References

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[2] A. C. Ferrari, J. C. Meyer, V. Scardaci, et al., Physical Review Letters, 97(2006)187401.

3 - 32 Effects of Swift Heavy Ions Irradiation on Graphene and Thin Graphite Films

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The single layer graphene and thin graphite films, got from highly ordered pyrolytic graphite by micromechanical cleavage, were irradiated by $^{209}Bi^{31+}$ ions with initial kinetic energy of 25 MeV/u provided by two cyclotrons HIRFL of IMP, Lanzhou. The Atomic Force Microscope (MFP-3D-SA AFM) was used to confirm both the single-layer graphene samples and the thickness of thin HOPG films. The Microscopic Confocal Raman Spectrometer (LabRAM HR800, JobinYvon Co.) was used to characterize the irradiation effects. The excitation wavelength of Raman Spectrometer is 532 nm, and the optical skin depth in graphite is approximately 50 nm.

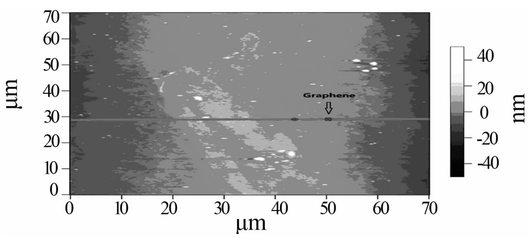

Fig. 1 AFM image of graphene sheets with different thickness.

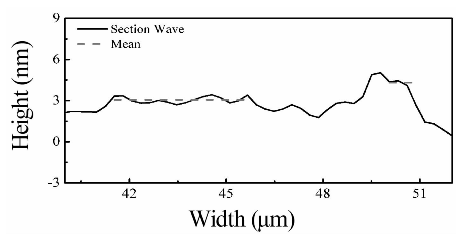

Fig. 2 The section wave correspond to the straight line on AFM image.

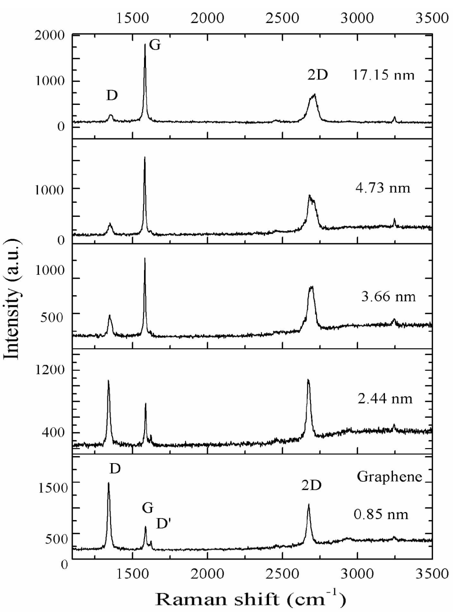

Fig. 3 Raman spectra of thin HOPG films.

Fig. 1 shows the AFM image on sample containing graphene sheets with different thickness. The graphene sheet pointed out by the arrow is confirmed to be single-layer graphene by Raman spectrum via the character of the 2D peak[1]. The section wave-related to the straight line (in Fig. 1) is shown in Fig. 2. The thickness of thin HOPG films can be confirmed by the height difference along the line. And the thickness of the marked single layer graphene isaround 1.2 nm as shown in Figs. 1 and 2. The thicknessgot from AFM is much higher than the theory thickness of 0.34 nm for monolayer graphene. This may be due to the low throughput of AFM. Moreover, the chemical contrast between graphene and the substrate will lead to an apparent chemical thickness of 0.5～1 nm.

Fig. 3 shows the Raman spectra of single layer graphene and thin HOPG films irradiated by 1235 MeV $^{209}Bi^{31+}$ with fluence of 6.5×10^{11} ions/cm^2. The D peak and D peak, which are the two most prominent features in the disorder-induced graphite Ramanspectrum[2] appear after irradiation. These disorder peaks predict the damageformed in both irradiated monolayer graphene and thin HOPG films. The intensity of D peak and D' peakdecrease with thickness increasing, and D' peak finally disappears when the HOPG films is thick enough. It can be seen that the thinner HOPG films are much easier to be destroyed by swift heavy ion irradiation than thicker ones.

In conclusion, the different radiation response of single layer graphene and thin HOPG films was confirmed through Raman and AFM analysis. It is proved that the thicker HOPG films have stronger anti-irradiation property than single layer graphene.

References

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3 - 33 Edge Effectson SEU Sensitivity of SOI SRAM

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During ground-based testing of single event upset (SEU), angled ion strikes are used to acquire higher linear energy transfer (LET) value. When a particle incident at an angle θ from the normal to the surface plane of the device passes a sensitive volume with thin rectangular parallelepiped (RPP), the effective path length of titled incidence increases by $1/\cos(\theta)$ compared to that of normal incidence. This increases the particle's "effective" LET by a factor of $1/\cos(\theta)$[1], i. e. $LET_{eff}=LET_0/\cos(\theta)$, where LET_0 is the particle's initial incident LET. In performing such experiments, it is also necessary to independently correct the measured upset cross-section by the same $l/\cos(\theta)$ factor due to geometric considerations of the incident particlesfluence[2], The SEU cross section (σ) is calculated by

$$\sigma=\frac{N}{F\cdot\cos(\theta)} \tag{1}$$

where N is the number of recorded errors, and F is the total fluence of particles. However, with the technology scaling, the above correction don't take consider of the edge effects of actual sensitive volume at the titled incidence. In this work, an experimental study to confirm the edge effects was performed.

Table 1 Details of the experimental parameters of degrader thickness and tilted angle

Degrader(μm)	Angle($^\circ$)	LET_0 ($MeV\cdot cm^2/mg$)	LET_{eff} ($MeV\cdot cm^2/mg$)
0	30	21.56	24.9
60	0	25.07	25.0
0	45	22.28	31.5
125	0	31.48	31.5

All of the tests were carried out using the initial energy 25 MeV/u ^{86}Kr beam from the HIRFL facility. The SOI SRAM chip(128 k×8 bit) is 0.5 μm CMOS technology. The incident angles of two group experiments were 30 degrees and 45 degrees, respectively. At each group, the different thickness Al foils was used as the degrader to get the same LET_{eff}. The experiment is performed on room temperature. The summary of detailed experiment conditions are given in Table 1.

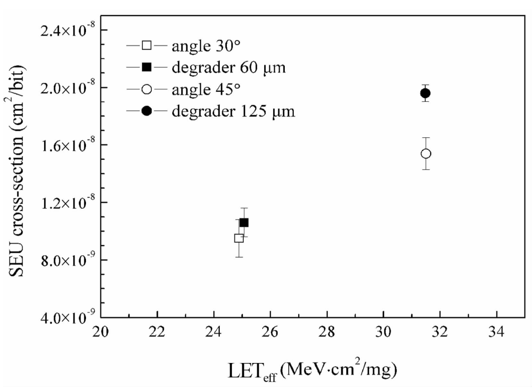

Fig. 1 The SEU cross section as a function of LET_{eff}. The error bars represent the standard deviation.

Fig. 1 shows The SEU cross section as a function of LET_{eff}. Note that the SEU cross section at the titled incidence is lower than that of at normal incidence with degrader at the same LET_{eff}, and the difference of SEU cross section is obvious with the tilted angle increasing. Especially at the 45 degrees, the SEU cross section at the tilted incidence is lower by 25% compared to that of normal incidence with 125 μm Al foils. Due to shallow trench isolation (STI) process in this device, no multiple-cell upsets (MCU)occurs at the titled incidence. The