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First results on characterization of a silicon carbide dosimeter in the framework of SAMOTHRACE ecosystem

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Summary. — Silicon carbide (SiC) detectors recently received an increased interest in the scientific community for their application in several fields such as medical one and nuclear physics. In this context, a part of the SAMOTHRACE (Sicilian Micro and Nano Technology Research and Innovation Center) project aims at developing silicon carbide detectors to be used as dosimeter, micro-dosimeter and beam monitor. In this contribution, the first results on the characterization of two types of SiC detectors will be presented: the devices have an active area of $\simeq 1$ cm^2 and a thickness of 10 μm and 100 μm, respectively.

1. – Introduction

The outstanding properties of wide band gap semiconductors have stimulated an increasing research effort towards different application fields. High band gap materials such as diamond and silicon carbide have been proposed as an alternative to silicon in semiconductor-based radiation detection devices. Furthermore, thanks to the high sensitivity per unit volume, solid-state detectors have been suggested as suitable alternative for nowadays dosimeters. Another characteristic of these devices is their immediate dose response, in contrast to passive integrators such as TLDs or films. From the different properties of diamond, Si and SiC (table I), the radiation hardness makes the SiC devices suitable for environments with high levels of radiations. SiC is characterized by a higher resistance to temperature and high band-gap, which allows a signal-to-noise ratio fairly higher than Si devices [1, 2]. Also, SiC is relatively insensitive to light, property that can be useful for wearable devices. In this stimulating environment, the aim of the work

Table I. – *Comparison of the properties of three materials for radiation detection* [1].

Property	D	Si	4H-SiC
Atomic number Z	6	14	14–6
Density (g cm^{-3})	3.51	2.33	3.22
Relative permittivity	5.7	11.9	9.7
Energy gap (eV)	5.5	1.12	3.23
e-h pair creation energy (eV)	13	3.6	7.6–8.4
Displacement energy (eV)	43	13–15	30–40
Breakdown electric field (V cm^{-1})	10^7	$3\cdot 10^5$	$3–4\cdot10^6$
Electron mobility (cm^2 V^{-1} s^{-1}) at 300 K	1800	1450	800
Holes mobility (cm^2 V^{-1} s^{-1}) at 300 K	1200	450	115
Saturated electron drift velocity (cm s^{-1}) at 300 K	$2.2\cdot10^7$	$0.8\cdot10^7$	$2\cdot10^7$
Thermal conductivity (W K^{-1}cm^{-1})	24–25	1.5	4.9

presented in this contribution is to characterize and to develop Silicon Carbide devices for medical and nuclear applications. This work is made possible thanks to the synergy between CHIRONE collaboration and SAMOTHRACE [3] ecosystem which converged on a common ground in advancing this project's development.

2. – Experiment and data analysis

Two SiC devices with a surface of $1\,\text{cm}^2$ and thickness of $10\,\mu$m and $100\,\mu$m, respectively, were characterized to use them as a dosimeter, micro-dosimeter and a beam monitor, respectively. The first detector characterized during our experimental campaign is a $10\,\mu$m thick SiC, monolithic type divided into four active pads. At first, electric measurements were done to characterize the SiC. In particular, the so-called capacitance-voltage (CV) measurements allowed us to deduce the capacitance of the SiC detector and its depletion voltage. The current-voltage measurements (IV), on the other hand, are able to estimate the so-called dark current, created by the free carriers in absence of any incoming particle. Another focus of the activity has been the optimization of the detector's performance in terms of energy and timing resolution, maximizing the signal-to-noise ratio. Due to the segmentation of the detector in four pads, more work is necessary to take into account potential inter-pad, cross-talk and edge effects. These measurements have been performed at the laboratory of INFN-LNS with the use of a ^{148}Gd α radioactive source. Figure 1 shows the SiC device tested (left) together with the ^{148}Gd α radioactive source and its support (right). To perform these measurements a NeT instruments preamplifier, and a DT5725 CAEN digitizer (250 MHz), have been used. Figure 2 shows an energy *vs.* rise-time scatter plot (a), characterized by two

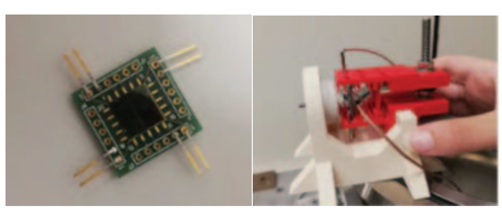

Fig. 1. – SiC devices tested (left) and SiC detector mounted on its support with a ^{148}Gd α radioactive source (right).

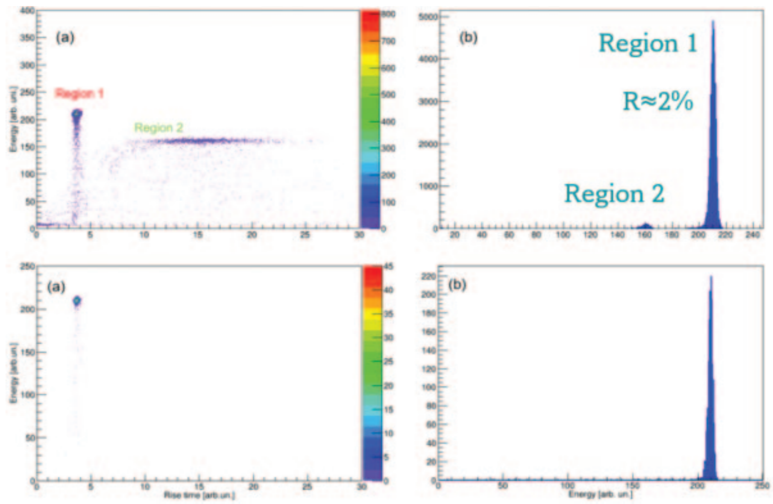

Fig. 2. – (a) Plot of rise time *vs.* energy for one pad of the tested SiC, (b) energy projection of (a).

regions of events: the first one with rise time<20 [arb.un.] and energy>450 [arb.un.], and the second one with energy<400 [arb. un.] and 20 [arb.un.]<rise time< 90 [arb.un.]. Figure 2(b, top) shows a projection in energy of fig. 2(a, top). By means of a Gaussian fit on the peak at higher energy, a resolution around $\simeq 2\%$ has been obtained. Events from the second region have a multiplicity mainly equal to one ($\simeq$ 90%), so interpad events or spurious cross-talk contribution are excluded. Such events can be, on the other hand, associated with a poor charge collection on the edges of the detector: if a collimator is in fact placed in front of the detector, in such a way that only the central part of the latter is hit by the alpha particles, such events disappear (fig. 2(a, bottom)). A second SiC, 100 μm thick, monolithic device has also been tested, built with the aim of being used as a beam monitor [4]. In addition, a test at INFN-LNL was performed using a secondary neutron beam —originated by a proton 5.5 MeV beam impinging on a LiF target— driven into a CH_2 plastic (200 μm thick), placed in front of the SiC detector. Neutrons, interacting with the plastic, produce protons that are detected by the SiC. The electronic chain used for this experiment consists of a Mesytec preamplifier, connected to a Caen Digitizer (1 GHz–16 channels), directly connected to a laptop. The same threshold was used for the pad number 2 and 3, while a higher threshold was used on the pad number 1, and the number 4 was too noisy to be used (fig. 3). A simulation was performed thanks to the GEANT4 toolkit to recreate the SiC device and compare its simulated response with the experimental data. A neutron beam at 4.5 MeV was simulated as shown in fig. 4. According to the literature, the spectra are ending around 4.5 MeV. Some discrepancies between experimental and simulated data were observed, requiring an improvement of in progress simulations.

3. – Results and conclusions

Two sets of monolithic SiC detectors with a surface of 1 cm^2 and divided into four pads have been investigated. A 10 μm thick SiC device to be used as a dosimeter was first tested with electronic measurements (IV-CV) and characterized under a ^{148}Gd α source. An effort to investigate interpad, crosstalk and edge effects has been done thanks

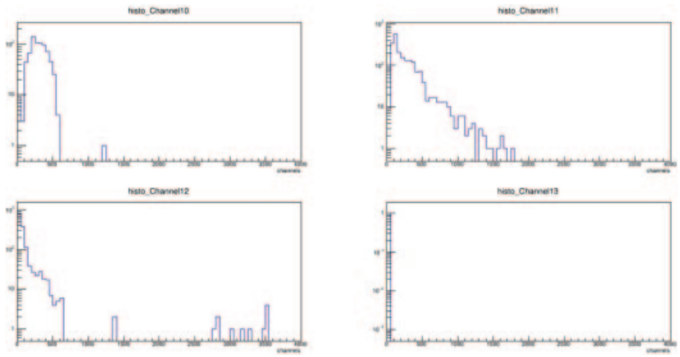

Fig. 3. – Experimental energy spectrum in arbitrary units for recoiling protons.

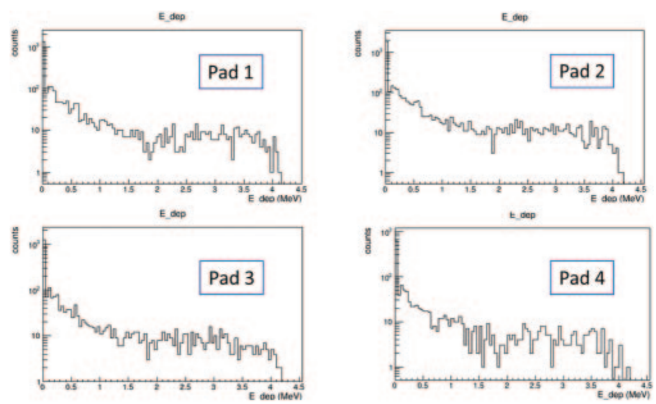

Fig. 4. – GEANT4 simulation of a SiC's response under a 4.5 MeV neutron beam.

to the use of collimators. From the data analysis, edge effects have been highlighted. The next step, on the 10 μm thick SiC, will be using different preamplifiers to be sure of the nature of the edge effects. Following, a 100 μm thick device has been tested under a neutron beam. At first, a data analysis was performed to obtain a preliminary experimental energy spectra, then the experimental energy spectra was compared with the simulated ones obtained with GEANT4 toolkit. In the future, the two energies of neutrons originating from the p+LiF reaction will be simulated to better study the energy resolution of the detector.

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