Encapsulation of Oxide-passivated Ion-implanted Silicon Detector

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Performance of oxide-passivated silicon detectors, when operated in vacuum, is usually not much affected. However, as the silicon oxide is hydrophilic in nature, there is a need to encapsulate the detectors for using them in normal ambient. The adsorption of water increases the surface conductance of the silicon dioxide. In biased condition, it leads to spreading of the depletion region under the oxide and thus affects the leakage and noise characteristics. Oxide-passivated ion-implanted p^+/n-Si/n^+ diodes are fabricated in our lab for the detection of charged particles. Encapsulating their oxide surface with an acrylic based resin is seen, as reported here, to make them suitable for use in air.

Detector Fabrication and Evaluation

The procedure followed to fabricate the oxide-passivated planar type of silicon diodes (Fig.1) was reported earlier [1]. For the present study, high-resistivity (4.5/10 kΩ-cm) n-type Si<111> polished (one side) wafers of 50 mm diameter were cleaned in dil Hf and then loaded for oxidation at 1025 °C. Silicon dioxide layer of about 0.6μm thickness was grown for the electrical passivation of the silicon surface. The oxide was also used as the masking material during implantation. A combination of dry, wet and chlorinated oxidation for about 4 hours, followed by annealing in nitrogen for half an hour, was carried out. Oxidized samples were cooled to the room temperature slowly. Windows of 44mm diameter were opened through the oxide on the polished side by masking and etching in Hf to implant boron. B^+ and P^+ ions of 25 keV energy and dose of $1x10^{15}/cm^2$ were implanted at room temperature. The implants were activated at 700°C for half an hour in nitrogen to form the required p^+/n-Si/n^+ structure. Contacts to both the p^+ and the n^+ sides were made by depositing ~40 μg/cm² of Al by thermal evaporation. Al contacts were aged [2] at room temperature for more than a month to fabricate diodes showing low leakages.

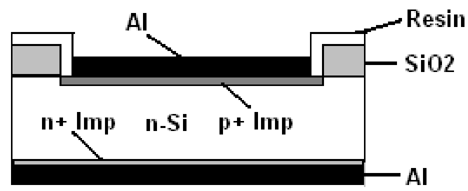

Fig.1. Schematic of the encapsulated oxide-passivated ion-implanted Si detector.

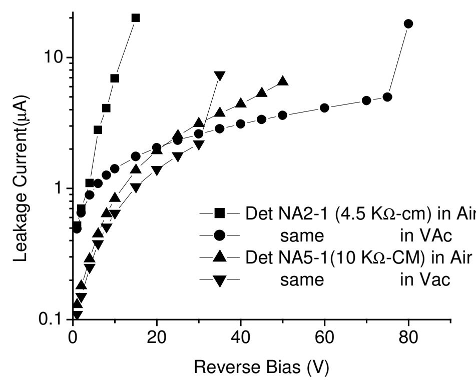

Fig.2. Leakage characteristics of detectors with unprotected oxide.

Large-area (1500mm²) diodes showing sharp and stable breakdown voltages of more than 70V (Fig.2) were fabricated. They were found quite suitable for use as charged-particle detectors in vacuum (~10^{-1} torr). However, when operated in air, they were found too noisy. There was a large variation in their leakage behaviour in air. It could have arisen because of the variation in the process-dependent surface conductance of oxide in the presence of moisture.

Encapsulation

Protection of the silicon oxide against moisture was tried with some of the available epoxy and resin. A method, which has produced acceptable results, is given here. The detector oxide was given a hydrophobic chemical treatment in dimethyldichlorosilane [3] first and then an overcoat of acrylic-based resin (Danmet chemicals make CRC). The conformal coating was air dried for 30 minutes. Evacuation was carried out for two hours to remove the solvent further. Thickness of the encapsulating layer was about 0.1mm. Encapsulated detectors were kept in the normal ambient and their leakage characteristics were monitored over a period of time. It took 5-6 days to record stable leakage/noise characteristics.

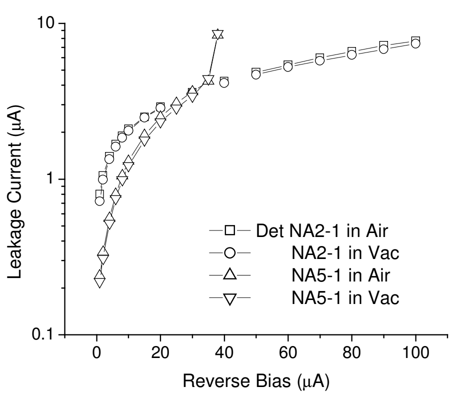

Fig.3. Leakages characteristics of the encapsulated Si detectors.

Encapsulated Detector Performance

The encapsulated detectors showed nearly the same leakage behavoiur in vacuum and air (Fig.3). They were still noisier in air (Fig.4), but could be operated with sufficient bias to detect 5 MeV alpha particles. The response of a 10kΩ-cm detector, with a bias of 10V, to Am-Pu alpha source is produced in Fig.5. The 1500mm^2 –area detector exhibited noise-limited energy resolution of ~115 KeV.

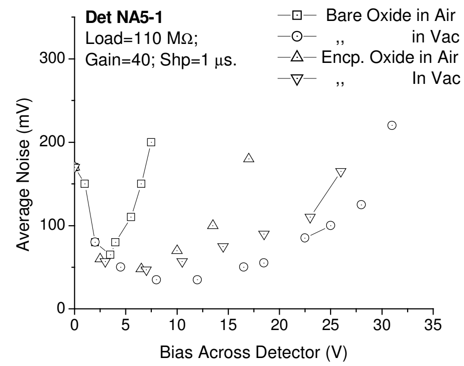

Fig.4. Wide-band av. noise characteristics.

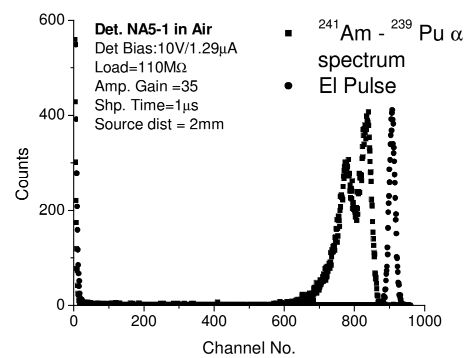

Fig.5. Am-Pu alpha spectrum obtained with a large-area (1500mm^2) encapsulated detector.

Use of better grade (El) resin in the encapsulation process is expected to improve the performances of the oxide-passivated detectors in air further.

Acknowledgement

The author is thankful to Dr. J.V. Yakhmi, Associate Director, Physics Group for his encouragement and support.

References

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[3] D. Sahoo, *ibid,* 52(2007)615.