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Swift heavy ion induced thermoluminescence studies in polycrystalline aluminum oxide

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When energetic swift heavy ions interact with matter, inelastic collision (leading to electronic energy loss-S_e) and elastic collision (leading to nuclear energy loss -S_n) take place. In the present study, the effect of energetic ion species on thermoluminescence (TL) of polycrystalline aluminum oxide (PAO) is reported. PAO pellets of 6 mm diameter are irradiated with energetic Au^{9+}, Ni^{7+} and Si^{7+} ions for the fluence of 1×10^{13} ions cm^{-2}. A single well resolved prominent TL glow with peak at 538 K is observed in Si^{7+} irradiated samples. However, in Ni^{7+} and Au^{9+} irradiated samples a prominent TL glow with peak at 610 K along with a shoulder at 513 K is observed. On the other hand, when PAO samples are irradiated with γ-rays two well separated TL glows with peaks at 483 K and 638 K are observed. A prominent PL emission with peak at 430 nm besides a weak emission with peak at 480 nm and a shoulder at 525 nm are observed in 120 MeV Au^{9+}ion irradiated samples when excited with 320 nm. These PL peaks are attributed to F, F_2^+ and F_2^{2+}-centers respectively. However, in Si^{7+} irradiated samples a single PL emission peak at 430 nm is observed and it is attributed to F-centers.

Thermoluminescence is the luminescence emitted from a previously irradiated insulator or semiconductor as a result of thermal stimulation. The TL intensity is a function of dose of radiation absorbed by the sample and thus is used in radiation dosimetry. The process can be described phenomenologically using the energy band scheme involving delocalization of electrons from traps followed by recombination with holes resulting luminescence emission[1]. Al_2O_3 is one of the earlier materials studied for its possible application as a radiation dosimeter owing to its superior thermal and chemical stability and low effective atomic number[2]. Further, aluminum oxide has been used historically as an imaging plate for tuning high current electron beam accelerators with good success. The material survives for couple of months and it appears to exhibit monotonic increase of light output with electron beam current[3]. Swift heavy ions (SHI) are very useful for modification of the properties of films, foils and surface of bulk solids. It penetrates deep into the target material and produces a long and narrow disordered zone along its trajectory. The passage of SHI induces very rapidly developing processes which are difficult to observe during or immediately after their occurrence. The information about these processes is stored resulting damage, such as size, shape, structure of defects, etc. The degree of disorder can range from point defects to a continuous amorphized zone along the ion path, commonly called latent track[4]. In the present study, the thermoluminescence and photoluminescence of SHI irradiated polycrystalline aluminum oxide are reported.

Theory

When a fast energetic ion penetrates in a solid it loses its energy mainly by two nearly independent processes: (i) elastic collisions with the nuclei known as the S_n-nuclear energy loss $(dE/dx)_n$, which dominates at an energy of about 1 keV/amu; and (ii) inelastic collisions of the highly charged projectile ion with the atomic electrons of the matter known as S_e- electronic energy loss $(dE/dx)_e$ which dominates at an energy of about 1 MeV/amu or more. In the inelastic collision (cross-section ~10^{-16} cm^2) the energy is transferred from the projectile to the atoms through excitation and ionization of the surrounding

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electrons. The amount of electronic loss in each collision varies from tens of eV to a few keV per Angstrom (Å). The passage of SHI in materials mainly produces electronic excitation of the atoms in the materials. SHI causes exotic effects in different classes of materials which otherwise cannot be generated by any other means. Quantitatively, it is capable of depositing electronic excitation energy of about 1-10 keV/Å in the materials. Such a large electronic excitation brings out various changes in materials. During the passage of SHI through materials, neighboring positive target ions are produced by electronic excitation induced ionization. These positive ions are mutually repulsive. The time to cover atomic sites is short in comparison to the response time of the conduction electrons. So during the passage of the ion a long cylinder containing charged ions is produced.

Figure 1 shows the variation of electronic energy loss (S_e) and nuclear energy loss (S_n) for Au ions in aluminum oxide target. The variation of electronic energy loss (S_e) and nuclear energy loss (S_n) for Si ions in aluminum oxide is shown in Fig. 2. The calculation of S_e and S_n is done using SRIM 2003 program[5]. It is observed that, in both the cases the maximum energy deposition takes place by means of inelastic collisions (electronic energy loss-S_e) but not by elastic collisions (nuclear energy loss-S_n) by the ions having the energies in the range of few MeV to few hundreds of MeV. However, in the present study the maximum Se deposited in aluminum oxide is observed from gold ions when compared to that with silicon ions.

Experimental Procedure

Polycrystalline aluminum oxide used in the present investigations is synthesized by combustion technique. In order to handle the phosphor easily, 100 mg of polycrystalline Al_2O_3 powder was grained into a fine powder using an agate and mortar and mixed with a drop of polyvinyl alcohol in a cylindrical pilot of the palletizer to make pellets. Pellets of 6 mm diameter and 1 mm thickness from the above mixture were obtained by applying pressure of about 70 MPa using a home-made palletizer at room temperature. As prepared pellets were irradiated with SHI for fluence 1×10^{13} ions cm^{-2} using 15UD Tandem Pelletron Accelerator in Materials Science beam line at Inter University

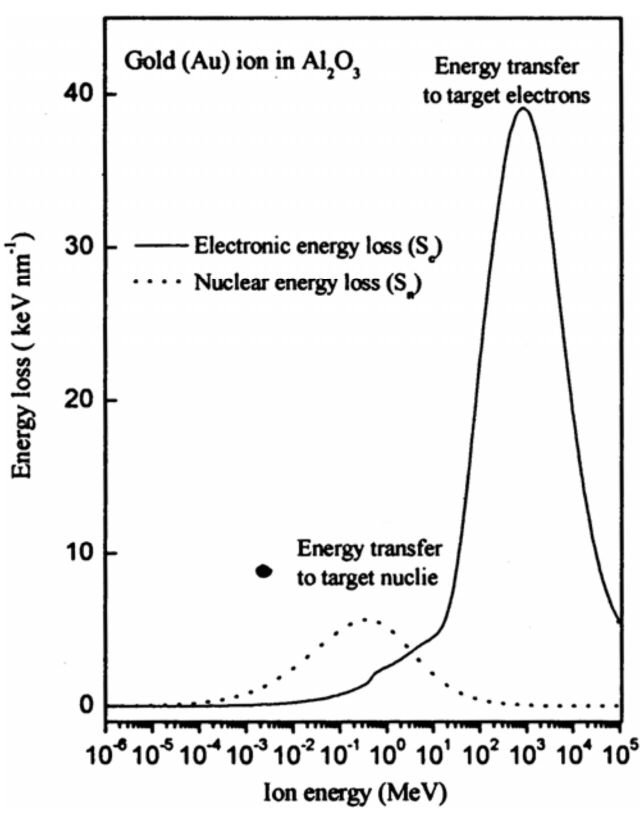

Fig. 1— Variation of S_e and S_n of gold ion in Al_2O_3 due to elastic and inelastic collisions with energy in the range 1 eV to 100 GeV

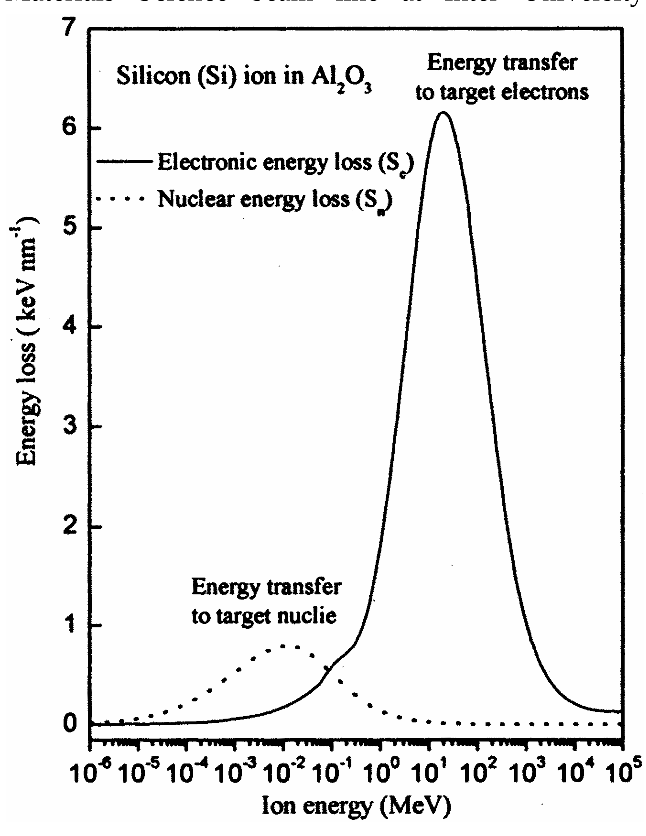

Fig. 2—Variation of S_e and S_n of silicon ion in Al_2O_3 due to elastic and inelastic collisions with energy in the range 1 eV to 100 GeV