Chapter 28
Silicon Carbide Schottky Diodes for Alpha Particle Detection

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Abstract The fabrication and characterization of SiC Schottky diodes for the detection of alpha particles at room temperature are described. A 5 × 5 matrix of diodes has been fabricated in order to verify the dependence of the device response on randomly distributed wafer defects. A dedicated exposure apparatus has been fabricated to test the detectors. Some preliminary alpha energy spectra obtained with the lowest reverse current diodes are shown.

28.1 Introduction

Silicon carbide (SiC) has been largely investigated for the fabrication of high power, high frequency, high temperature electron devices due to its excellent electronic properties. It is a wide bandgap semiconductor material with high thermal conductivity and high breakdown electric field strength [1]. These properties, connected to a high chemical and radiation resistance, make it suitable for sensor applications in harsh and hostile environments [2]. In the last years, SiC has also been proposed for the fabrication of semiconductor radiation detectors able to work at elevated temperatures in high radiation fields [3, 4].

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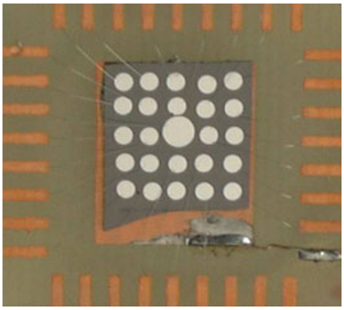

Fig. 28.1 Photograph of the device

In this work we propose the fabrication and characterization of SiC Schottky diodes for the detection of alpha particles at room temperature.

28.2 Device Fabrication and Characterization

Devices were fabricated on a 1 cm × 1 cm sample diced from a 4H-SiC *n* type wafer (SiCrystal AG) with a top low doped *n* type ($N_D = 3 \times 10^{15}$ cm^{-3}), 20 μm thick epilayer, separated from the substrate by a high doped *n* type ($N_D = 1 \times 10^{17}$ cm^{-3}), 2 μm thick buffer layer. In order to verify the dependence of the diode characteristics on the randomly distributed wafer defects, a 5 × 5 matrix of diodes was defined. The ohmic contact, common to all diodes, was deposited by e-beam evaporation on the back side of the die and consists in a double metal thin film (Ti 30 nm/Ni 200 nm). A rapid thermal annealing at 1,000°C for 300 s in nitrogen was performed in order to obtain a good ohmic contact. The 25 Schottky contacts were defined by evaporating a double metal thin film (Ni 100 nm/Al 500 nm) through a stencil mask. After the contact definition, the die was glued to a PCB board by means of silver paste and wedge bonding was used to connect diodes to the board pads.

A photograph of the sample at the end of the fabrication process is shown in Fig. 28.1: all diodes have a diameter of 1.2 mm, except the 3–3 (row–column) diode (2.1 mm).

All devices have been characterized by means of *I–V* measurements at room temperature and the forward *I–V* curves for some diodes are shown in Fig. 28.2a. It can be noted the dispersion of the curves of diodes with the same nominal Schottky contact area. This phenomenon has been found also in the reverse *I–V* curves with a variation of the current density up to five orders of magnitude among diodes placed in different sample areas. Considering that diodes will be reverse biased for radiation detection, the availability of high quality SiC wafers with low density of defects, like micropipes and stacking faults, is mandatory for this type of application.

In Fig. 28.2b the reverse current density of a diode measured at room temperature is shown.

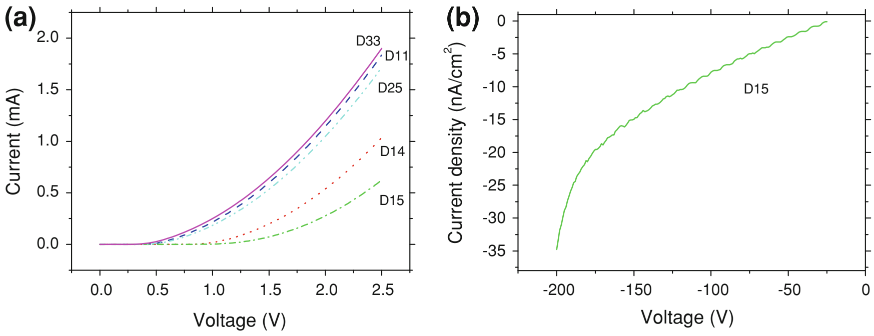

Fig. 28.2 **a** Forward *I–V* curves for some of the tested diodes; **b** reverse current density of a diode measured at room temperature

Table 28.1 Alpha radioactive sources and relative energies and activities

Source	Nuclide	Principal alpha emission energy (MeV)	Activity (kBq)
Source 1	^{239}Pu	5.157	2.22
	^{241}Am	5.486	1.60
	^{244}Cm	5.805	0.95
Source 2	^{239}Pu	5.157	3.70

28.3 Measurement Set-up

In order to test the previously described detector, a dedicated exposure apparatus has been fabricated. It was made up of an aluminum case containing the SiC sample holder which allows to place the detector in front of the ionizing radiation source at an adjustable distance. The case shields the device from electromagnetic external noise and the inner pressure can be reduced by means of a rotary pump. The device output signal was transmitted to the acquisition chain consisting in a charge preamplifier in cascade with a standard Canberra multi channel analyzer (MCA) for signal conditioning and analysis.

28.4 Experimental Results

A multiple alpha (^{239}Pu, ^{241}Am and ^{244}Cm) and a ^{239}Pu radioactive sources were used for the experiments (Table 28.1). The optimum source-to-detector distance which maximizes the alpha energy loss into the diode depletion layer (about 8.5 μm thick at 200 V) was evaluated by the TRIM© code: considering an air gap of 26 mm between the source and the detector, the resulting average alpha range was 8.1 μm with a 2% straggling (Fig. 28.3).

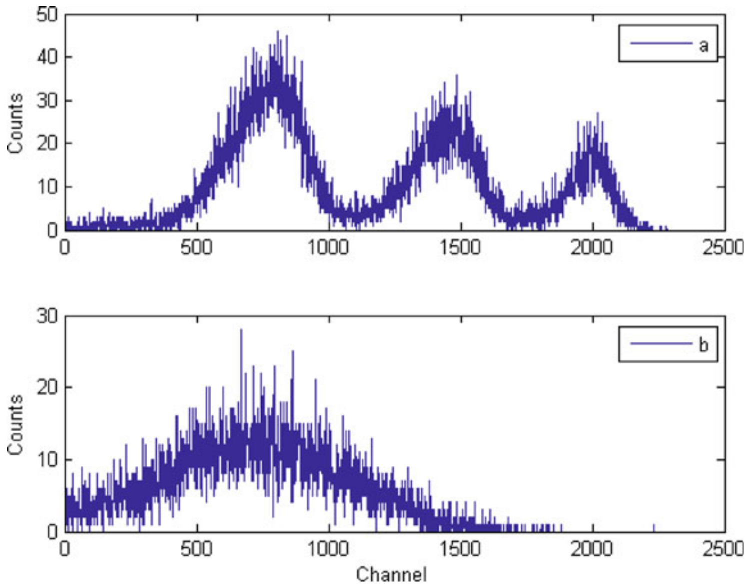

Fig. 28.3 Energy loss per unit length (eV/Å) at a source-to-detector distance of 26 mm

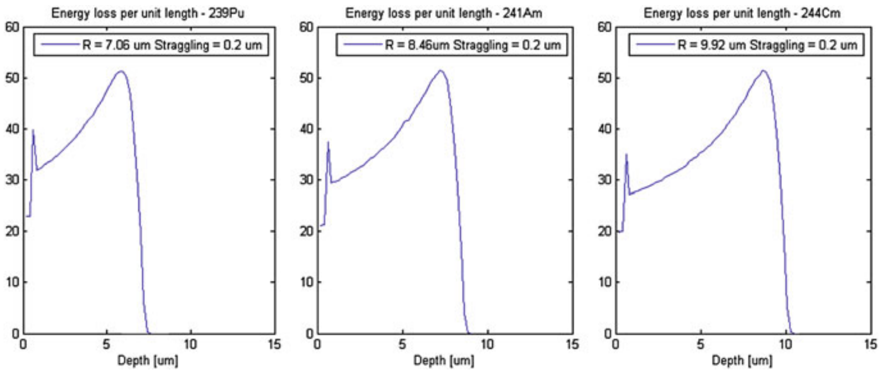

Fig. 28.4 Alpha energy spectra: **a** multiple alpha source (^{239}Pu, ^{241}Am, ^{244}Cm); **b** ^{239}Pu alpha source

Two spectra obtained with a reverse bias voltage of 200 V are shown in Fig. 28.4: (a) multiple alpha source (acquisition time: 14,400 s) and (b) plutonium source (acquisition time: 4,500 s). As it may be noticed, with the same experimental conditions, the single ^{239}Pu peak is coincident with the corresponding plutonium peak from the multiple source.

28.5 Conclusions

The fabrication and characterization of Schottky diodes on a SiC substrate have been described. The Schottky contact consists in a double metal thin film (Ni 100 nm/Al 500 nm) defined by means of evaporation through a stencil mask. The dependence of the diode characteristics on the randomly distributed wafer defects has been confirmed by *I–V* measurements performed on a 5 $\times$ 5 matrix of devices. Preliminary detection measurements at room temperature have proven the feasibility of using these devices as alpha particle detectors.

References

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