Fabrication of Ultra-thin Oxide-passivated Silicon Surface Barrier Detectors

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In this paper, we describe fabrication of the ultrathin (≤ 50 µm) fully depleted silicon surface barrier detectors, which were passivated using thermally grown silicon oxide. The detectors exhibited leakage current of 2 µA at a reverse bias of 1.1 V. These detectors could resolve the energies of the α-particles from a dual source (^{241}Am – ^{239}Pu).

Introduction

Ultra-thin (≤ 50 µm) fully depleted silicon surface barrier detectors are needed for several applications e.g. particle identification measurements and heavy ion spectroscopy [1]. These detectors are essentially gold/n-Silicon Schottky barrier diodes with their edges passivated with epoxy. However the fabrication of these detectors is tricky due to the following factors: (i) the ultra-thin Si prepared by lapping and acid etching, maintaining the thickness uniformity across the wafer diameter is quite difficult; (ii) at very low thickness, Si wafer breaks easily owing to its brittleness; and (iii) leakage current though the epoxy, which usually increases with time. The commonly used epoxy has hydrophilic nature that makes them prone to react with atmospheric moisture and oxygen, which in turn, increases the leakage current with time. Thus, in order to enhance the longevity of these detectors, one of the alternative methods is to use the thermally grown oxide layer as a passivating material. In this paper, we describe the fabrication of ultrathin oxide-passivated silicon surface barrier detectors and their characterization.

Fabrication process

Various stages of the fabrication process are shown in Fig. 1. First, a thermally oxidized n-type (111) Si-wafer (25 mm diameter, 800 µm thickness and 11 kΩ-cm resistivity) was taken. The thickness of the SiO_2 layer was 0.7 µm. This wafer was then carefully thinned to ~80 µm by lapping from one side such that the oxide layer of the other side is not damaged. The thickness was further lowered down to ~30 µm by chemical etching of the lapped side, while protecting the oxide side. The photograph of the thinned sample is shown in Fig. 1 (a) [2]. Thickness variation within ± 2 µm was measured in sample area of 5-6 mm diameter.

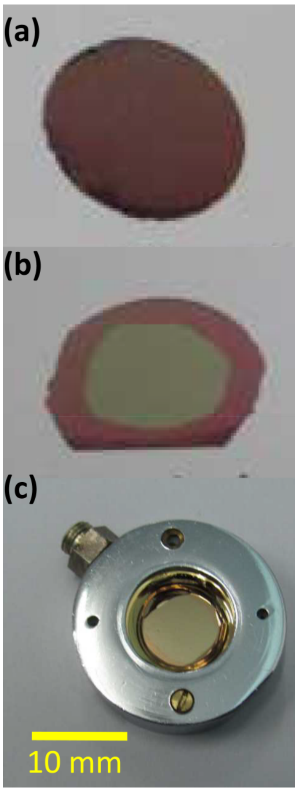

Fig. 1 Photographs of the different fabrication process stages of the ultrathin oxide-passivated silicon surface barrier detectors: (a) ultra-thin (30µm) oxidized Si wafer; (b) oxide is etched out from the center; (c) final assembled detector after Au metallization.

In the second step, a window was opened at the centre of the oxide layer by using 10% HF, as shown in Fig. 1(b). In the third step, this wafer was fixed on a ceramic mount. Then a thin gold layer of 20 nm was deposited onto the side having the oxide layer at the edge. On the back side, an ohmic contact was prepared by depositing 200 nm thick Al using vacuum evaporation at 10^{-6} Torr. Finally, the ceramic mount was hooked up in SS transmission assembly having the microdot connector, as shown in Fig. 1(c).

Results and discussions

Typical semi-log reverse bias current-voltage characteristic of an ultrathin oxide-passivated silicon surface barrier detector is shown in Fig.2. Usually these detectors work in the reverse bias and for the radiation energy measurements, depending on the active area, the leakage current should be less than 2µA for better results. The data of Fig. 2 clearly show that up to 1.1 V, the leakage current remains < 2 µA, clearly indicating that these detectors can be operated at 1 V. However, the operating voltage can be further increased if the quality of oxide layer is improved.

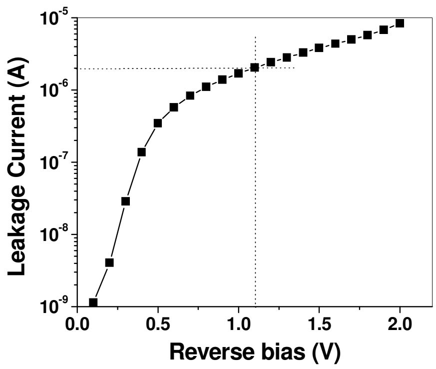

Fig. 2 Current voltage characteristics of a detector recorded in the reverse bias. The dotted line show that a leakage current of >2µm occurs at >1.1 V.

In order to test the applicability of the fabricated ultra-thin detectors for detection of charged particles, they were exposed to α-particles from a dual source (^{241}Am – ^{239}Pu). The typically recorded α-particle spectrum is shown in Fig. 3. The energies of the α-particles emitted from ^{241}Am and ^{239}Pu sources are respectively, 5.48 and 5.15 MeV. These two energies have clearly been resolved by the ultra-thin detector. The optimum energy resolution of 95 keV was obtained for these ultra-thin detectors when a reverse voltage of 112 V was applied through a preamplifier of 110 MΩ load resistance and the leakage current observed was 1.01 µA.

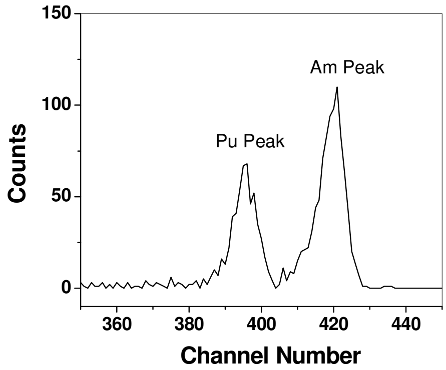

Fig. 3 Typical α-particle spectra recorded using ultra-thin detector when exposed to dual source (^{241}Am – ^{239}Pu).

Conclusions

We have demonstrated fabrication of the ultra-thin (≤ 50 µm) fully depleted silicon surface barrier detectors, which were passivated using thermally grown silicon oxide. The detectors exhibited leakage current of 2µA at a reverse bias of 1.1 V. These detectors have an optimum energy resolution of 95 keV and could easily resolve the energies of the α-particles from a dual source (^{241}Am – ^{239}Pu).

References

[1] F.S.Goulding and B.G.Harvey, Ann. Rev. Nucl. Sci. 25, 167 (1975).
[2] A. Ray, Proc.of DAE-BRNS NSNI-2010, 263-264.