firmed through Raman and AFM analysis. It is proved that the thicker HOPG films have stronger anti-irradiation property than single layer graphene.

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3 - 33 Edge Effects on 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 $1/\cos(\theta)$ 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(°)	LET_0(MeV · cm²/mg)	LET_{eff}(MeV · cm²/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.

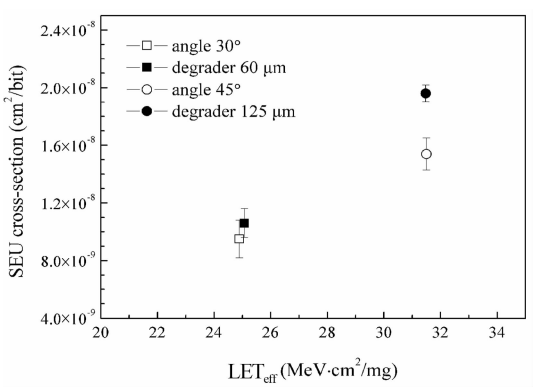

Fig. 1 The SEU cross section as a function of LET_{eff}. The error bars represent the standard deviation.

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

decrease of upset cross section of angled ion strikes is attributed to the edge effect. When a particlestrikes at the edge of sensitive volume withatitled angle, the pathlength in the sensitive volume is decreased. Thisresults in the deposited charges decrease. Theedge effect is more obviouswith the angle increasing.

In conclusion, the experiment result reveals that the SEU cross section obtained by angled incidenceis underestimated. So it is necessary and important to furthercorrect the SEU cross section of titled incidence on SOI SRAM.

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3 - 34 Effects of Heavy Ion Accumulated Dose Irradiation on Single Event Upset Sensitivity

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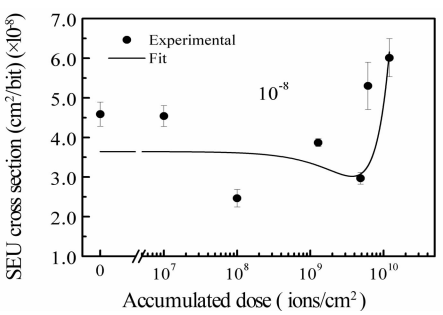

Fig. 1 SEU cross section as a function of ^{112}Sn irradiation accumulated dose. The error bars represent the standard deviation.

At space, large dose gamma and proton irradiation produce interface states and trapped charges in the device's gate oxide[1]. Interface states and trapped charges will alter the electrical characters of the device, such as the threshold-voltage shifts, leakage current increase and so on. Those phenomena are commonly referred to as total ionizing dose (TID) effects. On the other hand, heavy ion irradiation mainly produces single event effects (SEE) through direct ionization on devices. For example, single event upset (SEU), one of the SEE, is very common in SRAM, which seriously threaten device reliability in orbit. The synergistic effects of total ionizing dose on SEU sensitive in SRAM has also been investigated[2-3]. However, the synergistic effects appears two opposite trends at different type devices[4]. No rigorous explanation for this phenomenon was given, and it is also not clear that heavy ion accumulated dose exposure effects SEU sensitivity in SOI SRAM. Therefore, an experimental investigation about the synergistic effects of the heavy ion accumulated dose on SEU sensitive in SOI SRAM was performed.

In this experiment, the previous heavy ion accumulated dose irradiation and SEU testing were carried out using the initial energy 3.7 MeV/u^{112}Sn beam from the HIRFL facility. The SOI SRAM including 1Mb (128 k×8 bit) was exposed to a series of dose level with a power supply bias of 5 V and subsequently subjected to identical tests for SEU cross section. The experiment was conducted in the vacuum and at room temperature.

The experiment result that SEU cross section changes with ^{112}Sn accumulated dose is shown in Fig 1. It is clear that the SEU cross section remains unchanged at less than 1×10^7 ions/cm^2, decreases with the accumulated dose increased, and increases at 5×10^9 ions/cm^2 accumulated dose. The reason for this phenomenon is discussed below. When the heavy ion accumulated dose is at low of 1×10^7 ions/cm^2, few ions strike at the gate oxide areas. Hence, the low dose irradiation doesn't affect the SEU cross section. With the accumulated dose increased, the SEU cross section decrease is attributed to the memory imprint effects[3]. But when the accumulated dose approaches to 5×10^9 ions/cm^2, increased leakage currents decreases the critical charge for upset[4], which leads to the increase of SEU cross section. In conclusion, the sensitivity of single event upset is impacted by heavy ion accumulated dose.