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Average energy dissipated by mega-electron-volt hydrogen and helium ions per electron-hole pair generation in 4H-SiC

Alessandro Lo Giudice
CNR-INFM, Experimental Physics Department and NIS Centre of Excellence, University of Torino (I)

Franco Fizzotti, Claudio Manfredotti, and Ettore Vittone[a)]
Experimental Physics Department, NIS Centre of Excellence, University of Torino and INFN-To, Torino (I)

Filippo Nava
Physics Department and INFN, University of Modena and Reggio Emilia (I)

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The pulse height response for He and H ions with energies between 1 and 6 MeV incident upon n-type 4H-SiC epitaxial Schottky diodes has been investigated. The average amount of energy, ε, given up by the incident radiation to form electron-hole pair in this material was obtained by comparison with the average energy loss per pair in silicon detectors and it was found to be (7.78 ± 0.05) eV at room temperature. This value is smaller than that foreseen by Klein's semiempirical linear relationship between ε and the semiconductor band gap. © *2005 American Institute of Physics*. [DOI: 10.1063/1.2135507]

Since the 1960s, silicon carbide has been considered a promising material to make ionizing radiation detectors. The large band gap, high carrier saturation velocity, high breakdown field, and high bonding energy make SiC an attractive alternative to Si especially for applications involving elevated temperature and in high radiation environments.

In recent years considerable advances in material synthesis and processing have allowed for the realization of neutron,[1,2] charge particle,[3–5] and x-ray detectors[6] using the n-type 4H-SiC polytype.

These detectors have been extensively studied both from the point of view of their electronic properties, defect distribution, spectroscopic characteristics, and radiation hardness.[7,8]

However, experimental data available in literature concerning measurement of average energy consumed by ionizing radiation to generate electron-hole pairs (ε), exhibit a remarkable dispersion, as shown in Table I. For this reason and because of the renewed interest in this material, in this letter we report on a measure of ε in 4H-SiC using alpha particles (from 1.2 to 5.8 MeV) and protons (from 1 to 2 MeV).

Two Schottky diodes fabricated from epitaxial 4H-SiC were used; details on diode fabrication and characterization can be found elsewhere.[2,8,10]

Briefly, diode A was realized by the Alenia Marconi system (AMS) on an approximately 40-μm-thick n-type 4H-SiC epitaxial layer [4.5×10^{14} cm^{-3} donor concentration (N_D)] grown on standard micropipe density (100–200 cm^{-3}) n^+-type 4H-SiC wafers purchased from CREE Research Inc. The Schottky contact was formed on the Si face of the epitaxial layer by deposition of about 100 nm gold film. Standard lithographic techniques were used to define circular electrodes with a diameter of 1.5 mm and a 100 μm wide guard ring structure. Ohmic contact was made on the substrate side (C face) by the deposition of a multilayer Ti/Pt/Au.[8]

Diode B was made by AMS evaporating a Ni/Au multilayer on a (49.0 ± 0.8)-μm-thick n-type 4H-SiC epitaxial layer ($N_D=1.5\times10^{14}$ cm^{-3}) grown by the Institut für Kristallzüchtung, Berlin on low micropipe density (16–30 cm^{-3}), n^+ substrate from CREE. In this case the electrode diameter was 5 mm and the guard ring was 150 μm wide.[2,10]

The ion beam induced charge measurements were performed irradiating the 4H-SiC diodes and a reference silicon surface barrier detector (ORTEC model B-015-050-1000) with He ions emitted from a calibrated triple alpha source (^{239}Pu, ^{241}Am, ^{244}Cm; 1 kBq/isotope) and using the 2.5 MV LNL AN2000 Van de Graaff accelerator as a tunable source for He and H ions in the energy range of 1–2 MeV.[8] In the second case, the ion beams from the Van de Graaff accelerator were focused onto the detector surface to a spot of about (0.1×0.1) mm^2; the ion currents were maintained below 0.1 fA in all the experiments in order to avoid any pileup effect. In both the cases, the measurements were performed at room temperature in high vacuum conditions (pressure below 10^{-3} Pa).

The value of ε is related to the energy of the incident particle E available for electron-hole pair generation, via

$$E=\varepsilon\cdot N_{eh}, \tag{1}$$

where N_{eh} is the average number of pairs created in the active volume of the detector. The determination of N_{eh} was

TABLE I. Measured values of ε_{SiC}.

Reference	Material	ε (eV)	Radiation
9	6H-SiC	9.0 ± 0.7	e^-
6	Epitaxial n-type 4H-SiC Schottky diode	7.8	x ray
3	Epitaxial n-type 4H-SiC Schottky diode	7.71	α
7	Epitaxial n-type 4H-SiC Schottky diode	8.6	α
4	Semi-insulating 4H-SiC	8.4	α

[a)]Electronic mail: vittone@to.infn.it