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3D simulations of device electrical characteristics of 3D-Trench electrode detector

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Summary

The square 3D-Trench electrode Si detector structure is simulated using a 3D Silvaco TCAD tool. Electrical characteristics including electrostatic potential, electric field, leakage current, and capacitance have been simulated in detail. It has been found in simulations that both leakage current and the voltage to reach the geometry capacitance (full depletion voltage, V_{fd}) increase with radiation fluence. The leakage current and full depletion voltage at 1×10^{16} neq/cm² are $41.3 \mu\text{A}$ (volume is $2 \times 10^6 \mu\text{m}^3$) and 90 V, respectively. The geometry capacitance is 99 fF for the structure in our study. The full depletion voltage calculated by CV characteristics at different radiation fluences give similar results to those analyzed by the potential and holes concentration profile simulations. In this optimal configuration the full depletion voltage can be up to 7 times less than that of a conventional 3D detector with all column electrodes.

The square 3D-Trench electrode Si detector cell structure is shown in Fig.1. As can be seen from Fig.2 that leakage current increases with radiation fluence. Dotted vertical lines in the figure denote the full depletion voltages as extracted from the corresponding CV simulations (see Fig.3). The voltage to reach the saturation of leakage current also increases with fluence. For fluence of 1×10^{14} , 1×10^{15} and 1×10^{16} neq/cm², the saturation leakage current are 6.37×10^{-9} , 3.33×10^{-8} and 4.13×10^{-7} A, respectively. The capacitance curves in Fig. 3 shows that the geometry capacitance is independent of radiation fluences, which is 99 fF in our case. Fig. 4 shows that the full depletion voltage determined by CV characteristics is almost proportion to fluence, and it is only 90 V for a fluence of 1×10^{16} neq/cm². The magnitudes of the leakage current, capacitance and full depletion voltage obtained from simulations are in agreement with those in literature.

Fig. 1 Structure of the square 3D-Trench electrode detector

Fig. 2 Simulated detector I-V characteristics at three different fluences

Fig. 3 Simulated detector C-V characteristics at three different fluences

Fig. 4 Simulated detector full depletion voltage determined by simulated CV characteristics at different fluences

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