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Influence of Floating Body Effect on Radiation Hardness of PD SOI nMOSFETs

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Abstract: H-gate and closed-gate PD SOI nMOSFETs are fabricated on SIMOX substrate, and the influence of floating body effect on the radiation hardness is studied. All the subthreshold characteristics of the devices do not change much after radiation of the total dose of 10^6rad(Si). The back gate threshold voltage shift of closed-gate is about 33% less than that of H-gate device. The reason should be that the body potential of the closed-gate device is raised due to impact ionization, and an electric field is produced across the BOX. The floating body effect can improve the radiation hardness of the back gate transistor.

Key words: floating body effect; radiation hardness; SOI

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1 Introduction

Silicon-on-insulator (SOI) CMOS devices have many advantages over bulk silicon devices, and have been used in large-scale circuit implementations[1]. However, the parasitic phenomena in SOI nMOSFETs arising from the floating body effect constitute a major concern[2]. These include the kink in the saturation region of drain output characteristics, early device breakdown induced by the parasitic lateral bipolar transistor and anomalous subthreshold slope and so on. Several techniques have been proposed to reduce the floating body effect, in which body-tie is the most effective one[3,4]. But the influence of the floating body effect on the total dose radiation hardness has never been studied.

In this paper, the influence of the floating body effect on the total dose radiation hardness of PD SOI nMOSFETs is studied. The possible mechanism is also presented.

2 Experiment

PD SOI nMOSFETs were fabricated on SIMOX wafers with a buried oxide thickness of 370nm and the top silicon thickness of 197nm. The SOI nMOS technology has a n^+ doped polysilicon gate, a gate oxide thickness of 20nm, and LOCOS isolation. Lightly doped drain (LDD) technology is utilized, and gate polysilicon and source/drain areas are silicided using titanium silicide. The layouts of the H-gate and closed-gate devices are shown in Fig. 1.

The characteristics of the nMOSFETs were measured with a HP 4145A parameter analyzer. Radiation experiments were performed using Co^{60} gamma rays with a dose rate of 230rad(Si)/s. The source, back gate, and body tie were grounded, and the front gate and drain were biased at 3V during the radiation. All the measurements were finished within 1h after the radiation.

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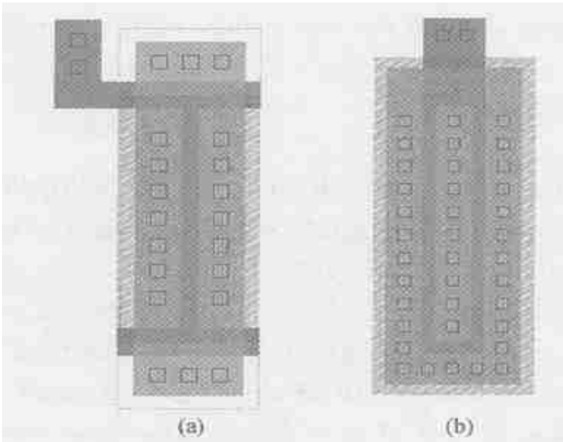

Fig. 1　Layouts of the H-gate (a) and closed-gate devices (b)

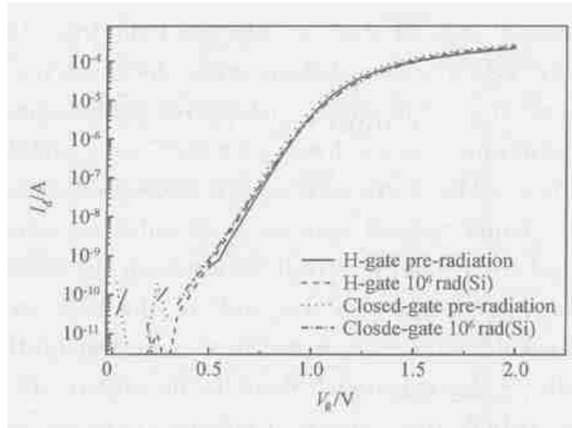

Fig. 2　Subthreshold characteristics of 60/1.2μm H-gate and closed-gate devices before and after a radiation of 10^6rad(Si)

3　Results and discussion

Figure 2 shows the subthreshold characteristics of 60/1.2μm H-gate and closed-gate devices before and after a radiation of 10^6rad(Si). The threshold voltages did not change much and there were no leakage current. Thus the devices have a radiation hardness higher than 10^6rad(Si). Figure 3 shows the back gate subthreshold characteristics. The curves shift to the left with increasing total dose due to the positive charge induced by radiation. The back gate threshold voltage of H-gate device is reduced by 20.49V, from 40.12 to 19.63V. On the contrary, that of closed-gate device is reduced by only 13.13V, from 39.82 to 26.69V, which is about 33% less than that of H-gate device. Figure 4 shows the threshold voltage of H-gate and closed-gate devices with different width as a function of total dose. All the threshold voltages of H-gate devices are changed similarly with the increasing of total dose reducing by about 20V after 10^6rad(Si) radiation. However both threshold voltages of the closed-gate devices are reduced by only about 13V.

The electricfield across the oxide is an important factor to influence the radiation response of the oxide. In closed-gate device, the body region is floating. At high drain bias, impact ionization will tend to raise the body potential. The elevated body potential will produce an electric field from the body region to the substrate while the substrate is biased at 0V. The electric

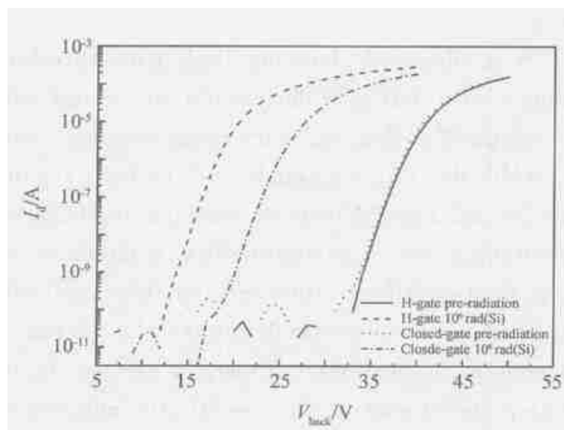

Fig. 3　Back gate subthreshold characteristics of H-gate and closed-gate devices

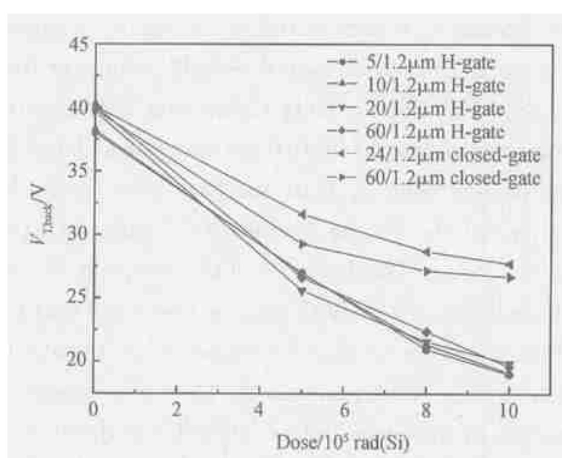

Fig. 4　Threshold voltage of H-gate and closed-gate devices with different width as a function of total dose

field drives the holes created during radiation toward the BOX/ substrate interface ,while electrons escape to the Si/ BOX interface. Holes trapped near the BOX/ substrate interface have a small electrical influence on the silicon film and do induce a less shift of the back gate threshold voltage. However in H-gate devices ,the body is grounded and there is no electric field across BOX. The damage of radiation is higher and the shift of the back gate threshold voltage is more obvious. Thus The floating body effect could improve the radiation hardness of the back gate transistor.

It is observed that the back gate threshold voltage shift of H-gate devices did not change with the width. The floating body effect increases with the width due to the resistance of the body region. The potential of the body region far away from the body tie may be raised and the device shows an obvious floating effect. However ,the threshold voltage of the whole device is determined by the part of channel with the lowest threshold voltage. In the H-gate device with a short width, the entire body region is grounded ,which will induce an important shift of the back gate threshold voltage. On the contrary ,in the H-gate device with a large width ,the potential of the central body region is raised and the shift of back gate threshold voltage at this place is less. But the body region near the body tie is grounded and the shift there could be as large as the narrow devices. Thus the back gate threshold voltage of the H-gate device may change with the distance from the body tie. The threshold of the channel near the body tie may be lower and that far from the body tie may be higher after radiation. The lowest one determines the back gate threshold voltage of the device ,which is similar to the narrow devices. Thus the back gate threshold voltage shift of H-gate devices did not change with the width.

4 Conclusion

H-gate and closed-gate PD SOI nMOSFETs are fabricated on SIMOX substrate ,and the influence of floating body effect on the radiation hardness have been studied. All of them show a radiation hardness more than 10^6rad(Si). The back gate threshold voltage shift of closed-gate is about 33 % less than that of H-gate device. The reason should be that the body potential of the closed-gate device is raised due to impact ionization and an electric field is produced across the BOX. The floating body effect can improve the radiation hardness of the back gate transistor. The electric field reduces the damage of radiation and induces a less shift. The back gate threshold voltage shift of H-gate devices does not change with the width even though the wider devices have more obvious floating body effect. The part of channel near the body tie endures a more important shift of the back gate threshold voltage ,which will determine the radiation tolerance of the whole device.

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PD SOI nMOSFETs 中浮体效应对辐照性能的影响

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摘要: 在 SIMOX 衬底上制备了 H 形栅和环形栅 PD SOI nMOSFETs ,并研究了浮体效应对辐照性能的影响. 在 10^6 rad(Si) 总剂量辐照下 ,所有器件的亚阈特性未见明显变化. 环形栅器件的背栅阈值电压漂移比 H 型栅器件小 33 % ,其原因是碰撞电离使环形栅器件的体区电位升高 ,在埋氧化层中形成的电场减小了辐照产生的损伤. 浮体效应有利于改进器件的背栅抗辐照能力.

关键词: 浮体效应; 辐照; SOI

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