3 - 30 Theoretical Method for Estimating Profile of Single Event Transient Current

Geng Chao, Liu Jie, Xi Kai, Zhang Zhangang, Gu Song and Liu Tianqi

The single event transient (SET) currents, the peak and collected charge saturation in particular, are vital to characterizing the single event upset. The section provides a physics-based method for estimating the SET current and charge collection. The detailed information of SET current is extracted from the physical model within technology computer aided design (TCAD).

This theoretical method utilizing the amount of charge collection, transporting time of the incident ion, and the ion track[1-3] established time, are applied to determine a reasonably accurate SET pulse in reverse biased p-n junction. In addition, the results of charge collection (through drift and diffusion) at the drain node and SET current are obtained by mathematical integration and Monte Carlo simulation without using the TCAD.

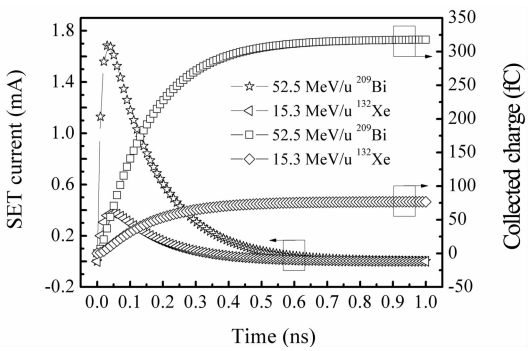

Fig. 1 The SET current and charge collection output from incident ion strikes at the drain node with the incident ion of 52.5 MeV/u ^{209}Bi and 15.3 MeV/u ^{132}Xe, respectively.

The SET current pulse illustrated in Fig. 1 are calculated from the outputted data by Monte Carlo simulation. The worst case depicted by Fig. 1 is extracted from the results of 10^3 ions at the primary incidence. The transients can be characterized by the metric of width and magnitude. Thus, the SET current presented in Fig. 1 in both of two kinds of incident ions reveals the charge collection process. It is interesting noted that the simulated SET current pulses are so different in spite of the same LET value of incident ions. For instance, the discrepancy of the peak of SET current is about 1.3 mA, and in contrast to 15.3 MeV/u ^{132}Xe, the SET current induced by 52.5 MeV/u ^{209}Bi falls sharp after the peak. In addition, the saturation of collected charge is 0.32 pC from 52.5 MeV/u ^{209}Bi and 0.08 pC from 15.3 MeV/u ^{132}Xe, respectively. To summarize, the radiation feature (e.g. ion species, ion energy) play an indispensable part in the radiation environment for analyzing the radiation effects on the semiconductor device, thus this section gives the SET current pulse induced by two kinds of ions with different energy, and it is concluded that utilizing the SET current pulse and collected charge to elucidate the charge collection process is necessary and reasonable. Therefore, with the integration of the amount of collected charge and the ion track establishment from Monte Carlo simulation, the SET current and saturation of charge collection can be accurately characterized and identified for the space radiation application.

References

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3 - 31 Raman Spectroscopic Study of Irradiation Effects on Monolayer Graphene

Zeng Jian, Liu Jie, Yao Huijun, Zhai Pengfei, Duan Jinglai, Sun Youmei and Hou Mingdong

Graphene, composed by a hexagonal two-dimensional network of carbon atoms, is a unique material with exotic electronic properties. Its electron transport is described by the Dirac equation and this allows access to quantum electrodynamics in a simple condensed matter experiment. Many aspects of ion irradiation induced damage on graphene have been the subject of much interest recently. Most investigations deal

with the low and medium energyelectron-beam irradiation or the projectiles in energy range of eV to keV. Only few studies have been performed with swift ions of several MeV per nucleon[1]. Here, both monolayer graphene and HOPG were irradiated by $^{209}Bi^{31+}$ ions with the fluence of $10^{11}\sim10^{12}$ ions/cm^2 at room temperature.

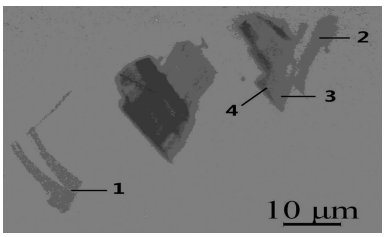

Fig. 1 Typical optical image on sample containing graphene sheets of different thickness. The monolayer graphene was marked by number 1.

The monolayer graphene samples were gotten from highly ordered pyrolytic graphite (HOPG, Advanced Ceramics Co., Grade ZYB) by micromechanical cleavage. Optical microscope was used to map the graphene sheets and identify the single layer graphene. The Microscopic Confocal Raman Spectrometer (LabRAM HR800, JobinYvon Co.) was used to characterize both the irradiated and pristine graphene samples.

Fig. 1. shows the typical optical image on sample containing graphene sheets of different thicknesses. The Microscopic Raman Spectrometer with laser wavelength of 514.5 nm is used to characterizeall of the different parts with different layers. HOPG films with different layersconfirmed via Raman spectra are marked by different number, for instance the monolayer graphene is marked by number 1.

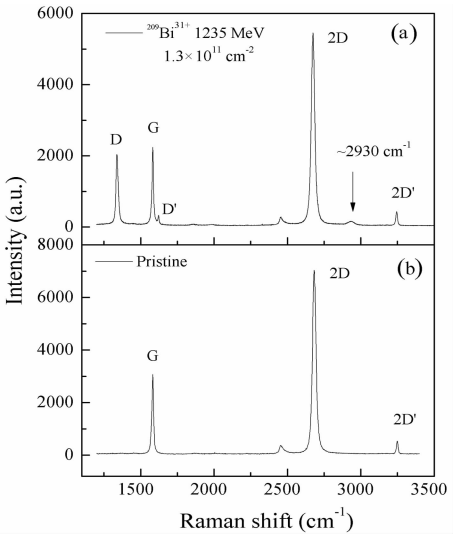

Fig. 2 Raman spectra of pristine and irradiated monolayer graphene sample.

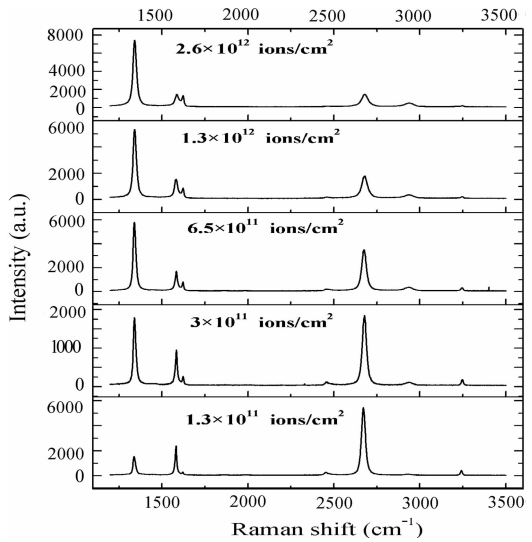

Fig. 3 Raman spectra of monolayer graphene samples irradiated by 1235 MeV $^{209}Bi^{31+}$ with different fluence.

The Raman spectra of pristine and irradiated monolayer graphene samples are shown in Fig. 2. Three most intense features: G peak ($\sim$1582 cm^{-1}), 2D peak ($\sim$ 2683 cm^{-1}) and 2D peak ($\sim$3249cm^{-1}), can be observed in the pristine sample, shown in Fig. 2(b). Ferrari, et al., showed Raman spectroscopy could be used to identify the number of layers, especially the monolayer and bilayer graphenesamples[2]. As shown in Fig. 2(b), the 2D Raman bond is symmetrical, and the intensity ratio of 2D peak to G peak is about 2.38. Then the piece of graphene sheet marked "1" can be confirmedas defect free monolayer graphene via the character of the 2D peak and the absence of a D bond signal.

Raman spectra of monolayer graphene samples irradiated by 1235 MeV $^{209}Bi^{31+}$ with fluence of 1.3×10^{11} cm^{-2} are shown in Fig. 2(a). New peaks defined as D peak($\sim$1339 cm^{-1}) and D peak ($\sim$1621 cm^{-1}) come outafter irradiation. The broad band around 2930 cm^{-1} is attributed to D+G overtone.

For investigating the irradiation effect on monolayer graphenefurther, the samples areirradiated by 1235 MeV $^{209}Bi^{31+}$ with different fluence. The Raman spectra are shown in Fig. 3. And it can be found that the intensity of D and D' peak caused by irradiating increase with the fluence increasing.

In conclusion, Raman Spectrometer has been used to investigatethe irradiation effects monolayer graphene. It has found that the irradiation exposures results in appearance of strong disorder D band and D' band indicating damage to the graphene lattice. Moreover, the I_D/I_G increases with the fluence increasing.

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

Zeng Jian, Liu Jie, Yao Huijun, Zhai Pengfei, Sun Youmei and Hou Mingdong

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.

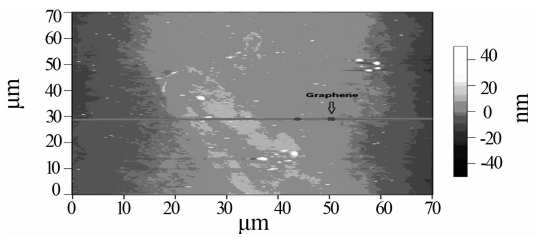

Fig. 1 AFM image of graphene sheets with different thickness.

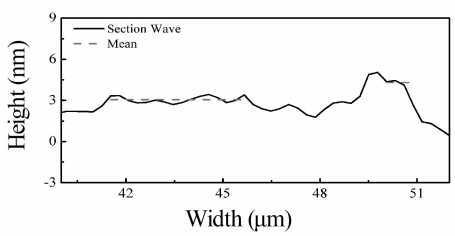

Fig. 2 The section wave correspond to the straight line on AFM image.

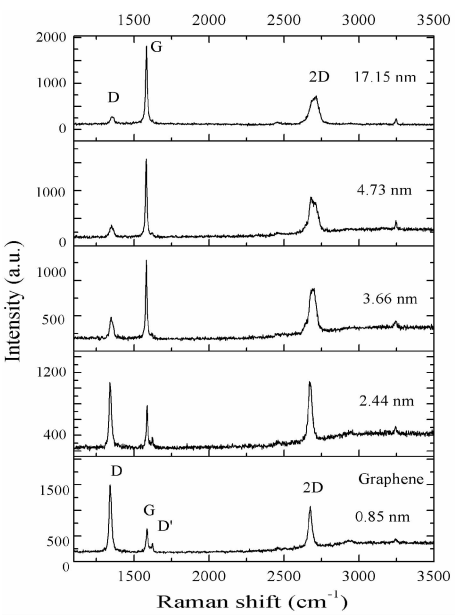

Fig. 3 Raman spectra of thin HOPG films.

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 con-