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Investigations on Damage of GaAs Detectors caused by Neutrons (Peak Energy 1 MeV) and Co^{60} Photons

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Abstract

In April 1994 we irradiated more than 60 GaAs detectors made from the same wafer with different fluencies in the ISIS neutron source at the Rutherford Appleton Laboratory. The detectors were produced in Aachen from SI-GaAs from American Xtal Technology (AXT). All detectors remained functional after irradiation with up to $1 \times 10^{15} \frac{n}{cm^2}$. Even at the highest radiation level the reverse current density of the detectors is below $50 \frac{nA}{mm^2}$ at 200V bias voltage, only a factor of four higher than before irradiation. After $1 \times 10^{15} \frac{n}{cm^2}$ the signal for minimum ionising particles is a factor of two lower than before irradiation. No difference was seen between detectors that were biased during the exposure and those that were not. The detectors were operated at room temperature during and after the exposure.

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1 The irradiated devices

The 300 μm thick SI-GaAs wafer from AXT was completely processed in Aachen in 1993. The detectors were formed by reverse biased $NiCr/Au$ Schottky contacts with 3mm diameter. The back-side contact was formed by only one uniform $NiCr/Au$ Schottky contact over the entire wafer. This contact was forward biased and thus showed ohmic behaviour. Figure 1 shows the arrangement of the 110 diodes on the wafer.

Figure 1: The design of the irradiated GaAs detector

irradiation fluence / $\frac{n}{cm^2}$	# of diodes	# of biased diodes
-	20	-
1×10^{14}	20	5
5×10^{14}	23	5
1×10^{15}	20	5

Table 1: Radiation levels for the different devices

The wafer was sawn in four pieces and three of them were sent to the ISIS neutron source. To examine the difference between biased and not biased detectors, five diodes on each wafer were biased with 200V during the three weeks of irradiation time. Table 1 lists the radiation levels and the number of irradiated diodes on each wafer quadrant. The energy spectrum of the neutrons used here is strongly peaked at 1MeV as can be found in [1].

The typical I-V characteristic of the GaAs detectors before irradiation is shown in figure 2. The reverse current density at 200V bias voltage is $12 \frac{nA}{mm^2}$, a value very homogeneous for all 110 diodes. The breakdown voltage for these detec-

Figure 2: Typical I-V characteristic for a GaAs detector

tors is about 375V so that we are able to measure the dependence of the signal for a minimum ionising particle on the bias voltage continuously and safely up to 350V. The signal increases nearly linearly with the applied bias voltage and is bigger than $16000e^-$ at 350V (figure 3).

Figure 3: Signal for minimum ionising particles versus applied bias voltage

2 Measurements after irradiation

After the irradiation all detectors were found to work satisfactorily at room temperature. The I-V characteristics plotted in figure 4 shows that the current density after $1 \times 10^{15} \frac{n}{cm^2}$ is below $50 \frac{nA}{mm^2}$ at 200V bias voltage. At 300V it is still below $70 \frac{nA}{mm^2}$. The homogeneity of the sample has not changed with the irradiation. There was no difference seen between biased and not biased detectors. Figure 5 shows typical minimum ionis-

Figure 4: IV characteristics after irradiation at room temperature

ing particle spectra before and after irradiation. The signal is clearly visible even with a shaping time of $1\mu s$. In this example the applied bias voltage is 200V while the radiation level for this sample is $5 \times 10^{14} \frac{n}{cm^2}$.

The average signal for minimum ionising particles decreases with the radiation level as shown in figure 6. Starting with about $16000e^-$ at 300V bias voltage the signal drops to $7000e^-$ after the highest radiation level ($1 \times 10^{15} \frac{n}{cm^2}$).

Figure 5: Typical $Sr^{90} e^-$ spectra before and after $5 \times 10^{14} \frac{n}{cm^2}$ with a shaping time of $1 \mu s$

3 Conclusion

More than 60 GaAs detectors have been irradiated at the ISIS neutron source with fluences reaching up to $1 \times 10^{15} \frac{n}{cm^2}$. All detectors work well after the irradiation without requiring cooling. The very good homogeneity of the detector sample was not affected by the exposure. No difference was found between detectors that were biased during the exposure and those that were not. The current density is below $70 \frac{nA}{mm^2}$ at 300V after $1 \times 10^{15} \frac{n}{cm^2}$. The signal for minimum ionising particles is about $7000e^-$ at 300V after the highest radiation level and neither annealing nor anti-annealing is seen. Former investigations with Co^{60} photons (total dose 100Mrad) did not show any significant changes in detector parameters [2]. More detailed information about the measurements presented here can be found in [3].

Figure 6: Signal for $Sr^{90} e^-$ versus radiation level

4 Acknowledgements

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References

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