existence of three types of lifetimes- τ_1 (annihilation of p-positronium), τ_2 (annihilation of free positron) and τ_3 (annihilation of o-positronium) [1]. The Tao-Eldrup model [2,3] was applied upon τ_3 to calculate hole radius (R). The value of R and intensity (I3) of o-positronium (o-Ps) were observed to be increased after ion beam treatment. The further analyses were employed to calculate the free volume (Vf) and fractional free volume (FFV) of holes from the obtained values of R and I3 [4]. The AFM studies reveal the surface modifications in the ions irradiated polymer films. The structural, optical, chemical and thermal properties were investigated by X-ray diffraction (XRD), UV-visible (UV-vis) and Fourier transform infrared (FTIR) spectrophotometry. Different parameters such as crystallite size, band gap energy and activation energy were calculated from the obtained data of XRD and UV- vis respectively. The results will be discussed during presentation.

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I-2

Swift Heavy Ions Induced Variation in the Transport Properties of Semiconducting Nanowires

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Irradiation effects on nano materials are always the center of attention in the large vision of their efficient use in technology. The primary outcome of irradiation in a crystalline structure is regarded as the damage events especially; target vacancies, displacements and replacement collisions are effective in the view of conduction of charge carriers through the medium. Cadmium selenate is one of the promising material among II-VI group semiconductors due to its great potential in the field of electronics and optoelectronics. Nanodevices based on nanowires have shown appreciably improved performance owing to the higher crystallinity and size-confined transport properties. High surface-to-volume ratio endows the high sensitivity in semiconducting nanowires that gives rise to large conductivity change associated with binding molecules as compare to bulk 3-dimensional counterparts. This study is related to synthesis of the cadmium selenate nanowires within optimized and controlled parameters and investigates the effect of ion beam on the properties of the nanowires. Nanowires were synthesized via template-assisted electrodeposition technique using polycarbonate track-etch membranes. The synthesized nanowires were exposed to 100 MeV O⁷⁺ ion beam with a fluence variation from 10¹¹ to 10¹³ ions/cm² at Inter University Accelerator Centre, New Delhi, India. Electrical resistivity of ion irradiated semiconducting nanowires was found to vary with the ion fluence. However, no phase change was observed in the XRD spectra of ion irradiated nanowires. Alteration in the granular properties and diffusion of defects (electric and chemical potential gradient) could be responsible for the variation in electrical resistivity of ion irradiated nanowires.

Complementary approach for heavy ion dosimetry with Ag+-doped phosphate glasses

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The Ag⁺-doped phosphate glass is well-known as a personal dosimeter based on the radio-photo-luminescence (RPL) detection. The intense luminescence due to the ionizing radiation is emitted by the excitation with ultraviolet light, which is proportional to the amount of the irradiated dose. Recently, we have found out this glass can be operated as a nuclear track etch detector [1]. The glass is etchable in the alkaline solutions and able to form etch pit for heavy ion irradiation. It means that we can observe not only RPL but also nuclear etched tracks in the same glass. The luminescence efficiency strongly depends on the LET (linear energy transfer) of heavy ions, which drastically decreases at the high LET region of > 10 keV/µm. For Xe ion beam irradiation, very high LET particles of several thousand keV/µm, the absorbed dose obtained from RPL underestimates ~70% for calibrated ionization chamber output. Meanwhile, the dose obtained from LET spectrum of nuclear etched tracks is good agreement with ionization chamber's. The physical quantities due to the different physical processes of excitation and ionization were successfully observed in the same glass plate, which shows good correlation between RPL and nuclear etched tracks for several LET data points. We found a complementary approach of radiation dose evaluation by combining both information of RPL and nuclear etched tracks. The nuclear track detection would supply the alternative signals in the glass dosimeter.

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Nickel Ion Beam Induced Modification in the Electrical Conductivity of Cu Nanowires

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Swift heavy ion beam irradiation induced modifications in metals has lead to a curiosity for evaluating the depth dependence of damage process that could be the source of deviation in their physical properties. In this contest, the present work aims to study the conduction of electrons in pre- and post- ion irradiated copper nanowires. The advance methods of preparing the nanoporous templates and development of techniques capable of filling the pores of such membranes are the two factors that accelerate the development in the field of synthesis and characterization of the nanowires. Electrodeposition process extensively used to synthesize the nanowires due to controllability of growth in the direction normal to the substrate surface and ambient operating condition of temperatures and pressure. Cu nanowires of 80 nm diameter were synthesized using track-etched membranes via template-assisted electrodeposition technique. Nickel (Ni¹²⁺) ion beam of 160MeV energy was made incident on cylindrical Cu nanowires along their axis at Inter University Accelerator Centre (IUAC), New Delhi, India. X-ray diffraction pattern of pre- and postions irradiated Cu nanowires inveterate the polycrystalline nature of nanowires with cubic lattice geometry. A detailed investigation of I-V characteristics of pristine and irradiated Cu nanowires was recorded using a 2-probe Keithley 2400 series source meter. Observations indicated that I-V characteristics of irradiated Cu nanowires at various fluence sustained the ohmic behavior, but with different slopes. Variation in transportation of electrons through the grain boundaries and increase in the amplitude of lattice vibrations may be responsible for the alteration of the electrical conductivity of the copper nanowires.

Study of SHI irradiation induced modification in thin films of tin oxide

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Thin films of tin oxide (SnO_2) of 100 nm thickness were grown on silicon <100> and glass matrices by electron beam evaporation deposition technique under high vacuum. Thicknesses of the films were calibrated by piezo-sensor attached to the deposition chamber. Nanocrystallinity is achieved in these thin films by 100 MeV Ni using 1 pna current at normal incidence with ion fluencies varying between 5×10^{11} ions/cm² and 1×10^{13} ions/cm². Swift Heavy Ion beam irradiation was carried by using 15UD Pelletron Accelerator at Inter University Accelerator Centre, New Delhi, India. Optical studies of these ion irradiated thin films were done by UV-Visible spectroscopy. Surface topographical studies and grain size calculations are done by Atomic Force Microscopy (AFM) technique in tapping mode. Roughness exponent was deduced from Power Spectral Density (AFM-PSD) data generated from AFM signals. Glancing angle X-ray diffraction (GAXRD) results using Brucker-D8 advance model instrument show improvement in crystallinity and new phase formation due to swift heavy ion irradiation. Grain size and particle size is verified by AFM and GAXRD results respectively. Depth profile and elemental composition was verified by Resonance RBS method. Detailed results will be discussed during the presentation.

Micro structural Studies of 145 MeV Ne6+ ions induced in Polytetrafluoroethylene (PTFE) polymer

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The passage of heavy ions in polymeric material produces a lattice deformation. The deformations may be in the form of latent tracks or may vanish by self-annealing in time. The availability of heavy ion beam from accelerator has brought new impetus to the field of ion beam modifications as changes in the electrical, chemical and optical properties of polymeric materials have been observed as a result of irradiation with swift heavy ion (SHI). Modification depends on the ion, its energy and fluence and the material itself. In the present work characterization of the optical, chemical, structural electrical modifications in PTFE induced by 145 MeV Ne⁶⁺ ions were carried out through UV-Visible spectroscopy, Fourier Transform Infra Red spectroscopy (FTIR), X-Ray Diffraction (XRD) and LCR meter. 100 µm thick PTFE polymer procured from Good fellow, Cambridge Ltd. England (UK), were irradiated by 145 MeV Ne⁶⁺ ions to the fluences of 10¹⁰,10¹¹, 10¹², and 10¹³ ions/cm² at Variable Energy Cyclotron Centre (VECC), Kolkata, India.

The optical band gap (Eg), calculated from the absorption edge of the UV spectra of the films in 200-800 nm region varied from 2.23 eV to 1.63 eV for pristine and irradiated samples. At the highest fluence of 10^{13} ions/cm² the maximum change in optical band gap ~26% has been observed. The cluster size changes from 236 to 443 carbon atoms per cluster. Carbon enriched domains created in the polymer during irradiation may be responsible for the decrease in the band gap. In FTIR spectra, appreciable changes have been observed after irradiation, indicating molecular fragmentation, cross-linking, formation of unsaturated group and free radicals. X-Ray Diffraction (XRD) analyses show significant change in crystallinity with fluence. Dielectric constant (ε') decreases with frequency whereas it increases as the frequency increases. Tanδ also increases with fluence. Tan δ has positive values indicating the dominance of inductive behavior. A sharp increase in A. C. conductivity in pristine as well as in irradiated samples is observed with frequency. Due to irradiation the increase in conductivity with fluence at a given frequency may be attributed to scissoring of polymer chains, resulting in an increase of free radicals, unsaturation, etc.

Characterization of swift heavy ion induced modification in polymeric material

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Polyethylene terephthalate (PET) belongs to the polyester family of polymers and attracted due to its excellent physical and mechanical properties. In the present study we have investigated structural and dielectric properties of pristine and irradiated PET polymer using XRD, FTIR and LCR meter. PET polymer of thickness 50 μ m was procured from Good fellow, Cambridge Ltd. England (UK), and irradiated with various fluences of Si⁸⁺ ions of 100 MeV energy using pelletron accelerator at Inter University Accelerator Center (IUAC), New Delhi. FTIR spectra indicate overall decrease in the intensity of typical band at higher fluence. On irradiation dielectric constant (ϵ ') decreases with frequency whereas it increases with the ion fluence. Variation of loss factor (tan δ) with frequency for pristine and irradiated with Si ions reveals that tan δ increases as the frequency increases. Loss factor also increases with fluence. Due to irradiation the increase in conductivity with fluence at a given frequency may be attributed to scissoring of polymer chains, resulting in an increase of free radicals, unsaturation, etc. XRD analysis clear shows decrease in crystallite size with increase in fluence and no other impurity phase was observed.

Radon and Thoron (²²²Rn and ²²⁰Rn) concentration distribution study on three detection planes inside of a closed room using Nuclear Track Methodology

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The aim of this study is to determine the indoor radon and thoron concentration distribution on three detection planes, inside of a controlled closed room with microclimate conditions with Nuclear Track Methodology (NTM), using CR-39 Lantrack bared detectors. One hundred sixty two (162) 1.9cm x 0.9cm CR-39 polycarbonate chips were placed in each one of the three planes, 2.0m x 2.0m square structures, distributed uniformly in 18 columns and 18 lines, in each plane.

After three months exposure to indoor radon and thoron inside of the closed room, with a main concentration value of 862 ± 49 Bq/m³, all the detectors were chemically etched in KOH-6.25M solution to $60\pm1^{\circ}$ C for 18 h, following the well established protocols for indoor radon survey, by the Dosimetry Applications Laboratory of the Physics Institute, UNAM; and later on read by Digital Image Analysis System (DIAS).

The results show that the radon and thoron concentration distribution is not homogeneous in anyone of the planes faces. The six faces of the three planes measured, have a very particular distribution. From the results can be observed that each side of each plane shows a peculiar distribution, with gradients of concentrations higher than 50% from one area to another of the same measured plane. These results can help to understand the dynamics of the radioactive gases, and their measurements.

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Noble gases as tracers for the groundwater and streams in central mountainous regions of Taiwan

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Noble gases have been considered as sensitive tracers for groundwater due to their unique geochemical characteristics. In this study, groundwater of the monitoring wells and river water were collected for geochemical analysis, including Radon concentration and Helium isotopes, from central mountainous regions of Taiwan to discuss their fluid sources. The results of hydrogen and oxygen isotopic values are -77.8~-36.5 permil and -10.7~-6.3 permil, respectively, falling on the local meteoric water line of Taiwan. It revealed that groundwater source in studied area is mainly from the precipitation. The helium isotopic ratios of the samples range from 0.78 to 1.13 Ra. It implies that, in addition to the air-saturated water, there are additional sources for the groundwater in central mountainous regions of Taiwan. Interestingly the water sample from Liwu River was detected high ²²²Rn concentration, 7.66 kBq/m³, which is much higher than background values in normal river water. It suggests that local groundwater with high ²²²Rn concentration of 1.38~75.4 kBq/m³ may play important role for the Liwu River.

Temporal Variations of Soil Gas Concentration for Seismic Precursory Study in the Longitudinal Valley, Eastern Taiwan

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Gas monitoring stations located along the NNE-striking Longitudinal Valley Fault, which is an extremely active high-angle thrust on the boundary between Eurasia plate and Philippine Sea plate, continuously record the time series of soil gas data in this study. The variations of soil radon concentration are similarly to the variations of soil CO₂, which is considered as the carrier gas for radon gas migrating from deep source area to surface. Fluctuations of soil-gas can reflect a change in fault permeability along with stress-strain state variations. Results show semi-diurnal variation of soil-gas is probably generated by solar/lunar tide effect, achieve \pm 500 Bq/m³ and 0.4% for Rn and CO₂, respectively. Variations exceeding from the normal trend can be used to identify some events associated with geodynamic processes such as earthquake and heavy rainfall. These anomalies usually appeared a few days before the local earthquakes, which mainly occurred in eastern Taiwan. Meanwhile, significant increase in soil-gases were recorded two months before the Rueisuei earthquake (ML = 6.4, October 31, 2013) and recurrent anomalies were observed prior to 3 weeks before the Fanglin earthquake (ML = 5.9, May 21, 2014) occurred in the Longitudinal Valley area, respectively. Therefore, we could suggest that the longer the precursory time of soil gas anomaly correspond to the larger magnitude of the impending earthquake. It is worthy of continuous monitor on multiple parameters, it will allow us to better understand the relationship between soil gas variations and regional geodynamic processes in the area.

Measurement of natural radionuclides and radon exhalation rate of soil samples in some places of Karbi Anglong district of Assam, India using Gamma ray spectroscopy and can technique method.

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Uranium and thorium, with their daughter products are recognized as the two main sources of natural radiation. Usually in small quantities, these elements are widely distributed in rocks and mineral deposits. Apart from these elements, the element K-40 is also most abundant in crustal rocks. Although K-40 is a much weaker source of radiation than the member of U and Th series, its abundance makes it an equal contributor to U-238 and Th-232 in the natural radiation flux. Estimation of these radionuclides is of extreme importance to know their activity in a particular place to assess any possible radiological hazard to man from such materials. Soil gas radon emission is a process of natural radioactivity that takes place due to the presence of uranium in the deeper level of the soil. The accumulation of indoor radon in dwellings is due to uranium, radium present in the soil, building materials etc. Therefore, estimation of indoor radon, radon exhalation rate and concentration of natural radioactivity (U-238, Th-232, K-40) is extreme importance to find possible correlation among these parameters. In the present investigation, uranium-238, radium-226 and potassium-40 has been determined by Gamma ray spectroscopy method. The U-238 concentration varies from 35.67 ± 0.55 Bg.kg⁻¹ to 94.91 ± 3.17 Bg.kg⁻¹ and the Th-232 concentration varies from 36.74 ± 1.34 Bq.kg⁻¹ to 579.10 ± 5.36 Bq.kg⁻¹ where as K-40 concentration varies from 154.79 ± 2.27 Bq.kg⁻¹ to 1907.69 ± 16.74 Bq.kg⁻¹. The radium equivalent activity varies from 100.15Bq.kg⁻¹ to 1031.90 Bq.kg⁻¹ with a mean value of 722.98 Bq.kg⁻¹. The absorbed dose rate of the studied locations varies from 46.21 nGyh⁻¹ to 486.39 nGyh⁻¹ with a mean value of 341.29 nGyh⁻¹. The external hazard index (Hex) for the soil samples were found to be 0.27 to 2.77 with a mean value of 1.94. Bare mood technique has been applied to estimate the indoor radon concentration and can technique method has been used for the measurement of radon exhalation rate of soil samples. The average indoor radon concentration varies from 93.10 ± 7.19 Bq.m⁻³ to 266.01 ± 12.15 Bq.m⁻³ in the studied locations. The lifetime fatality risk estimates to be 1.23 x 10⁻⁴ to 3.57 x 10⁻⁴. A significant variation of radon exhalation rate of soil samples varies from 366.89 mBqm⁻²h⁻¹ to 2055.80 mBqm⁻²h⁻¹ from place to place. A good positive correlation (correlation coefficient, R=0.95) has been observed between uranium concentrations and radon exhalation rate

of soil samples. A positive correlation (R=0.80) has been observed between uranium concentration and indoor radon concentration.
Radon concentration and exhalation rate measurements by SSNTD

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Radon levels in buildings vary widely from area to area also depending on local geology. Thus, it is important to assess the radon prone areas of a region on the basis of geological data and search for any possible correlation between the local geology and the indoor radon concentrations.

We report about indoor radon measurements in Ragusa, SE Sicily, placed in the Hyblean Plateau (northern region of the African Plate), carried out in collaboration with schools. The survey was performed using solid state nuclear track detectors, CR-39 type, and a well-established methodology for chemically etching and reading, developed at the Radioactivity Laboratory of the Department of Physics (University of Catania). In case of high indoor radon values, in order to establish the origin, in soil gas radon measurements were carried out, together with radon exhalation rates from building materials using the closed-can technique by means of CR-39 detectors.

Use of statistical methods for analysis of time-series soil-gas monitoring data for seismogenic studies in Taiwan

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Number of statistical approaches have been proposed and applied to quantify influence of single or all meteorological parameters either on time-series soil-gas radon or other precursor's parameters. The present study is also aimed at the appraisal and filtrations of these environmental/meteorological parameters and to create database for earthquake precursory study. As per the present practice, the data from various stations are examined synoptically to evaluate earthquake precursory signals against the backdrop of rainfall and other environmental factors. For the earthquake prediction the efficiency of an operation system depends not only upon its logical correctness, but also upon the response time. In recent years database was developed from the established network of continuous soil-gas monitoring stations along different faults covering NW, SW & eastern Taiwan. Efforts were made to improve data processing system for earthquake precursory studies by filtering the data from noise generated by environmental/meteorological parameters. The data processing includes a low-pass filter to reduce the noise level. It filters out the high frequency noise and daily variation caused by different parameters like measurement uncertainty, background noise, environmental parameters and earth tides. The rolling average and normalization were used to quantify the probability distribution of variation in the data. In an effort to reduce the response time and increase the efficiency, automatic operating methodology was adopted to process the data from the monitoring stations. The data from the monitoring stations were automatically uploaded to the web service which provides the data management/exhibition with less response time database. In addition to monitoring station data seismic parameters (i.e. magnitude/location/depth of event, intensity/epicentral distance at monitoring station etc.) and meteorological parameter data are also uploaded from Central Weather Bureau of Taiwan (www.cwb.gov.tw) simultaneously. It would be helpful in increasing efficiency of earthquake prediction studies.

Keywords: soil-gas, meteorological parameters, statistical filters, earthquake precursor, Taiwan

Long-term radon level dynamics in the Amer faulty soil.

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In previous radon studies in the Amer faulty region, higher soil radon levels were found in the vicinity of the main fault, a very clear seasonal effect was observed, and more recent active fractures and areas with high superficial fracturing were identified. With the aim to confirm the results obtained in these previous studies, to explain the radon levels origin and its dynamics and to increase the geophysical knowledge of this active faulty region, additional studies have been carried out. They consisted on analysing new data from additional integrated and continuous soil radon measurements using passive and active detectors and exploring new profiles by means of punctual soil radon and thoron measurements and the electrical resistivity tomography technique, complemented with radionuclide content of soil materials obtained by gamma spectrometry. Results agree with those obtained previously, soil radon measurements present a wide range of values, [1~150] kBq·m⁻³, mean radon concentrations are higher close to the main faults, showing higher dispersion where materials that cover faults are less homogeneous and can affect significantly radon transport, for instance along profiles located in urbanised soils. Soil radon concentrations do not present correlation (r2=0.09) with ²²⁶Ra concentrations obtained in the soil samples extracted from radon measurement points. The identified area with the highest mean values (> 60 kBq \cdot m⁻³) and more seasonal variation has been studied in more detail for four years. A significant correlation (r2=0.66) between daily mean values of soil radon and atmospheric temperature has been obtained. The daily variation of atmospheric temperature produces an important variation of soil radon level, delayed for about six hours. All these spatial and temporal soil radon variations can occur in regions with similar geological characteristics and they should be taken into account when punctual soil radon measurements are required before making a decision about the most appropriate construction technique for new buildings.

Integrated radon-thoron monitoring in Tatun volcanic areas of northern Taiwan using solid state nuclear track detectors (LR-115) for volcanic and seismic study

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In the present study integrated radon-thoron monitoring has been carried out in Tatun volcanic areas of northern Taiwan using solid state nuclear track detectors (LR-115) for volcanic and seismic study. The Tatun volcanic area is located on the northernmost tip of Taiwan which includes more than 20 volcanoes. It is north of the Taipei basin, the capital of Taiwan with a total population of more than seven million inhabitants. Radon-thoron discriminators with LR-115 films installed in different sites having different temperature at about 50cm depth. After preliminary observation, we have selected a suitable site for integrated radon monitoring at Hsiaoyoukeng (SYK), Dayoukeng (DYK) and Gungtzeping (GTP) of Tatun volcanic areas of northern Taiwan. In addition to that, we also have integrated radon monitoring station at Bayein (BY) along with active radon detector RAD7 for comparative study. This paper presents the possible fluctuations and radon behavior due to seismic events and volcanic eruptions at selected suitable sites for integrated radon monitoring in details.

ENHANCED RADON/THORON EMISSION FROM SANDSTONES CONTAINING URANIUM/RADIUM MINERALS

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Radon / Thoron are the decay products of uranium / thorium. These important decay products after being produced, are trapped in the samples through natural process, causing health hazards as well as being helpful in exploration of uranium / thorium and oil deposits. Signals from them have also been used to obtain earthquake warning information. This paper besides reviewing this important subject, briefly, summarizes minimize e.g. some of the experimental studies regarding trapping and releasing of radon / thoron in nature as well as by exploring the field samples to shock waves produced in the vicinity of the radon / thoron trapped centers. Effects of physical characteristics of the samples on the emission rates have also been studied.

Optimization of etching conditions for CDs/DVDs used as detectors for high radon concentrations

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The combination of the high radon absorption ability of the polycarbonate material of CDs/DVDs with its track-etch properties to measure radon was first proposed in 2001. Since then the applications of this method have expanded significantly, including measurements of high radon concentrations, e.g. in soil gas, underground mines, radon spas and dwellings with exceptionally high radon. As the method employs electrochemical etching of alpha-tracks at a certain depth beneath the disk surface, saturation at high track density might occur. To overcome this problem and to expand the useful range of the method towards high radon concentrations several approaches are possible which, however, introduce new sources of uncertainty. In this report we explore how the depth at which the alpha-tracks are etched and the voltage applied for electrochemical etching can be simultaneously varied, in order to measure high radon concentrations and to achieve the best uncertainty. As a result optimized regimes for etching CDs/DVDs are proposed and the expanded range of the method evaluated.

A Comparative study of indoor radon contributed by diffusive and advective transport through concrete

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The indoor radon entry through floor is a complex phenomenon. Two possible mechanisms to understand the indoor radon entry are diffusion and advection. The present work is aimed to answer that out of diffusive and advective transport, which is dominant process for indoor radon entry under normal room conditions. For this purpose the radon diffusion coefficient and permeability of concrete were measured by specially designed experimental set up. The leakage test of the experiment set was performed to ascertain the accuracy of measurement. The radon diffusion coefficient of concrete was measured by scintillation radon monitor. The radon diffusion coefficient through concrete was found to be $(3.78\pm0.39)\times10^{-8}$ m²/s and independent of the radon gas concentration. The radon permeability of concrete varied between 1.85×10^{-17} to 1.36×10^{-15} m² for the bulk pressure difference fewer than 20 Pa to 73.3 kPa. To find the absolute permeability of concrete at low pressure (normal room condition), a Klinkenberg curve was plotted. From the measured diffusion coefficient and absolute permeability, the radon flux from the concrete surface having concentrations gradient 16 kBq/m³ and typical floor thickness 0.1 m was calculated by the application of Fick and Darcy laws. Using the measured flux attributable to diffusive and advective transport, the indoor radon concentration for a typical Indian model room having dimension $(5 \times 6 \times 7)$ m³ was calculated under average room ventilation (0.63 h⁻¹). The results showed that the contribution of diffusive transport through concrete is dominant over the advective transport.

Synthesis and Characterization of Conducting Polymers as a radiation sensor

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Continued exposure to radiation has become a menace and needs immediate necessity of, robust, cost effective and reliable sensors for monitoring at work place and ambient air quality. Presently a few sensors for neutron and gamma radiation monitoring are available in the market with active and passive mode. The search for novel and superior materials, which are capable to sense the neutron and gamma radiations, and hence subsequently possess characteristics property to discriminate these radiations, is of immediate concern. Metal conducting polymer composites (MCPCs) is treated as active material and have widen their scopes in many fields like, organic light emitting diode, energy storage devices, microelectronics, photovoltaic cells and organic field effect transistor etc. Therefore, the use of MCPCs can also play an active role in sensing applications. Conducting polymer, Polyaniline (PANI) doped with nano particles such as Gold and Silver are synthesized using by electrochemical route. Various process parameters viz; deposition time, monomer and supporting electrolyte concentration, current density, potential window and scan rate, are optimised during synthesis process. Electrochemical synthesis in general leads to growth of nanoparticles with different sizes and there is always a definite size distribution. For very controlled reactions, size distribution of nanoparticles is narrower but for metal-polymer nanocomposite systems the size distribution is always slightly broader as the polymer matrix also grows simultaneously and it hinders homogeneous growth. Various characterization techniques are used to have structural, chemical and morphological investigation of MCPCs. Scanning Electron Microscope (SEM) micrographs exposed good fibrous structure with different size and uniform distribution of gold metal particles (Au) over the surface of PANI conducting polymer matrix. The EDX measurement is performed in a complete area of square millimetre range to ensure the uniform distribution of metal nano-particles. The MCPCs are also subjected to irradiated process and subsequent characterisation are performed to study the changes occurred after irradiated. After irradiation the current-voltage (I-V) characteristics measurement shows the change in conductivity. X-ray diffraction (XRD) study also reveals the changes in parameters indicating modifications in functional properties in MCPCs after irradiation. Raman spectroscopy indicates the formation of conjugated structures in MCPCs after irradiation indicating the occurrence of SP2 hybridisation.

The fabrication of metal polymer composite and modification in their functional properties after irradiation indicates these composites to be feasible to be used as radiation sensors.

Radon-Thoron and their Progeny Measurements in Multi-Storeyed Malls in District Faridabad, Haryana (India)

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Radon is the first and only gaseous and inert element of the radioactive chain and it contributes more than 50 percent of total dose to human population from natural sources of radiation. It is the second most leading cause of lung cancer after smoking. Radon gas is heavier than air, and therefore it is not normally a problem in the upper storey of buildings but in the basement due to less ventilation radon monitoring is necessary. In the present study seasonal variation of the activity of radon, thoron and Potential Alpha Energy Concentration (PAEC) and annual effective dose has been calculated in multistoreyed malls situated in Faridabad, Haryana (India). The measurements were carried out using LR-115 (type-II) Solid State Nuclear Track Detectors. The value of radon activity and PAEC due to radon varied from 5.08±0.33 Bq/m³ to 38.42±1.46 Bq/m³ in summer (April to July), 13.68±0.45 Bq/m³ to 87.97±1.79 Bq/m³ in winter (October to January) and 0.55±0.03 mWL to 4.15±0.15 mWL in summer (April to July), 1.47±0.04 mWL to 9.51±0.19 mWL in winter (October to January) respectively from top floor to basement of malls. The value of thoron activity and PAEC due to thoron varied from 3.01±0.21 Bq/m3 to 18.31±1.22 Bq/m3 in summer (April to July), 7.66±0.89 Bq/m³ to 35.03±2.18 Bq/m³ in winter (October to January) and 0.08±0.01 mWL to 0.49±0.03 mWL in summer (April to July), 0.20±0.02 mWL to 0.94±0.05 mWL in winter (October to January) from top floor to basement. The annual exposure and annual effective dose due to radon, thoron and their progenies varied from 0.03 WLM to 0.19 WLM in summer (April to July), 0.07 WLM to 0.43 WLM in winter (October to January) and 0.10 mSv to 0.72 mSv in summer (April to July), 0.26 mSv to 1.62 mSv in winter (October to January) respectively from top floor to basement. Due to poor ventilation in basement of malls the annual effective dose is high as compare to upper floors where proper ventilation is provided.

Keywords: radon, thoron, progeny, multi-storeyed mall

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Negative Correlation between Radon and Lung Cancer: A Possibility of Radiation Hormesis

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It is reported that radon is the second leading cause of lung cancer after smoking and through various epidemiological studies, researches and investigations, it is established that exposure to ²²²Rn in mines has caused excess lung cancer in several group of miners. Substantial controversy, however, exists regarding the health effects of exposure to alpha radiation emitted from radon in dwellings and general environment. The exposure response to miners is generally linear (Lubin et al. 1997). Notwithstanding this, there are several epidemiological and experimental evidences where average radon levels are high, and in all of these cases lung cancer rates are well below average i.e., there is a negative correlation between radon level and lung cancer (Cohen 1995 and 1997).

In this paper, a comprehensive study and critical analysis of the available literature, data and reports has been carried out so as to reach some definite conclusion. As a support to the findings that a negative correlation between radon level and lung cancer exists, the results of a limited study of radon levels and lung cancer incidences in Haryana are also presented. The radon levels were measures in the entire state using LR-115 Type II plastic track detectors and the cancer data was collected from the Medical College at Rohtak, in Haryana.

Keywords: Radon; Lung cancer; Hormesis, Health

Use of CR-39 with different sizes for detecting Rn-222 progeny inside unventilated or poorly ventilated indoor environments

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Radon activity in indoor environments has been intensively studied in the last four decades, probably because it is the main natural contamination to which man is subjected. It is well known that radon daughters are in fact the true contaminants. However, there is not yet a robust and accepted methodology for passive measuring radon progeny activity in the air. Sets of CR-39 nuclear track detectors of different sizes were exposed in poor ventilated indoor environments, far from any material surfaces. The exposures occurred in two steps: sets with 6 detectors were exposed during 7 months in 14 environments, and sets with 10 detectors were again exposed during approximately 5 months in 3 of these same places. It was observed that track density was as greater as smaller was the detector's size. Alpha particle track densities were fitted against an equation deduced based on the assumption that the behavior of radon progeny in the air was described by Fick's Law, i.e., the main transport mechanism of these particles was diffusion. It was also considered the deposition phenomenon (plate-out) of radon progeny (free or attached to aerosols) on environmental surfaces, including the detector themselves. Radon activity in the air was determined independently by NRPB/SSI monitor technique. The resulting equation for the track density was fitted to the experimental track densities measured on each exposed set of detectors. It was observed, indeed, that in most of the poor ventilated environments the Fick's law was valid under c2 test, which means that radon and its progeny would be in equilibrium of activities. If, confirmed with more experimental data, these results are important for two reasons: i) because results of simultaneous measures of radon and progeny for long term expositions are rare, and ii) because poorly ventilated indoor environments are commonly used all over the world. However, these fittings quantification needs improvement, both regarding statistical tests and computer simulations.

Radon and Gas Geochemistry of Ground Water in the Ilan Plain, Northeast Taiwan

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Ilan Plain is located at the northeast Taiwan and has been tectonically spreading due to the westward back-arc rifting of the Okinawa Trough. In previous studies, geological survey, geophysical research, and stratigraphic correlation were conducted to rebuild the aquifer systems in the Ilan Plain. However, few gas geochemical data of ground water are available. In this study, it is first time to systematically analyze the gas geochemistry, including Rn, of ground water from 37 wells to recognize the gas sources/components in the Ilan Plain. Water samples can be classified as three main groups, most samples are classified as sulfate and bicarbonate groups, few samples belong to chloride group due to the contamination of sea water. Based on the major dissolved gases compositions, the ground water samples can be divided into two groups, i.e., CH₄-enriched group and N₂ enriched group. Ten out of total 37 wells show CH₄-enriched affinities with CH₄ proportions of 30-50%, in which three wells exhibit very high CH₄ contents, up to 70-90%. Two of the CH₄-enriched wells are located in the northwest, and the remains are in the southeast of Ilan Plain. The dissolved radon concentrations are in the range of 800-10000 Bq/m³ in the studied area. It is interesting to note that the radon actives are higher in the west mountain areas and gradually decreasing toward the east coast areas. Meanwhile, the oxidation-reduction potential and dissolved oxygen data show positive correlations with the radon actives. It implies that the recharge of the ground water in the Ilan Plain may be from the Hsuehshan Range in west. Furthermore, elevated helium isotopic results suggest that mantle component may play an important role for the gas sources in the southeast and center of the Ilan Plain, where may be corresponding to the extensional structure or the suspected faults in the Ilan Plain.

JP-17

Techniques for radon in soil gas measurements by absorption in polycarbonates

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This work explores two approaches for measurement of radon-in-soil-gas by absorption in polycarbonates (PC). The first approach is a straightforward application of the compact disk method for radon measurements: compact disks (CDs or DVDs) are exposed to radon-in-soil-gas and the radon activity concentration is determined by chemical pre-etching, electrochemical etching (ECE) and automatic counting of the ECE tracks at 80 microns below the CD surface. The second approach is new and is based on liquid scintillation (LS) counting of polycarbonates. In this approach 15 g PC pellets are exposed to radon-in-soil-gas and after the exposure the pellets are placed in LS vials and measured by LS counting. The radon activity concentration during the exposure is estimated from the measured activity absorbed in the PC pellets using the known radon absorption properties of the PC material. Reference measurements with diffusion chambers with Kodak Pathe LR II SSNTDs were performed in each measurement point. More than 110 radon-in-soil-gas measurements were performed in 6 different terrains. It is found that the measurements by ECE of compact discs and LS counting of PC are consistent with the reference measurements by diffusion chambers. Very good linear correlations between the three techniques are observed. The results from this study demonstrate the applicability of the CD method for radon-in-soil gas measurements and show that the LS counting of PC is suitable when fast, screening radon-in-soil gas measurements are necessary in a large number of points.

Effectiveness analysis of filters used with radon detectors under extreme environmental conditions for indoor/outdoor long-term exposures.

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A previous study on long-term exposed nuclear track detectors showed that the use of plastic filters to protect radon detectors measuring in high humid environments should be considered. Active and passive detectors, used as continuous monitors and integrating devises respectively, were exposed with different filter configurations at the INTE radon chamber controlled conditions. In this work we present all the results of those exposures and the delay time of the radon diffusion through each filter. Additionally, some of the studied filter/detector configurations were used to measure radon in several workplaces and outdoor sites under real extreme environmental conditions (i.e. humidity, acidity, dust ...) for 3-4 months. The exposure locations were: i) a small spa, located in the north-eastern Spain, where measurements were performed in humid and hot rooms; ii) at Peniscola marsh, a wetland with a high humid environment, where outdoor air at 1 m from soil were measured at several sites; and iii) a production plant of dicalcium phosphate, located in the north-eastern Spain, where indoor and outdoor air present a very high dust content and even acid environment in some outdoor points. Mean radon levels obtained with passive detectors in the spa were [89 - 222] Bq m⁻³, and punctual and continuous measurements by active detectors showed a wide range of radon levels, up to 1.7 ± 0.1 kBq m⁻³. Outdoor mean radon levels obtained at Peniscola marsh were [36 - 43] Bq m⁻³, and outdoor and indoor radon levels at the dicalcium phosphate production plant present a wide range of values, up to 68 ± 24 Bq m⁻³ obtained were phosphate rock is unloaded, and up to 760 ± 98 Bq m⁻³ in galleries where it is transported before treatment. Analysis of detectors exposed in locations with the most extreme environmental conditions showed that some parts of detector were partially degraded, so used filters seem not to be protective enough for long-term exposures.

Annual Effective Dose due to Radon, Thoron and their Progeny in dwellings of Aligarh City, and around Thermal Power Station in Aligarh District, U.P., India

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The radon and thoron measurements in dwellings impart useful knowledge regarding the radiological risk to human population, which arises mainly due to their radioactive decay products. The present study was conducted to measure integrated radon and thoron concentration levels in dwellings in the city of Aligarh and around the thermal power station situated in Aligarh District. Solid State Nuclear Track Detectors (LR-115, TYPE-II) based twin cup dosimeters were used for this purpose. Radon and thoron progeny concentration levels in terms of Potential Alpha Energy Concentrations (PAECs) and annual effective dose received by the inhabitants in studied dwellings were calculated from observed values of radon and thoron gas concentration in Aligarh city were found to be 30.3 Bqm^{-3} (SD = 10.6) and 10.2 Bqm^{-3} (SD = 6.1) respectively and around thermal power station 23.6 Bqm⁻³ (SD = 5.2) and 7.7 Bqm⁻³ (SD = 1.9) respectively. The mean value of radon and thoron progeny concentration were 3.3 mWL (SD=1.1) and 1.1 mWL (SD= 0.7) respectively, in Aligarh city and 2.6 mWL (SD=0.6) and 0.8 mWL (SD= 0.2) around thermal power station. The average value of annual effective dose in studied dwellings was found to be 0.9 mSv (SD= 0.3) in Aligarh city and 0.7 mSv (SD= 0.2) around thermal power station.

Keywords: SSNTDs; Radon; Thoron; Twin Cup Dosimeter; Annual effective dose.

Radon Diffusion Studies through Building Construction Materials: Effect of compaction

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The exposure of human beings to radiation from natural and man-made sources is a continuing and inescapable feature of life. Ionizing radiations are harmful to human beings and hence mankind must be protected from unnecessary or excessive exposure. Natural sources of exposures are due to sources of extra-terrestrial, terrestrial origin, ingestion and inhalation processes. Radon (²²²Rn) has been identified as the largest single source of radiation exposure to world population. As some of the radon daughters are isotopes of polonium which are predominantly alpha-emitting radionuclides with energy above 5 MeV, the relatively high biological effectiveness of these radiation has to be taken into account. Radon generation, transport, entry and accumulation indoors depend on a lot of parameters most of which are time-dependent. Diffusion of radon, driven by concentration gradient, is most significant in the gas phase.

In the present study, soil, cement and fly ash samples were compressed at different pressures to observe the effect of compaction on radon diffusion coefficient and diffusion length through these building materials. The effect of compaction on radon diffusion through building construction materials, has been studied using steel pipes of diameter 4.3 cm and length 25 cm clamped vertically. The building construction materials under study in the pulverized form was filled inside steel pipes and then compressed at different pressures (33.7 10^3 N m⁻² to 135 10^3 N m⁻²) to observe the effect of compaction on radon diffusion coefficients and diffusion lengths. Then steel pipes carrying compressed material were fixed to a radon chamber with a latex membrane in between the compressed material and radon source. A piece of LR-115, type-II plastic track detector was fixed at the top of each steel pipe such that sensitive side of the detector always faced the source. After 30 days interval, the detectors were retrieved, processed, and the α -tracks counted for the calculation of radon concentration. It is observed that the radon diffusion coefficient decreases with the increase in compaction of building materials.

Keywords: Radon diffusion, compaction, fly ash, soil, LR-115.

A Study of Indoor radon, Thoron Progeny Levels in Some Dwellings by Using SSNTD

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Radon and its progeny are the main contributors in the radiation dose received by general population. Solid State Nuclear Track Detectors (SSNTD) are widely used for the measurements of indoor radon and thoron levels. They are the most effective passive detectors available to obtain time integrated levels of radon, thoron and their progenies. Results of the measurement of indoor radon / thoron concentrations and their progeny levels in different types of R.C.C. (Reinforced Cement Concrete) dwellings in and around Numaligarh Refinery of Assam, India, for a one complete year in four seasons are presented in this paper. The measurements were carried out by using LR-115 (TypeII) detectors in plastic twin chamber dosimeters (BARC type). The estimated indoor radon and thoron levels varied from 93.57 Bq. m⁻³ to 126.01 Bq.m⁻³ and 23.80 Bq.m⁻³ to 58.70 Bq.m⁻³ with mean values 111.96 Bq.m⁻³ and 37.55 Bq.m⁻³ respectively. The estimated indoor radon and thoron progeny levels varied from 0.34 mWL to 0.47 mWL and 0.04 mWL to 0.09 mWL with mean values 0.40 mWL and 0.06 mWL respectively. The estimated inhalation dose received by the inhabitants of the study area varied from 0.23 μ Svh⁻¹ to 0.61 μ Svh⁻¹

Keywords: Radon, Thoron, Dwellings, LR-115

An investigation of ²²⁶Ra ²³²Th and ⁴⁰K, radon exhalation and radiation doses in coal and flyash samples of coal based Thermal Power Plants

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Coal is one of the important sources used for power generation. Its combustion part known as fly ash is used in the manufacturing of bricks, sheets, cement, land filling etc. Due to its small size and hence large surface area, the ash has a greater tendency to absorb trace elements. Coal and its by-products often contain significant amounts of radionuclides, including uranium which is the ultimate source of the radioactive radon gas. Combustion of coal enhances the natural radiation in the vicinity of the thermal power plant through the release of the radionuclide's and their daughters in the surrounding ecosystem. In the present study, radon exhalation rates in coal and fly ash samples from the Badarpur Thermal Power Plant, New Delhi, India has been measured using sealed Can Technique having Solid State Nuclear Track Detector (LR-115 type-II). The activity concentrations of ²²⁶Ra, ²³²Th, and ⁴⁰K are also measured the same samples. Radon exhalation varies from 0.78 mBq/Kg/h to 2.88 mBq/Kg/h. A new active technique, smart radon monitor (SRM) based on scintillation cell based is also used for measurement of radon exhalation rate. Thoron exhalation rate is measured using Smart Thoron Monitor (STM). Thoron surface exhalation rate measured by Scintillation based Thoron Monitor for coal and flyash samples of Badarpur Thermal Power Plant, New Delhi, India is varied from $327.84 \text{ Bg/m}^2/\text{h}$ to $874.24 \text{ Bg/m}^2/\text{h}$. Similarly, the radon mass exhalation rate measured by active technique (SRM) varied from 14.06 mBq/Kg/h to 118.08 mBq/Kg/h for the samples collected from Badarpur Thermal Power Plant, New Delhi, India .Natural radioactivity is measured by an NaI(Tl) detector of size 2.5×2.5 inches with a multichannel analyser (MCA). Radioactivity ranges from 19.33 Bq kg⁻¹ to 48.56 Bq kg⁻¹ for 238U, 18.89 Bq kg⁻¹ to 87.60 Bq kg⁻¹ for 232 Th and 419.20 Bq kg⁻¹ to 695.00 Bq kg⁻¹ for 40 K. The absorbed gamma doses (D) in air due to naturally occurring radionuclide's in the coal and flyash sample varied from 44.95 to 102.36 nGyh-1.The annual effective dose (De) varies from 0.055 to 0.125 mSvy⁻¹.Measured value of radium equivalent activity (Raeq) of sample from the area range from 92.60 to 175.96 Bq kg⁻¹. The value of internal hazards index (HIn) and external hazards index (Hex) varies from 0.31 to 0.70 and 0.25 to 0.59 respectively. Radiation hazard index (representative level index) Ivr varies from 0.40 to 1.21 Bq kg⁻¹. It is observed that the radon exhalation rate from fly ash samples from is higher than from coal samples. It is observed that activity concentration of radionuclide's in fly ash is enhanced after the combustion of coal. The results will be discussed during presentation.

Study of indoor radon, thoron in dwelling of Delhi, India using double dosimeter cups with SSNTDS

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The radon gas can migrate into the atmosphere from the ground through cracks and fissures via diffusion, fluid convection etc. transport mechanism.Inhalation of radon and its daughter products can cause a significant health hazard when they are present in enhanced levels. A relationship between lung cancer and inhalation of radon and its decay products has been demonstrated. So, monitoring of radon and thoron in dwellings is important from the point of view of radiation hygienic.

Solid State Nuclear Track Detectors (SSNTDS)based double dosimeter cup were used for estimating radon (²²²Rn) and thoron(²²⁰Rn) gases in dwelling of sector-16 Dwarka,Delhi region in India, The dosimeters employ two LR-115 type-II peliculable, cellulose nitrate detector films inside each of two chambers fitted with filter and polymeric membrane for the discrimination of radon and thoron gas. Etched tracks in the exposed detectors were counted by spark counting system. Radon concentrations vary from 4.4 to 29.82 Bqm⁻³ whereas Thoron concentrations vary from 2.77 to 13.63 Bqm⁻³. The annual effective dose from radon-thoron were found to vary from 0.18 to 0.94 mSvy⁻¹. Results will be disscused in the light of various cooments.

Study of natural radioactivity, radon exhalation rate and radiation doses in coal and flyash samples from Rajghat Thermal Power Station, Delhi, India

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Radiation hazard from airborne emissions of coal-fired power plants have been cited as possible causes of health, environmental, and technological problems associated with the use of coal. Some trace elements in coal are naturally radioactive. These radioactive elements include uranium (U), thorium (Th), and their numerous decay products, including radium (Ra) and radon (Rn). Assessment of the radiation exposure from coal burning is critically dependent on the concentration of radioactive elements in coal and in the fly ash that remains after combustion. Radon exhalation is important for the estimation of radiation risk from various materials. Solis State Nuclear Track Detector (SSNTD) based Sealed Can Technique was used for measure radon exhalation rate. Radon exhalation rate vary from 0.44 mBq/Kg/h to 2.34 mBq/Kg/h for coal and flyash samples collected from Raighat Thermal Power Station, Delhi, A new active technique smart radon monitor (SRM) based on scintillation cell is also used for measurement of radon exhalation rate. Thoron exhalation rate is measured using Smart Thoron Monitor (STM). Radon mass exhalation rate measured by active technique (SRM) varied from 15.00 mBq/Kg/h to168.07 mBq/Kg/h for the samples collected from Rajghat Thermal Power Station, Delhi. Similarly, thoron surface exhalation rate measured by Scintillation based Thoron Monitor (STM) for coal and flyashsamples of Rajghat Thermal Power Station, Delhi is varied from 176.0 Bg/m²/h to781.1 Bg/m²/h.Natural radioactivity is measured by an NaI (Tl) detector of size 2.5×2.5 inches with a multichannel analyser (MCA). Radioactivity ranges from 23.72 Bq kg⁻¹ to 46.80 Bq kg⁻¹ for ²³⁸U, 14.05 Bq kg⁻¹ to 58.74 Bq kg⁻¹ for ²³²Th and 487.54 Bq kg⁻¹ to 929.46 Bq kg⁻¹ for ⁴⁰K. The absorbed gamma doses (D) in air due to naturally occurring radionuclide's in samples varied from 46.55 to 75.85 nGyh⁻¹. The annual effective dose (De) varies from 0.057 to 0.093 mSvy⁻¹. Measured value of radium equivalent activity (Raeq) of sample collected from the area range from 95.23 to 137.72 Bq kg⁻¹. The value of internal hazards index (HIn) and external hazards index (Hex) varies from 0.25 to 0.43 and 0.32 to 0.56 respectively. Radiation hazard index (representative level index) Ivr varies from 0.39 to 0.91 Bq kg⁻¹. The detailed results will be discussed during presentation.

The Effect of Grain Size on Radon Exhalation Rate in Natural-dust and Stone-dust Samples

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Radiation dose to human population due to inhalation of radon and its progeny contributes more than 50% of the total dose from the natural sources. Inhalation of Radon and its progeny are the leading cause of lung cancer, so it is very important to measure radon exhalation rate in building construction materials. In the present study we have measured the variation of exhalation rate of radon with varying grain size of stone dust and natural dust. The samples under study were first crushed, grinded, dried and then passed through sieves with different pore sizes to get various grain sizes (µm) (i.e. ≤ 300 and ≥ 150 , ≤ 600 and ≥ 300 , and ≥ 600 of natural dust and ≤ 150 and \geq 75µm, \leq 300 and \geq 150, \leq 600 and \geq 300, and \geq 600 of stone dust). The measurement of radon concentration and exhalation rates were carried out using LR-115 type-II alpha sensitive plastic track detectors employed in canister technique. The measured values of radon mass exhalation rate varied from 6.66-42.12 mBgkg⁻¹hr⁻¹ with an average value 23.45±7.6 for stone dust $3.26-54.60 \text{ mBgm}^{-2} \text{ hr}^{-1}$ with an average value 28.93 ± 9.0 for natural dust and value of radon surface exhalation rate varied from 152-384 mBgm⁻² hr⁻¹ with an average value 279 \pm 42 for stone dust,119-522 mBqm⁻² hr⁻¹ with an average value 309±67 for natural dust. The exhalation rate was found to be increasing with the decrease in grain size due to surface sorption. The obtained values of radon exhalation rate for all the samples are found to be under the radon exhalation rate limit reposted worldwide.

Keywords: Radon concentration, Radon exhalation rate, grain size, stone dust, natural dust.

Radon Chamber Designed for Studying the Behaviour of Radon and its Progeny using the Surface Barrier Detector

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Radon chamber is a basic need for a radiation laboratory involved in research related to radon. It is said that the health hazard is not from the radon but of its short lived alpha emitting progeny ²¹⁸Po and ²¹⁴Po; as they formed they stick to the surfaces of bronchial tissues solid and la. To study the behavior of radon and its progenies a controlled environment cannot be provided other than a radon chamber. For the said purpose a radon chamber was fabricated in the CIIT, Radiation Physics Laboratory (RPL). Well characterized uranium ore (²²⁶Ra activity concentration of 41.14±0.04 kBq/kg) was used as a source of radon. Radon and its progeny were studied in the exposure chamber by using a surface barrier detector (SBD). It was found that the ratio of ²¹⁸Po and ²¹⁴Po counts approaches to one as time elapses. The experimentally determined behaviour of radon and its progeny was found between the experimental and theoretical results.

Radon doses in the indoor environments of Murree and Islamabad: A comparison of active and passive techniques

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To study the radiological impact of indoor radon levels in different seasons on population residing at different altitudes, air samples were collected from Islamabad (Alt. 1760 ft.) and Murree (Alt.7323 ft.) areas. Radon concentrations are measured using active technique by taking in-situ measurements on RAD-7, solid state α -detector and passive technique by taking time integrated measurements on CR-39 detector, in winter, spring, summer and autumn. The results of both techniques are analyzed and compared. The suitability of active technique is discussed. The measurements on both techniques lead to annual mean effective doses 1.83 and 1.20 mSva⁻¹, to the inhabitants of respective regions. The results show that populations residing on higher altitude received comparatively less doses. The estimated levels are also compared with the recommended limits and found safe.

Keywords: Active and passive techniques; Seasonal variation; altitude levels, Radon Concentration; Annual effective Dose; Health Hazards.

Towards an in-vivo chemical dosimeter for hadron therapy based on fluorescent probes

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Among the means used in the treatment of cancer, radiation therapy is recognized as a successful method, and is widely represented in hospitals worldwide. In most cases, it consists in photon irradiation (X-Ray, gamma). However, some tumors exhibit radio-resistance against such radiations, which is one of the most important limitations of the method. Luckily, these tumors are often sensible to high energy ions. Moreover, ions allow much localized energy deposition, concentrated essentially in the Bragg peak, preserving the healthy tissues. This explains the development of hadron therapy.

To gain in efficiency, an interesting development is to adapt the radiotherapy in real-time to the way the tumor reacts to the irradiation. To do so, one should be able to monitor directly in the tumor the energy deposited. Our team is part of a project aimed at using fluorescent molecular probes to monitor the radiation chemistry in living cells under ions irradiation, which could also be used as chemical dosimeter (SIRMIO project). In this project our team studies the kinetics and the chemical yields of reaction of these probes with primary species formed by water radiolysis induced by alpha-particles and protons in the Bragg peak region (with initial energies ranging from 1 to 3 MeV).

The probe chosen for the quantification of hydroxyl radical is the 3-Carboxylic acid coumarin (3CCA). Under irradiation, 3CCA is known to react with hydroxyl radical to yield 7 hydroxy-3-carboxylic acid coumarin (7OH-CCA), which is highly fluorescent (1, 2). This allows very sensible estimation of the OH' radiolytic yield by fluorescence measurement of the 7OH CCA formed after irradiation. The time after which a radical reacts with the probe is linked to concentration of this latter. Thus, knowing the kinetic constant of the reaction, one can reconstruct the species time-dependent formation yield by varying the probe concentration.

For this study, we have worked on the 4 MV Van de Graaff accelerator of Icube, in Strasbourg, France. In order to estimate the yields of production of hydroxyl radical in solution under relatively low-energy ions, the particles were extracted from vacuum using a 200 nm thick silicon-nitride window, which allows minimal energy loss.

In this communication, the experimental setup will be presented, as well as the results obtained with protons and alpha particles, their comparison with literature (3, 4) and with modeling based on the ion track structure in liquid water (5).

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Study on radiation-induced damage of DNAs using an oligonucleotide with fluorescence modification.

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We have been developing a direct measurement method to verify radiation damage on the bio-material employing an oligonucleotide with fluorescence modification. The fluorescence modified oligonucleotide has a fluorescence site (6-FAM) and quenching site (TAMRA) on both terminals.

The optical energy deposited to the fluorescence modified site is transferred to the quenching site, and is released as optical energy of the longer wavelength. Fluorescence is inhibited even when excitation light is applied. This energy transfer is known as IEET (Intramolecular excitation energy transfer). Once there is breakage on the oligonucleotide by radiation, fluorescence will be emitted because of loss of inhibiting effect. Thus, radiation damage on the biomolecule can be detected with fluorescence spectrophotometer.

We synthesized fluorescence modified 27 mer oligonucleotide. The fluorescence modified 27 mer oligonucleotide sequence was 5' - 6-FAM - TCATCCTAGTCCTGTTGCTGCCAAGCT - TAMRA - 3', which corresponds to the region of the yeast gene. The 6-FAM (6-Carboxyfluorescein) and the TAMRA (Carboxytetramethylrhodamine) were adopted as a fluorescence and quenching material. The optimum excitation wavelength of the 6-FAM is 494 nm, and a fluorescence wavelength is 514 nm. The samples were dissolved in TE (Tris-EDTA) buffer to 100 nM, and put into a 1.5 ml shading tube to prevent degradation of fluorescence. The TE buffer solution was composed of 10 mM Tris, 1 mM EDTA. The volume of 1 sample is prepared to be 1.0 ml. The samples were irradiated with heavy ion beams and ⁶⁰Co gamma-rays. Fluorescence was measured using the F-2700 Fluorescence Spectrophotometer (HITACHI, Japan). The fluorescence intensity was verified at the optimum wavelengths of the 6-FAM.

In a present study, we found that the fluorescence intensities are increased as a function of absorbed dose up to around 100 mGy, and seems to saturate at higher absorbed dose region. These results suggest that the fluorescence-modified oligonucleotide is applicable to radiation dose evaluation technique. In addition, since its oligonucleotide sequence can be designed and synthesized to double strand structure, and the fluorescence and quenching sites can be selected to others. These flexibilities of this method might also be a strong point to the basic study for

radiation induced DNA strand breaks.

Applications of nuclear track membranes to filtration of medical injections and various transfusions to remove solid particles

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Nuclear track membranes produced by China Institute of Atomic Energy (CIAE) in Beijing, China, and the Joint Institute for Nuclear Research (JINR) in Dubna, Russia have been used in the studies of filtration of medical injections and various transfusion liquid medicine to remove solid particles from the medicine. It shows that the filtration devices made of nuclear track membranes are superior to that made of any other types of membranes. Experiments have demonstrated that the removal efficiencies for solid particles with diameters 5 μ m can reach over 95% and the flow rate is high enough for use in medical injection and transfusion. The reproducibility of removal efficiencies and flow rate of the new devices are satisfactory to the use in hospitals. Chinese authority in medicine has approved the new devices for use in Chinese hospitals. Similar type of filtration devices are being developed for removal of solid particles with sizes 3.0 and 2.0 μ m and less.

Nuclear track membranes are unique materials in medical sciences for their regular shape of pores, single pore size in each membrane, and its surface interception feature which makes easy to analyze the properties of the solid particles, such as cancer cells, glass shards, or rubber powder from breaking of the glass container or rubber cover.

Keywords: Nuclear track membranes; Filtration of medical injections and transfusions; Removal efficiency of solid particles from transfusions; Flow rate of liquid medicine through track filters; Application of track membranes.

Distribution of radioactivity in fuel-containing materials (Chernobyl "lava")and aerosols from the Chernobyl "Shelter" using combination of CR-39 etching technique and Imaging Plate radiography

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The major part (about 95%) of radioactivity of the former 4th Unit of Chernobyl NPP is located inside the confinement building "Shelter" and it is mainly concentrated in lava-like fuel-containing materials ("lava"). The lava consist of U-containing silicate glass matrix with inclusions of high-uranium zircon crystals, molten stainless steel particles and uranium oxide dendrites and grains. The lava is weathered both by self-irradiation and interaction with air and water. Surface disintegration of lava, oxidizing of U (IV) to U (VI), formation of secondary uranium minerals has been previously studied. Prediction of lava's destruction rate is based on different assumptions and heterogeneity of radioactive particles distribution plays an important role. Most likely, the activity of lava is mainly related to UOx inclusions. In some premises of "Shelter" the amount of radioactive aerosol particles increases over time due to remobilization of wet dust during drying of the concrete walls and as a result of the lava disintegration.

Aerosol samples and lava fragments were collected from the confinement building "Shelter" of Chernobyl NPP in the places of the reactor basement (at the level 0,0) and above at the level 6,0 m. Alpha-track analysis using CR-39 track detector along with computed radiography with Imaging Plates (Cyclone Plus Storage Phosphor System, PerkinElmer) have been used to analyze micro-distribution of alpha- and beta-emitting nuclides in lava fragment and aerosol particles.

In this study it is shown that alpha-radioactivity along with total radioactivity are homogeneously distributed in the lava fragment in spite of complex phase composition: silicate glass matrix, UOx inclusions, $(Zr,U)SiO_4$ crystals and Fe-Cr-Ni droplets. The determined alpha-activity and size distribution of aerosol particles allows estimating the inhalation dose risks and monitoring the process of lava's disintegration.

Development of fully automated colony counter system for the study of low-dose effects on cellular radiobiology

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Health risks from low-dose radiation has a concern for the potential risks from environmental and clinical radiations, especially after the Fukushima nuclear disaster, even public people has a great interest about the risks of low-dose radiation. Since experimental signal changes are extremely rare on DNA strand breaks and/or cell survivals at low-dose region, in the current situation, experimental data in this region with statistical significance are very difficult to obtain because of the need for large number of samples.

We have been developed a fully automated colony counter system by utilizing the nuclear track detection technologies in order to verify radiation damage on cellular radiobiology such as the cell survival at low-dose region. The system consists of a belt conveyor with microscopic optics, such as light source, lenses and a line sensor camera with sophisticated software. Effectiveness on high speed imaging by line sensor was proved as HSP-1000 microscope for CR-39 track detection in 2005 [1]. In this system, cell colonies on dishes flow on the belt conveyor with speed of about 7cm/sec, in short, one cell culture dish can be imaged within 1 sec with 10x magnifications. After taking image, in the computer memory, colonies on the dish are automatically distinguished as individuals, measured size and locations, counted the number of colonies and stored all the information with image. This analysis was transported from track detection algorisms (PitFit) which has been developed for the measurement of parameters on etch pit opening mouse based on the least-square ellipse fitting calculations.

We demonstrate the performance of the system and show some concept studies on higher statistic cellular radiobiology.

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Mesozoic-Cenozoic exhumation history and paleotopography of the Huangling massif in Central China from apatite fission track and (U-Th)/He data

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Huangling massif, located in the interior of the northern Middle Yangtze, is a key area to reveal the tectonic evolution history of Yangtze block. Apatite fission track and apatite (U-Th)/He data are combined together to research exhumation and paleotopograph of the Huangling massif since Mesozoic. The exhumation rate shows a fluctuation feature. It experiences two rapid exhumation stages from early Cretaceous to Paleocene with average rate at about 0.166mm/a and since Oligocene at around 0.048mm/a. The exhumation rate during Jurassic and late Cretaceous to Oligocene are low, at approximately 0.018mm/a and 0.011mm/a respectively. Based on current topography and integrated isostasy effect and sea level changes, this research gains the 4 different palaeotopographies on late Triassic, early Cretaceous, late Cretaceous and Oligocene respectively. The results show the palaeotopographies of Huangling massif witnessed a continuous downward trend, with the average elevation decline from about 2100m in late Triassic to around 650m at present, including two dramatic exhumation stage. Combine the result with the geological evidence of Yangtze block, we find the first stage during Cretaceous(140-80Ma±) has much relationship with the compression coming from the Qinling-Dabie orogen and the second period from Eocene to present(40~30-0Ma) is the response to Himalayan tectonic movement.

Key words: Fission track; (U-Th)/He; Exhumation; Palaeotopography; Huangling massif

A unique value of ²³⁸U spontaneous fission decay constant supported by fission-track dating with the external detector method: A reply to the 2000 IUPAC recommendation

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In 2000, the International Union of Pure and Applied Chemistry (IUPAC) recommended the evaluated value of (8.5+/-0.1) E-17 /yr for ²³⁸U spontaneous fission decay constant (lambda-f) based on a series of determinations performed since 1950, excluding all results of measurements by solid-state nuclear track detector (SSNTD) method (Holden and Hoffman, 2000). They pointed out the SSNTD methods have had problems, for example, partial fission track fading, poor thermal neutron dosimetry and dating of samples of known age with external detector technique, all of which caused the lower specific activity. To solve this issue, we reviewed the track-counting efficiency problem which affects the geometry factor used for the external detector method (Danhara and Iwano, 2013). Our finding of an unetchable track section at the termination of an etchable track was the breakthrough in this issue. Iwano et al. (1992) proposed a method in which neutron-induced fission tracks in minerals were correlated one-to-one with those in external detectors. With this method, the range deficits in different minerals and their effect on fission track ages determined with the external detector have been evaluated (Iwano and Danhara 1998). For example, we presented new data on the track-counting efficiencies of zircon and diallyl phthalate (DAP) resin. Track-counting efficiency in zircon was about 0.71 times that in DAP, even though the tracks in zircon were isotropically etched. This experiment allows us to deduce a mean unetchable track range (range deficit) of about 2.25 microns at each end of fission tracks in zircon and a latent track length in zircon of ~15.5 microns. In addition, the track-to-track matching data in combination with previous experimental data (Yoshioka et al. 2003), which have shown that the detection efficiency of DAP for fission tracks is 4-5 % higher than that of mica detectors, indicate a range deficit on the order of 0.5 microns in mica. We have finally demonstrated that the track-counting efficiency or geometry factor for the external detector technique is controlled by the range deficits among materials. By taking this effect into account, fission-track dating results of ten zircon standards were agreement with their known ages, which leads us to the further conclusion that 8.5E-17 /yr is the correct value for lambda-f. We stress that the unique lambda-f value of 8.5 E-17 /yr is supported by direct determinations and radiochemical or mass-spectrometric analyses, but also by the SSNTD method including dating of samples of known age with external detector technique.

Detrital zircons from mainland China in the Palawan Continental Terrane

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The Palawan Continental Terrane (PCT), a fragment of the margin of SE China, drifted south as a result of the Cenozoic opening of the South China Sea. This fragment is of great interest as it may contain a record of the early history of the continental margin of SE China that is not exposed on the mainland. The southeastern margin of South China has been considered to have been a passive margin in pre-Jurassic time. The study of detrital zircons from Mindoro Island indicates presence of a late Paleozoic subduction complex which is strong evidence that this complex was formed in the vicinity of SE China.

This study combines the geochronology and Hf-isotope compositions of zircons derived from modern river sediments and meta-sedimentary rocks from various islands of PCT in the Central Philippines. Integration of U-Pb ages and Hf isotope data on zircons has recently become a powerful tool to understand better the crustal evolutionary history (e.g., Griffin et al., 2004; Yu et al., 2010).

Detrital zircons separated from sandstone from northwest Panay, which is part of the PCT (Walia et al., 2013), were analyzed for their U-Pb age. In this sample about 80 % of the grains fall into the age range of 235-282 Ma, which is exactly the same age range observed for detrital zircons in modern sediments draining the NE part of the Mindoro Metamorphics in Mindoro (Knittel et al., 2010). In addition, meta-sediments from Palawan Island, Central Philippines, have given ϵ Hf (t) values which are comparable to those from Cathaysia Block of South China.

Paleoproterozoic zircon ages correspond to a major episode of magmatism in the Wuyishan terrane in SE China (Xu et al., 2007). This would suggest that both, the Mindoro Metamorphics and the oceanic plate, upon which the Saboncogon Formation was deposited, were situated close to the Asian margin in SE China.

An estimation of natural radioactivity and radon exhalation rate in soil samples from some areas of Jharkhand State of India

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The sources of radon in indoor air soil and bedrock beneath a building, building materials and the tap water. If the soil above the bed rock has an enhanced content of ²³⁸U, the soil becomes a potential source of radon gas in the soil air. Jharkhand state of India is rich in minerals and called as store house of minerals. Soil samples were collected from Rajmahal area, famous for coal and quartz mines and some areas around the East Singhbhum shear zone, a U-mining area of Jharkhand.

Activity concentrations of naturally occurring radionuclides (²³⁸U, ²³²Th and ⁴⁰K) were measured in these soil samples using high resolution γ -ray spectroscopic system (Mahur et al., 2008, 2013). Gamma spectrometric measurements were carried out at Inter-University Accelerator Centre, New Delhi using a coaxial n-type HPGe detector (EG&G, ORTEC, Oak Ridge, USA). The detector has a resolution of 2.0 keV at 1332 keV and relative efficiency of 20%. It was placed in 4" shield of lead bricks on all sides to reduce the background radiation from building materials and cosmic rays. Activity concentrations in soil samples of Rajmahal area were found to vary from 755.2 ± 11.9 to 2115.0 ± 65.7 Bq kg⁻¹ with an average value of 1204.4 ± 23.8 Bq kg⁻¹ for ²³⁸U, from 50.1 ±1.5 to 4414.0 ± 74.7 Bq kg⁻¹ with an average value of 2726.6 ± 39.3 Bq kg⁻¹ for ⁴⁰K . Radium equivalent (Raeq) obtained from ²³⁸U, ²³²Th and ⁴⁰K activities varies from 849.9 to 8427.1 BqKg⁻¹; Absorbed gamma dose rates from 405.4 to 3643.2 nGyh⁻¹ and Health hazard index (Hex) from 2.3 to 22.7. Radon exhalation rate was also measured by "Sealed Can technique" using type LR 115-II nuclear track detectors. Radon exhalation rates vary from 3.1 to 7.8 Bqm⁻² h⁻¹.

Soil samples collected from some areas around the East Singhbhum shear zone, radon activity varies from 3794.3 Bqm⁻³ to 4891.4 Bqm⁻³ with an average value of 4368.6 Bqm⁻³ while radon exhalation rate varies from 1364.1 mBqm⁻²h⁻¹ to 1758.6 mBqm⁻²h⁻¹ with an average value of 1573.8

mBqm⁻²h⁻¹. Activity concentrations were found to vary from 6.1 ± 0.2 to 826.3 ± 8.5 Bqkg⁻¹ for ²³⁸U; from 8.7 ± 0.3 to 236.7 ± 3.2 Bqkg⁻¹ for 232Th and 291.5 ± 4.4 to 1391 ± 14.3 Bq kg⁻¹ for ⁴⁰K. The radium equivalent activity (Raeq) varies from 34.0 to 924.5 Bq kg⁻¹ with an average value of 260.4 Bqkg⁻¹. Total absorbed gamma dose rates in the surrounding air are found to vary from 15.1 to 402.0 nGyh⁻¹ with an average value of 120.8 nGyh⁻¹. The values are quit high as compared to the soil from normal region. Results will be disscussed.

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Radon exhaltion rate, natural radioactivity and radiation hazard assessment in Indian cement samples

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Building materials are the main source of radon inside the dwellings. Because of low level of radon emanation from these materials, long term measurements are needed.Radiation doses vary depending upon the concentrations of the natural radio nuclides like ²²⁶Ra, ²³²Th and their daughter products and ⁴⁰K, present in cement samples. These radio nuclides pose exposure risks due to their gamma ray emission and internally due to radon and its progeny that emit alpha particles. In the present study, radon exhalation rate and the activity concentration of ²²⁶Ra, ²³²Th and ⁴⁰K radionuclides in cement samples from Aligarh region (U.P.), India have been measured by "Sealed Can technique" using LR-115 type II detectors and a low level NaI (Tl) based gamma ray spectrometer, respectively (Mahur et al., 2008)..

Radon activities are found to vary from 80.0 ± 12.3 to 320.0 ± 24.7 Bqm⁻³. Surface exhalation rates in these samples vary from 30.6 ± 4.5 to 115.1 ± 8.8 mBqm⁻²h⁻¹, whereas mass exhalation rates vary from 1.2 ± 0.2 to 4.4 ± 0.3 mBqkg⁻¹h⁻¹.

Activity concentrations of naturally occurring radionuclides (226 Ra, 232 Th and 40 K) were also measured in these cements samples. Activity concentrations of 226 Ra, 232 Th, and 40 K vary from 9 ±5 to 28 ± 14 Bq kg⁻¹, 21 ± 13 to 43 ± 15 Bq kg⁻¹ and 280 ± 145 to 573 ± 147 Bq kg⁻¹ respectively. From the activity concentrations of 226 Ra, 232 Th and 40 K, radium equivalent activity (Req) was calculated and found to vary from 58.9 to 109.1 Bq kg⁻¹. Results will be discussed in the light of various factors.

References: Mahur, et al., Nucl. Instr. and Meth. in Physics Research B 266 (2008) 1591-1597.
LP-6

Comparison between fission-track dating determined by LA-ICP-MS and neutron dosimeter through U-doped glass calibrated against U-thin films

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Fission-Track Thermochronology, FTT, is based on ²³⁸U spontaneous fission over the geological time scale. During fission event, fragments are released with high energy, modifying the mineral structure in a cylindrical region along of the fragments path. This modified structure region is known as latent track. The spontaneous fission decay constant, and the total decay constant, are physical constants controlling the accumulation of fission tracks. Uranium concentration is also needed to obtain the fission-track age and it is normally determined by irradiating the unknown age sample, along with a standard uranium-bearing glass, with thermal neutrons in a nuclear reactor. Despite the success of fission-track dating based on neutron irradiation, considerable waiting time for handling the irradiated minerals is necessary. In order to avoid such problem, fission-track community has working to define an appropriate calibration in order to determine U concentration directly through laser ablation inductively coupled plasma mass spectrometer, LA-ICP-MS. Soares et al. (2014) have published one calibration procedure which allows determining the fission-track ages which is independent of the age standard sample. However, before the replacement of nuclear reactor by a LA-ICP-MS, it is important to check if the results in both procedures agree each other when non-ideal samples are dated. Thus, this present work is aimed at comparing fission-track ages in apatite samples using both procedures. For that, Brazilian samples are dated by nuclear reactor and LA-ICP-MS. In order to obtain a better comparison, the uranium concentration is determined by LA-ICP-MS in the same apatite grains which neutron dosimeter was applied.

EPIDOTE STANDARD ETCHING FOR FISSION-TRACK ANALYSIS

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Epidote is a secondary mineral formed in geological faults. Dating this mineral is tool to obtain data about age formation or reactivation of geological faults. This information has a huge importance for the geologic modelling to hydrocarbons prospection. Due to these reasons the Fission Track (FT) community started to investigate this type of mineral. Between 1970 and 1980, several chemical etchings were used. However, no one was accepted as the most appropriate etching to reveal fission tracks in epidote. Some years later, epidote returns to the fore as a potential mineral for Fission Track Termochronology (FTM). The main goal of this work is to determine the most effective chemical etching for epidote through characterization methods. A total of twelve epidote samples were analyzed. From those, five are phenocrystals and seven are grains. Each sample was mounted in epoxi resin, polished and etched with HF and/or NaOH reagents in several experimental conditions. Characterization analyses were performed by using MEV-EDS, micro-Raman Spectroscopy and Optical Microscopy. Due to the fact that some samples do not reveal fission tracks, they were sent to the nuclear reactor with muscovite mica juxtaposed to epidote samples. Irradiation was performed with a nominal thermal neutron fluency of (4.99±0.05)×1015 neutrons/cm2. Firstly, twelve epidote samples were etched for 80 min in 40% HF at 15 °C. From those, just seven revealed fission tracks. Other attempts were done for the samples that not reveal fission tracks, changing various experimental parameters. After several attempts, it was observed that one sample was destroyed during etching, while the others did not reveal fission tracks. Micro-Raman and MEV-EDS measurements were carried out to check the identity of the mineral in the samples that did not reveal fission tracks. The comparison of the results with the spectrum and chemical composition of a standard epidote revealed that all samples are in fact epidotes. To find out why these samples were not revealing fission tracks, they were sent to the nuclear reactor. Analyzing the muscovite mica results, it was observed a low density of induced tracks which is related to a minor quantity of uranium in those samples. Therefore, the meaning of not having found fission tracks is, the low quantity of uranium in epidotes and the samples are geologically young (<30 Ma). After 37 experiments of etching and characterizations for samples that did not revealed fission tracks, it was concluded that the most appropriate etching for epidote fission track is HF 40%, for 80 min at15°C.

MICRO-RAMAN SPECTROSCOPIC AND XRD INVESTIGATION OF BRAZILIAN ZIRCON AT DIFFERENT TEMPERATURES

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Raman analyzes were performed on zircon from a syenite located in the Pocos de Caldas Complex, Brazil, with a Fission Track (FT) zircon age of 81.4 ± 6.2 Ma. Three isochronous heating (1, 10 and 100 hours) of zircon grains were subjected to temperatures between 300 and 750 °C. For each isochronous and temperature, Raman spectra and XRD analyses were accomplished. The results show variations in the intensity and FWHM (full width at half-maximum) in main band (1007 cm-1), and a singular change in the peaks from 356 to 439 cm⁻¹; and from 202 to 224 cm⁻¹. Each change was discussed. XRD results shows a punctual change in the spectra under high temperature conditions. In ambient conditions the spectra not present the CeO₂-X oxide, however after the thermal treatment it is identified. These alterations can be related with i) the start of phase transition of the zircon or with the ii) spectral polarization-dependence related to the annealing radiation damages.

Measurment of Radon exhalation Rate in Sand samples from Gopalpur and Rushikulya beach Orissa, Eastern India

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Natural radioactivity is wide spread in the earth's environment and exists in various geological formations like soils, rocks, water and sand etc. The measurement of activities of naturally occurring radionuclides ²²⁶Ra, ²³²Th and ⁴⁰K is important for the estimation of radiation risk and has been the subject of interest of research scientists all over the world. Building construction materials and soil beneath the house are the main sources of radon inside the dwellings. Radon exhalation rate from building materials like, cement, sand and concrete etc. is a major source of radation to the habitants. In the present studies radon exhalation rates in sand samples collected from Gopalpur and Rushikulya beach placer deposit in Orissa are measured by using "Sealed Can technique" with LR 115-type II nuclear track detectors. In samples from Gopalpur radon activities are found to vary from 371.4 ± 23.0 to 800.0 ± 33.8 Bgm⁻³ with an average value of 549.2 ± 27.8 Bgm⁻³. Surface exhalation rates in these samples are found to vary from 133.4 ± 8.3 to 287.7 ± 12.1 mBgm⁻²h⁻¹with an average value of $197.2 \pm 9.9 \text{ mBqm}^{-2}\text{h}^{-1}$, whereas, mass exhalation rates vary from 5.1 ± 0.3 to $11.1 \pm 0.5 \text{ mBqkg}^{-1}\text{h}^{-1}$ with an average value of $7.6 \pm 0.4 \text{ mBqkg}^{-1}\text{h}^{-1}$. Samples from Rushikulya beach show radon activities varying from 388.5 ± 23.7 to 997.1 ± 37.9 Bgm⁻³ with an average value of 549.2 ± 27.8 Bqm⁻³. Surface exhalation rates in these samples are found to vary from 139.7 ± 8.5 to $358.5 \pm 13.6 \text{ mBgm}^{-2}\text{h}^{-1}$ with an average value of $197.2 \pm 9.9 \text{ mBgm}^{-2}\text{h}^{-1}$, whereas, mass exhalation rates vary from 5.4 \pm 0.3 to 13.8 \pm 0.5 mBqkg⁻¹h⁻¹ with an average value of 7.6 \pm 0.4 mBqkg⁻¹h⁻¹. Results for radon exhalation rates and radon effective dose will be presented.

Study of radon exhalation rates, natural environmental radioactivity and radiation exposure from Indian commercial granites

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Uranium is a radiotoxic element found in trace quantities in almost all naturally occurring materials like soil, rocks, and sand etc. Building materials are derived from these materials and are the main source of radon inside the dwellings. Several varieties of granites are produced and used as flooring materials and as ornamental stones in buildings in India. Commercial type of granites with specific names corresponds to geographical and geological origins and mineral compositions. The natural radioactivity present in rocks having high radiation levels are associated with granites. Measurement of radon exhalation rates for granite samples were carried out through sealed can technique using LR-115 type II detectors. Wide variation in radon exhalation rates is found in the samples. Radon activity is found to vary from 380.0 to 4258.6 Bq m⁻³ with an average value of 1316.2 Bq m⁻³, whereas radon exhalation rate varies from 227.4 to 2548.8m Bq m⁻² h⁻¹ with an value of 854.7 m Bq m⁻² h⁻¹. Activity concentrations of naturally occurring average radionuclides (226 Ra, 232 Th and 40 K) were also measured in these samples using high resolution γ -ray spectroscopic system. Gamma spectrometric measurements were carried out at Inter-University Accelerator Centre, New Delhi using a coaxial n-type HPGe detector (EG&G, ORTEC, Oak Ridge, USA). The detector has a resolution of 2.0 keV at 1332 keV and relative efficiency of 20%. It was placed in 4"shield of lead bricks on all sides to reduce the background radiation from building materials and cosmic rays. From the activity concentrations of ²³⁸U, ²³²Th and ⁴⁰K in the granite samples, Radium equivalent activity (Raeg) varies from 34.6 to 1144.8 Bg kg⁻¹ with an average value of 278.9 Bg kg⁻¹. Total absorbed gamma dose rate varies from 6.0 to 535.6 nGyh⁻¹ with an average value of 132.3 nGy h⁻¹. Indoor and outdoor annual effective dose rate from these granite samples vary from 0.08 to 2.63 mSv y⁻¹ and 0.02 to 0.66 mSv y⁻¹, respectively. External hazard index, Hex for the granite samples studied in this work ranges from 0.09 to 3.16 with a mean value of 0.77.

LP-11

Radon activity, exhalation rate and radiation doses in coal and fly ash samples collected from NTPC Badarpur, Delhi, India

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Coal is a technologically important material used for power generation. The increasing demand for electricity generation for industrial development and human living standards worldwide is met by combustion of fossil fuels. Since coal contains ²²⁶Ra, ²³²Th and ⁴⁰K radionuclide, so it is important to measure the radiation risk to population. Coal and flyash samples were collected from NTPC (National Thermal Power Corporation) situated at Badarpur, Delhi, India.

Fly ash is used in the production of bricks, sheets, cement and also in land filling etc. As the elements in fly ash are concentrated due to combustion of coal in thermal power plants, the knowledge of radionuclides in fly ash plays an important role in health physics.

Radon activities and radon exhalation rates have been measured in coal and fly ash samples collected from NTPC (National Thermal Power Corporation) Badarpur, Delhi, India using "Seald Can Technique", which employs LR-115 type II solid state nuclear tracks detectors. In coal samples radon activity has been found to vary from 505.4 ± 39.0 to 932.1 ± 52.9 Bqm⁻³ with an average value of 687.2 ± 45.2 Bqm⁻³. Surface exhalation rate has been found to vary from 182 ± 14.0 to 336 ± 19.1 mBqm⁻²h⁻¹ with an average value of 248 ± 16.3 mBqm⁻²h⁻¹, whereas mass exhalation rate is found to be vary from 7.0 ± 0.54 to 12.9 ± 0.73 mBq kg⁻¹h⁻¹ with an average value of 9.5 ± 0.62 mBq kg⁻¹h⁻¹. Calculated values of indoor inhalation exposure (radon) effective dose are vary from 13.3 ± 1.02 to 24.5 ± 1.39 μ Sv y⁻¹ with an average value of 18.1 ± 1.18 μ Sv y⁻¹. In flys ash samples radon activity has been found to vary from 400.0 ± 34.7 to 483.9 ± 38.1 Bqm⁻³ with an average value of 447.1 ± 36.6 Bqm⁻³. Surface exhalation rate has been found to vary from 144 ± 12.5 to 174 ± 13.7 m Bq m⁻²h⁻¹ with an average value of 161 ± 13.2 m Bq m⁻²h⁻¹, whereas mass exhalation rate is found to be vary from 5.5 ± 0.5 to 6.7 ± 0.5 mBq kg⁻¹h⁻¹ with an average value of 6.2 ± 0.5 mBqkg⁻¹h⁻¹.

Precise track analysis and application for various radiation fields with high speed microscope and PitFit software

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CR-39 plastic is well-known as most sensitive nuclear track detector for proton and heavy ions. CR-39 is widely utilized for not only dosimetric fields such as personal neutron dosimetry and heavy ion dosimetry, environment radiation monitoring, space radiation dosimetry but also various applications such as the spectroscopy of laser-driven ion beams, high energy cosmic ray physics and nuclear physics. Previously, we have developed a high speed microscope system (HSP-1000) for nuclear track measurement with a line sensor camera in place of a traditional CCD camera [1]. The actual scanning speed including all of procedure such as stage movement, image processing on board and writing out image data to hard disk was typically 6.4 min/cm². The scanning speed limit strongly depends on the brightness of image for taking picture. Recently, the scanning speed has been drastically improved to be 1.1 min/cm² by TDI (time delay integrator) sensor replacing a line sensor. TDI allows to take a high-intensity image by the integration of brightness of lines with two dimensional sensor of 4096×96 pixels. For the high speed image acquisition, the image is continuously and automatically focusing with two line sensors system. On the other hand, the track analysis software (PitFit) has been specifically designed for measuring the parameters of etch pit openings [1]. The edge of etch pit is detected through the image analysis procedure of noise reduction and binarization of the image after setting a greyscale threshold. The track size and its position of center are extracted with an ellipse fitting algorithms. This method can easily make analysis of heavy ion tracks due to the high contrast of etch pit compared with background gray level, while it was difficult to detect shallow tracks with similar gray level as background. Recently, thus kind of shallow tracks such as recoiled proton due to neutron and low LET (liner energy transfer) particles of space radiation are easily and automatically extracted with the differential edge detection algorithm. In this report, we will show the advanced track microscope and track analysis system and the applications for various radiation fields.

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MP-2

New approach of a Nuclear Track counting and analysis system, including software, by Digital Image

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This work presents a novel and simple, digital-image-based system for the counting and analysis of formed nuclear tracks. The system consists of a set of common hardware components - camera, microscope and computer - and a new software program designed specifically for nuclear tracks and related applications.

It is well known that one of the bottlenecks in the methodology of nuclear tracks in solids is the counting of track density. The methodology presented here is based on the analysis of a digital image of the formed tracks. The program measures several track properties, including major and minor diameters, total area, eccentricity and extent of overlap; an algorithm distinguishes genuine tracks from defects and anomalies.

With this novel system it is possible to read a wide range of formed track diameters and track densities; with a monotonic response.

The software is very user friendly and simple to operate, and can be installed on any personal computer (PC). This new system with the proposed software, can be implemented in any laboratory, providing rapid and automatic track counting and analysis, and avoiding the need for tedious manual counting.

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MP-3

Improvement of overlapping nuclear track density measurement by using image processing techniques

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Detection of tracks produced by alpha particles, protons or nuclear fission fragments in plastic detectors, viz., Solid State Nuclear Track Detectors (SSNTDs), constitutes a very important tool in various areas. It is not easy for humans to count CR-39 nuclear tracks manually, especially when the track density is very high. An automated computer program called KTTMS2, written in C++ and running with a user-friendly interface, has been developed for recognition and parametric measurements of etched tracks in images captured from the surface of Solid-State Nuclear Track Detectors (SSNTDs). Well-known edge detection methods were applied to estimate the precision and accuracy of nuclear track densitometry using the CR-39 detector. Among the various routine edge detection methods, the Canny method was chosen because it was the most accurate technique. Because accuracy becomes more important as the track density increases, this allows more overlapping tracks to be detected. KTTMS2 (the proposed system) has an efficiency of 95% and can identify the noise as a background track (5%). Experimental results showed that the error percentage was reduced from 7.63% to 3.23% for high-density tracks when the count was adjusted by the estimated overlapping tracks.

TRACK PORE MATRIXES FOR OBTAINING OF MAGNETIC NANOWIRES: ELECTRODEPOSITION AND SOME PROPERTIES

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Paper is devoted to matrix synthesis of magnetic nanowires (NW) using the track pore matrixes as templates. This work consists of three parts: 1). Preparation of special polymer matrixes, 2). Electrodeposition of Co, Ni or Fe together with investigation of this process 3). Investigation of obtained ensembles of metal nanowires.

Preparation of track matrixes for template synthesis is described: variation of pores shape, density and pores walls modification. In most cases polymer (PET) films irradiated with swift heavy ions (1-2 MeV/nucl) and etched in alkali solution (up to pores diameter 0,08-0,2 mcm) were used as a templates. Results are presented and discussed.

Electrodeposition of Co, Ni and Fe was done from solution of sulfates of corresponding metals with some additives. Three-electrodes cell (with the reference electrode) was used and potentiostatic curves (the dependence of current on deposition time) were obtained for different matrixes and for different voltages.

For all the metals we found the effect of decreasing of deposition rate at the initial stage of metal deposition inside the pores, followed by increase at the final stage. This effect depends on pores diameter and the voltage value. Possibly this it is due to the competition of two processes: gradual decreasing of pore length (unfilled part) and decreasing of electrolyte concentration owing to slow ion transport in narrow channels. It might be also related with the role of pore walls (roughness and hydrophilicity), which must be rather high for nanosize channels.

Electrical resistance of the solution should be taken into consideration for all the metals under investigation. During the process different currents flow through the same cross section of

solution, so the voltage drops differ too. We found that current increase (in the last stage) is not proportional to the increasing cathode surface area: while the surface area becomes about 20 times larger after the filling of pores with metal, the current increases only by 3-5 times. This is caused by the shift of the cathode potential in the positive direction due to increased value of ohmic voltage drop in the solution in the vicinity of the cathode.

Deposition of Fe is the most difficult process because of non-stability of electrolyte due to Fe oxidation by the oxygen from atmosphere and formation of gas bubbles shielding the cathode. Iron electrodeposition process and the influence of additional parameters-temperature and agitation (mixing)- were investigated. The increasing of these parameters (as well as voltage increase) greatly accelerate the deposition speed.

For Fe NW Mossbauer spectroscopy, Synchrotron and X-rays microanalysis data were presented and discussed. It was shown that composition and structure of Fe NW depend on deposition voltage: 1). For low deposition rate (-600 mV) iron NW have the structure of α -Fe (typical sextet in Mossbauer spectra, intensive Synchrotron lines and clear lines of Fe (spectral analysis)); 2) For deposition at higher rate (-750...-900 mV) Mossbauer spectra demonstrated the changing of lines intensity (due to magnetization of NW) and/or additional lines of paramagnetic admixtures, the elemental analysis demonstrated appearance of S- and Al- lines; 3) For highest deposition rate (-1050 mV) all methods demonstrated the absence of pure Fe.

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Template based synthesis of metal, semiconductor and heterojunction nanowires using electrochemical deposition and their characterization

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The prime interest of researchers has been paid to synthesize low-dimensional nanostructures, such as nanowires, nanotubes, nanorods or nanobelts because of their potential applications in various fields arises due to unique structures with large surface-to-volume ratio [1,2]. Metallic and heterostructured nanorods have been studied widely and have established their applications in nanoscale optoelectronics, electronics, photovoltaic technology, electrocatalysts and nanobarcodes. The higher efficiency can be achieved by multi-junction nanowires based solar cell. Selenium nanowires find application in the areas of photoelectric cells, xerography, light-measuring devices, medical diagnostics and solar batteries. In the present work, metal Zn, semiconductor Se and the heterojunction Zn-Se and nanowires have been synthesized within the pores of polycarbonate track-etch membranes using template assisted electrodeposition techique at room temperature. The template method for synthesis of nanowires provides an effective control over the uniformity, dimensions and shape of the nanowires [3]. Elemental compositions of template-synthesized nanowires were studied by energy dispersive X-ray analysis. The crystallographic study of synthesised Zn, Se and Zn-Se nanowires was performed using the X-ray diffractometer (XRD). Scanning electron microscopy (SEM) confirmed the formation of Zn, Se and Zn-Se nanowires. The electronic transport properties of nanowires were performd by using I-V measurements at room temperature with the help of two probe system via Keithley 2400 series source meter. The variation in the I-V characterstics of metal, semicondutor and metal-semiconductor heterojunction nanowires was observed.

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The Strength of track etched membranes and composites polymer/metal obtained on their base by method of matrix synthesis.

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In present work the mechanical properties of track etched membranes (TM) and composites polymer/metal, obtained on their base by method of matrix synthesis, were studied. Matrix TM were made on the base of PET films of 12 mcm thickness, irradiated by high energy ions Kr. Cu was used as the filling agent. The strength of TM and composites was found by means of uniaxial extension on the universal experimental machine Autograpgh AGS - 5kN "Shimadzu" at speed of extension 2 mm/min. The samples were presented as strips with effective cross section 5x30 mm.

The influence of pore density on the TM and composites mechanical properties was studied for pore density from 1.18×10^7 to 1.04×10^9 cm⁻² and fixed diameter ~0.1 micro meters.

The influence of pore diameters on their mechanical properties was investigated for diameters from 0.067 μ m to 1.221 μ m and constant density 1.18*10⁷ cm⁻².

With the increase of pore density and pore diameters, the strength of samples decreases and the fracture become more brittle. Experimental results are analyzing by point of view of pore (or metal particles) interaction and the pore form evolution during the extension.

NP-4

Electrophysical and Gasodynamical properties of polymer films, irradiated with swift heavy ions.

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The area of changed polymer along the ion path (the latent track) has special properties that were investiagated in many papers. We suppose that macromolecules destruction followed by low-molecular compounds removing leads to creation of hollow volumes (the areas of lowered density in the polymer). We can also propose that these areas are penetrable not only for gases, but for liquids too. In the present paper the experiments are carried out on PET films with thickness 10 and 23 mcm irradiated by Krypton ions with energy 2 MeV/nucl., density 109 ions/cm². The measurements of gas and water penetration and electroconductivity were carried out in the present work to estimate the properties of hollow volumes. The electroconductivity measurement was performed in KCl, LiCl and such solutions assuming that the electrolyte penetrates through the latent track. The calculated track diameter is $DB = 4.0 \pm 0.1$ nm by water filtration, $DN = 3.75 \pm 0.5$ nm by nitrogen filtration and $DE = 4.35 \pm 0.2$ by electro resistance. These values are close enough.

Another process occurring while track formation is so-called graphitization, i.e. formation of carbon areas along the track. Graphite formation was confirmed in some papers. In the present one the measurements of electroconductivity of polymer films were carried out as comparison of conductivity of initial films and the irradiated ones (in dry state). The absence of differences in their conductivities allows supposing that graphite is not forming a continuous conductive channel.

Authors also carried out the conductivity measurements of pored membranes of polyimide and PETF: the electro resistance was investigated by impedance spectroscopy in range of diameters from 30 to 300 nm, in range of frequency from 1 GHz to 2.6 MHz and in different solution concentrations. Significant rising of small-pored samples conductivity was found. These results allow supposing a gel-layer existence on the pores surface. It may sufficiently affect the conductivity to increase it. This phenomenon is observed in low-diameter pores, but for the large pores the surface conductivity effect becomes negligible starting from 60 nm for polyimide membranes and starting from 300 nm for the PET ones.

APPLICATION OF SINGLE MOLECULES SPECTROMICROSCOPY FOR OPTICAL NANODIAGNOSTIC OF ETCHED TRACKS

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Etched track structure (porous structure in irradiated and etched polymer) is of great interest [1]. New experimental method - spectromicroscopy of single molecules (SMSM) - was used for investigation of this structure. The unique possibilities of SMSM [2] are based on two main features: a) for fluorescing molecular (nanocrystalline) probes imbedded into a sample under study all three spatial coordinates can be determined with sub-diffractional nanometer accuracy, b) photophysical (spectral) characteristics of the fluorescing probes (labels) are very sensitive to the parameters of their local environment. Properly applied, this technique allows to reconstruct porous materials structures by optical methods with nanometer resolution.

Using the method of luminescent labels some works were done for limited types of porous materials:single molecules diffusion in pores of Si_3N_4 [3], the movement and orientation of single molecules in porous silica [4]. At the same time, the classical type of filters- track membrane (TM) - has never been investigated. In this work the SMSM technique was used for nanodiagnostics of TMs for the first time. Polyetheleneterephthalate (PET) TMs with the thickness 10-20 m and pore diameters range 0.2 - 1 m were studied. Single molecules (SM) of terrylene and semiconductor quantum dots (QD) CdSe/ZnS and CdSeS/ZnS were used as luminescent labels.

Two types of experiments were done:

(1) Low-temperature experiments. Porous structure of TM was visualized by reconstruction of spatial positions of a big number of SMs. (Pores of TM were filled with the solution of terrylene in orto-dichlorobenzene). At helium temperatures it becomes possible to perform the measurements of SM zero-phonon spectral lines (ZPL) [5] selectively excited for different individual SM and having very high fluorescence intensities. The first results of SM detection in the PET TM are presented

and discussed.

(2) Room temperature experiments. In this case the luminescence of single QDs in highly diluted solution was excited by solid-state laser (Coherent Verdi V4) on the wavelength 532 nm. The Stoks-shifted luminescence images of QDs was detected by high-sensitive CCD-camera, thus the positions of single QDs were reconstructed with high accuracy. As a result, parameters of liquid flow along the membrane surface can be monitored by tracking the dissolved quantum dots that move with the flow and fluoresce under the laser excitation.

In conclusion-we demonstrated that the nanodiagnostics of TM can be realized by SMSM.

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Synthesis of gold and nanoporous gold nanowires array in etched ion-track membrane templates and fluorescence enhancement of the arrays

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Etched ion-track membrane can be fabricated from polymers after irradiation by ion accelerator, sensitization by UV light and etching by alkali solution. This membrane is an excellent template for the fabrication of one-dimension nano-materials. We report a method for non-cyanide electrodeposition of gold and gold-silver alloy nanowires array in this template. After removing the polymer template and chemical etching of silver from the alloy nanowires, nanoporous gold nanowires can be formed. Comparison with fluorescence molecules immobilized on glass, we observed enhanced emission intensities of fluorescence molecules on the gold nanowires array and nanoporous gold nanowires array, and the fluorescence intensity of nanoporous gold nanowires array is larger than the gold nanowires array without any nanopores.

Study of ${}^{12}C$ beam with the energy E = 2.5 GeV using layers of plastic CR-39

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Eight plastics CR-39 were irradiated with the accelerator ITEP carbon ions. There were used two locations of the plastics in the accelerator chamber with water. The sizes of the chamber exceeded residual ranges of ions. The plastic CR-39 layers were treated at temperature T=85° C with a solution 7.5N NaOH during two times of etching - 7 and 10 minutes. Next, using a computer microscope system there were obtained fifty electronic micrographs from each side of each plastic. On both surfaces of plastics there were seen holes of etched tracks. Then these micrographs were analyzed using a specially created computer code for algorithmic language C#. Good statistics processing of each detector surface reached by fifty simultaneous batch processing of the images and combining them into one large image. At first there were found average numbers of ions per one microscopic image with their root mean square deflections and there were drawn Gauss distributions of ion amounts for plastic surfaces 130 m x 104 m at set of depths inside the water chamber. Then the computer code found contours of all holes, fit into them ellipses, calculated their large and small axes and built frequency distributions over large and small axes of the ellipses. Then there were evaluated methods for calculation azimuth angles, angles between track axes and normal to a surface of the detector. After that, there were obtained frequency distributions over both angles. Then there was developed a mathematical method for the transition from axes values of the ellipses-like hole of etched inclined track to the radius of hole which would be etched after the same ion with the same energy, but passed in a direction perpendicular to the surface of the detector. After that it became possible to find cone vertex angles and to use the known formulas of relation of etching rate VT along a track with hole radii of perpendicular tracks and vertex angles of these tracks. At last using values VT and Track theory there was built up a method for calculation ion energy spectrum, distributions over energy losses and over ion residual ranges. The detailed analyses of all distributions are given.

Measurement of Radioactivity in Indian Vegetation using Gamma Spectrometry

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Vegetation (food stuff) is grown in soil that contains many radioactive elements such as ²³⁸U (uranium), ²³²Th (thorium) and ⁴⁰K (potassium), which may get deposited either due to radioactive fallout or/and by absorption from the soil and can pose serious health hazards. In the present work, natural radioactivity, radiological hazards and annual effective dose assessment was carried out in vegetation samples (vegetables, cereals and fruits) collected from fields and market. Gamma spectrometry using HPGe detector was used. The measured specific activity concentration of ²³⁸U (uranium), 232 Th (thorium) and 40 K (potassium) varied from 10.25 ± 0.94 Bg/kg to 29.13 ± 0.69 Bq/kg, 22.20 ± 2.46 Bq/kg to 58.21 ± 1.15 Bq/kg, and 1158.4 ± 26.05 Bq/kg to 1962.2 ± 18.17 Bq/kg respectively in various vegetable and cereal samples and varied from 2.5 ± 0.16 Bq/kg to 9.8 \pm 0.15 Bq/kg, 7.4 \pm 1.24 Bq/kg to 18.4 \pm 1.39 Bq/kg, and 287.13 \pm 11.23 Bq/kg to 815.72 \pm 12.50 Bq/kg respectively in various fruit samples studied in the present work. From these values, hazard indices, the minimum and maximum values of absorbed dose and indoor and outdoor annual effective doses were calculated for various samples used in the present investigation. The various values obtained were found to be within the recommended limits. The absorbed dose and annual effective dose for the vegetable and cereal samples in which fertilizers were used to enhance the crop yield were higher than that in fruit samples.

Keywords: Radiological hazards, vegetation, radium equivalent activity

Application of CR-39 plastic nuclear track detectors for quality assurance of MOX fuel pellet

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The plutonium-thermal use is expected as one of the approach for reuse of spent uranium fuel in nuclear power generation. On the other hand, many kinds of nuclides including Pu with extremely long half-lives are generated in the used fuels, which would be problems for storage and control of radioactive waste. The MOX (Mixed Oxide) consisting of plutonium dioxide enriched with 4-9% Pu and uranium oxide from spent uranium fuel would allow to reduce half-lives of radioactive waste significantly through the nuclear fission. The MOX pellet is produced through sintering process after the mixing of Pu oxide and U oxide powders. The quality of MOX pellet depends on the homogeneous dispersion of Pu. The region of highly concentrated Pu is sometimes observed as "Pu spot" in the pellet, which has the potential of anomalous combustion localized at that region. The detection of Pu spot and evaluation of its size and concentration are one of the important quality assurance of MOX pellet for the safety use in the nuclear power plant. We have applied CR-39 plastic nuclear track detectors for the measurement of Pu spot inside MOX pellet. CR-39 can image a cross-section of MOX pellet by recording α-particle tracks from Pu in the pellet, like autoradiography. The Pu spot is visibly imaged as a "black spot" due to the dense α tracks compared to homogeneously dispersed region. Conventionally, the Pu spot measurement has been carried out with manual scanning, which takes much longer times and huge amount of human work. We have developed the automatic detection and measurement system of Pu spot recorded on CR-39 by the image processing with filtering and clustering algorithms. The detection efficiency with CR-39 is achieved to be almost 100% compared with conventional manual scanning result. It provides more information about the number, size and position of Pu spot. This system will be a powerful tool of screening test for the quality assurance of MOX pellet.

OP-4

Application of the ion beam graft polymerization method to the thin film diagnosis

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There are many methods of non-destructive diagnosis, such as a supersonic echo, an X-ray radiography, and so on. Those diagnoses don't have sufficiently high resolution for a thin film measurement. On the other hand, the accelerator analyses are very good for thin film diagnosis. But it is difficult to observe the void inside of a thin film, because the analysis can only obtain the areal density. We have studied the radiation induced graft polymerization method with ion beam, and have developed the diagnosis method of a thin film using the ion beam graft polymerization. The thin sample, the thickness is micrometer order, is set to a polyethylene film. The sample and polyethylene are irradiated with the MeV-proton. The proton penetrates the sample and is incident on the polyethylene. The range of the proton in the polyethylene has an information inside of the sample. If the sample has a void or crack, the range at the part with void is larger than at the part without void. Many kind of materials, such as a polymer, a metal, a semiconductor, etc., can be observed with this method. The experiments were conducted for some thin polymers and some thin metals. Some basic data, the spatial resolution, observable size of void, and so on, for the diagnosis were obtained.

Ablation and Cone Evolution on ArF-Laser Irradiated CR-39

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CR-39 has been irradiated with an ArF laser (193 nm) at a repetition rate of 1 Hz. Conical microstructures (Taylor cone) formed on laser-ablated Poly allyl di-glycol carbonate (CR-39) exhibit smooth, Taylor cone shape walls and sharp tips together with interference and well defined fringe-structure with a period of 230 nm around cone base. Mechanism of cone formation and Cone evolution of CR-39 ablated surface were investigated by change of fluence (at a given pulse number), and pulse number (at a given fluence). Cone height, cone base and region of interfacewere increased in micrometer steps by increasing the total fluence. Ablation threshold fluence and effective absorption coefficient of CR-39 were determined. FTIR spectra were measured and EDX analysis of irradiated and untreated samples was performe