I. 18. Characteristics of Au-Si Nuclear Detectors Irradiated by 10 MeV α-Rays

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Introduction

The Au-Si surface barrier nuclear detectors have shown good performance for the charged particle detection. However, radiation damage in the semiconductor detector is serious problems because of the effect of carrier trapping with deep levels\(^1\-4\).

The purpose of this report is to investigate the irradiation effects of the detectors bombarded by 10 MeV α-rays. Degradation characteristics are studied by I-V(current-voltage), C-V(capacitance-voltage), radiation counting response and DLTS\(^3\)(deep level transient spectroscopy) measurements.

Experimental

The Au-Si surface barrier nuclear detectors used in this study were fabricated from phosphorus doped n-type Si wafer with a resistivity of about 2 kΩ-cm and thickness of 400 μm. After removing the oxidized layer of the one side of the Si specimens(9 mmφ), in order to make the rear ohmic contact, the aluminum spattering was carried out. The front surface barrier contact was formed by the evaporation of gold.

The detectors were irradiated with α-rays by using the Tohoku University Cyclotron. The irradiations with the 10 MeV α-rays were carried out perpendicularly on the Au surface side of the detector in the vacuum chamber at room temperature. The irradiation doses were up to \(5.5 \times 10^{10}\) n/cm\(^2\).

In order to study the irradiation effects on the detectors, the reverse current, capacitance, counting response to \(^{241}\)Am α-rays(5.48 MeV) and DLTS were measured before and after irradiation. The DLTS is a capacitance transient thermal scanning method at high frequency(1 MHz) and is used to determine the energy levels of deep traps in semiconductors.

Results and Discussion

In the I-V measurements, it was observed that the reverse currents increased after irradiation and with increasing of the α-ray irradiation doses. It is thought that the increasing
of the reverse currents is due to the carrier generation through the irradiation defect-states introduced in the depletion layer of the detector.

Figure 1 shows the C-V characteristics before and after irradiation with the 10 MeV α-rays. As seen in this figure, when the bias voltage is over 10 volts, the C-V characteristics after irradiation does not decrease in proportion as the bias voltage increases. This phenomenon is thought as next. Since the depletion layer width of the detectors for the 10 V bias corresponds to the range(70 μm) of the 10 MeV α-rays in the Si and the induced defect density is condensed in this region as shown by the profile of the Rutherford scattering cross section, the depletion layer does not increase, and consequently, the capacitance does not decrease even if the bias voltage increases.

Counting response of the detector to $^{241}$Am α-particles at 20 V bias is shown in Figure 2, before and after irradiation. After irradiation with the α-ray fluxes of $5.5 \times 10^{10}$/cm$^2$, the spectrum is markedly degraded. Small peaks at 5.44 MeV and 5.39 MeV disappear, and the peak position shifts toward the lower channel numbers. The full width at half maximum(FWHM) of the spectrum before irradiation is 26.2 keV, but after irradiation, FWHM becomes 78.4 keV. As this reason, it is thought that the carrier collection efficiency became degraded due to the trapping centers which were introduced by irradiations.

From the DLTS measurements, two energy levels are observed. The energies of two levels are estimated as 0.38 eV and 0.52 eV to the conduction band, respectively. It is thought that the 0.38 eV and 0.52 eV level are the states due to the divacancy and the interaction between divacancy and oxygen, respectively.

Acknowledgment

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References

Fig. 1. Capacitance-voltage characteristics before and after irradiation with 10 MeV \( \alpha \)-rays.

Fig. 2. Counting response to \(^{241}\text{Am} \alpha\)-rays (5.48 MeV) before and after irradiation with 10 MeV \( \alpha \)-rays.