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3 - 35 Large Dispersion of Deposited Energy in Devices with Different Active Film Thicknesses

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The Linear Energy Transfer (LET) is known as an average metric to study Single Event Effects (SEE) in electronic devices, characterizing a given ion beam. Yet because of the stochastic nature of particle-matter interactions, each incident particle has a different path though matter and thus deposits a different amount of energy in the sensitive volume of a device. That brings an error source to the experimental data, in which LET is used as a main parameter, ignoring this intrinsic dispersion of deposited energy. As technology scaling, devices are becoming more and more sensitive to this dispersion phenomenon. By using Geant4[1] Monte Carlo simulation, we investigated the dispersion in deposited energy as a function of sensitive silicon film thickness. During the simulation, 25 MeV/u krypton and 9.5 MeV/u bismuth ions, which are most commonly used in the SEE experiments performed at HIRFL, were chosen to incident in devices with three different silicon film thicknesses: 17 μm, 0.8 μm and 150 nm. For each ion, the charge it induced in the sensitive volume was recorded and analyzed.

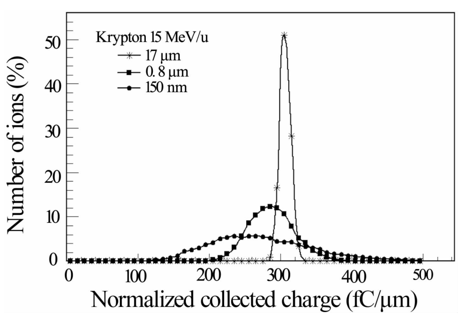

Fig. 1 Simulated number of ions as a function of the deposited charge, normalized to the silicon film thickness, for 25 MeV/u krypton ions in devices with different silicon film thicknesses.

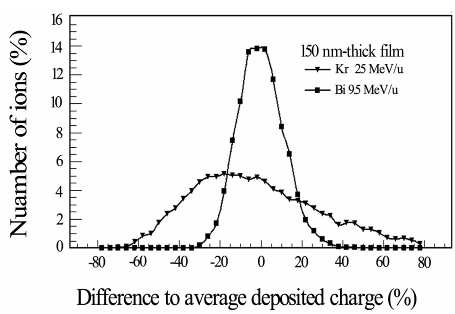

Fig. 2 Proportion of ions as a function of the difference of their normalized deposited charge value to the average value of the distribution for the 25 MeV/u Kr and 9.5 MeV/u Bi ions.

Fig. 1 shows the simulated number of ions as a function of charge, normalized to the silicon film thickness, induced by the energy the ion deposited in the sensitive volume. The simulated trends are consistent with the experimental observation in[2]. Since the LET increases with the decrease of the ion energy while it penetrates matter, the thinner the silicon film, the smaller the value of the average deposited charge per micrometer. As shown in Fig. 1, the energy dispersion, marked by the variation taken at half maximum, clearly increases with decreasing silicon film thickness, starting from a variation of ±1% for the 17 μm thick film up to ±50% for the 150 nm one. The variability in deposited energy is directly related to the stochastic scattering mechanisms of ions in matter. In a thick film, scattering events are obviously more numerous and thus smoothing out the variations in total deposited energy. Therefore, the dispersion phenomenon should be considered especially in devices with thin sensitive volumes.

The dispersion of deposited energy induced by 9.5 MeV/u bismuth ions is smaller than that induced by 25 MeV/u krypton ions when they are penetrating a device with a 150 nm thick active film. Fig. 2 shows the number of ions as a function of the absolute difference to the mean value of the generated charge. For 9.5 MeV/u bismuth ions, the difference to the average value is around ±20%. The average deposited charge is about 1000 fC/μm, so the distribution varies between less than 800 and more than 1200 fC/μm. Since the critical charge of some sensitive devices has reached less than 1 fC, this variation is far from being negligible. So the simulated results are of some instructive significance to the analysis of experimental data.

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3 - 36 Irradiation Effects of Swift Heavy Ions on Chemical Composition of Mica Crystal

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Muscovite as a special mineral material is very sensitive to irradiation of swift heavy ions, and it has several applications, such as solidstate nuclear track detection, microfilitering, fission track dating in geology and so on. In our investigation, sliced muscovite, with formula $KAl_2(Si_3AlO_{10})(OH)_2$, was irradiated by 414.4 MeV (3.7 MeV/u) ^{112}Sn ionswith fluencerangefrom 1×10^{11} to 1×10^{14} ions/cm^2 from HIRFL accelerator. The chemical composition of irradiated samples was studied by X-ray Photoelectron Spectroscopy (XPS).

After irradiated by swift heavy ions, the surface of mica crystal was cleaved into small flakes at high fluencesuch as 1×10^{13} ions/cm^2. The relative content of elements K, Al, SiandC, asshown in Fig. 1(a), is determined with area normalization method anddescribed in the form of histogramin Fig. 1(b). It illustrates that the content of K and Aldecreaseswith the ion fluenceincreasing. It is interesting to note thatthe content of Si increases gradually at beginning. After the ions fluence reaches a certain threshold, the content of Si begin to decrease.

As we known, mica is consisted of negatively charged aluminosilicate sheets which are bound to alternating layers of K^+ ions. Because of the layered structure, mica can be easily cleaved. After irradiatedby high energy ions especially at high fluences, the outmost surface was cleaved into small pieces. Irradiation of swift heavy ionsdestroyed the bonds between K^+ ions and aluminosilicate sheets as well as the well-defined layered structure of mica surface, and removedthe K^+ ions on the outmost surface, which leads to the decreasing of K element on the top surface of samples. At higher fluences (1×10^{13}, 1×10^{14} ions/cm^2), the content of K was not observed in this experiment.

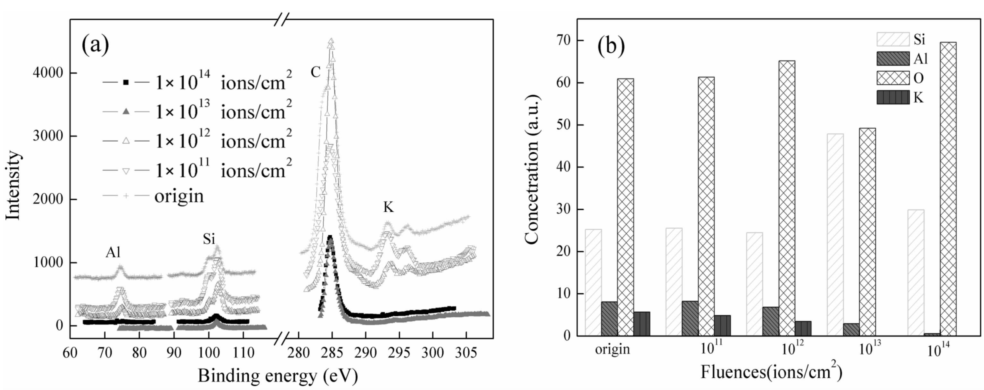

Fig. 1 Atomic concentration determined by XPS of irradiated mica surfaces at different fluences compared to pristine sample. (a) XPS spectra; (b) content distribution of K, Al and Si.

It was observed from Fig. 1(b) that at lower fluences, i.e. 1×10^{11} and 1×10^{12} ions/cm^2, the content of Si in mica has not been obviously changed. While at higher fluence 1×10^{13} ions/cm^2, an enrichment of