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Hassan Hamad, Christophe Raynaud, Pascal Bevilacqua, Sigo Scharnholz, Dominique Planson. Temperature Dependence of 4H-SiC Ionization Rates Using Optical Beam Induced Current. ECSCRM'14, Sep 2014, Grenoble, France. pp.MO2-IP-08. hal-02133683

HAL Id: hal-02133683

<https://hal.science/hal-02133683>

Submitted on 27 May 2019

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Temperature dependence of 4H-SiC ionization rates using Optical Beam Induced Current

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The behavior of the power components designed with the silicon carbide 4H-SiC in environments with varying temperature is a key parameter indicating their reliability. This paper shows the dependence of the ionization rates of 4H-SiC with respect to the temperature. Ionization rates are not too widely studied and the results already found are, more or less, dispersed [1-3]. Their determination helps predict more accurately the critical electric field and hence the breakdown voltage. Studying the ionization rates under varying temperatures allows the design of high breakdown voltages components under different temperature conditions. The method involves using an optical beam with appropriate wavelength to light perpendicularly a reverse biased PN junction. The photon absorption leads to the generation of electron-hole pairs (EHPs) that may or may not be submitted to an electric field depending on the depth at which they are created. EHPs created in the space charge region (SCR) will be accelerated, and thus an induced current is measured hence the naming of the method: Optical Beam Induced Current (OBIC) as shown in fig. 1. For voltages near the breakdown voltage, the electric field becomes high, the EHPs gain a kinetic energy and collide with the atoms in the crystalline structure leading to the generation of a new EHPs, which in turns may lead to the creation of new EHPs; this is manifested by an increase of the OBIC signal. The multiplication coefficient is defined as the ratio between the induced current at a given voltage and at 0 V (where there is no multiplication). The ionization coefficients curves are derived from the multiplication curves.

The measurements are realized on circular avalanche diodes protected with MESA etching and having a breakdown voltage of 59V. At the center of the diode, an optical window is located allowing the optical beam to penetrate into the SCR (fig. 2) [4]. A pulsed UV laser with a wavelength of 349 nm is used to generate the EHPs. The pulse energy can be adjusted up to 120 μ J. The pulse duration varies between 3 and 7ns according to frequency and pulse energy (fig. 3).

The laser beam is scanned along the diameter of the diode to measure the OBIC signal. The measurement is done between 200 K and 400 K temperatures with a step of 25 K. In addition, for each temperature value the voltage is scanned up to the breakdown voltage. Fig. 4 shows the OBIC signal vs. the beam position for several reverse voltages at 250K. Fig. 5a shows the multiplication ratio vs. the voltage at 250K and fig. 5b shows the ionization rates vs. the inverse of the electric field at the same temperature. More results showing the variation of ionization rates vs. temperature will be published in the final paper. Studying these variations allows determining the dependence law between ionization rates and the temperature variation.

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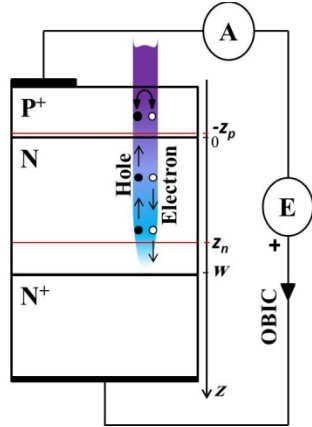


Fig. 1: Schematic view of OBIC principle.

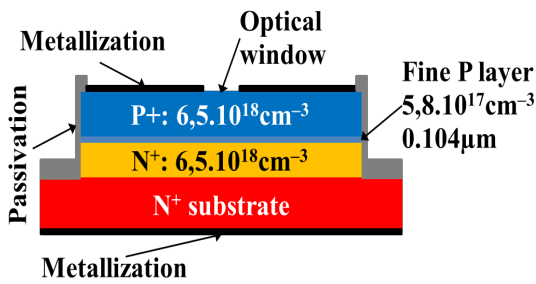


Fig. 2: Cross section view of avalanche diode.

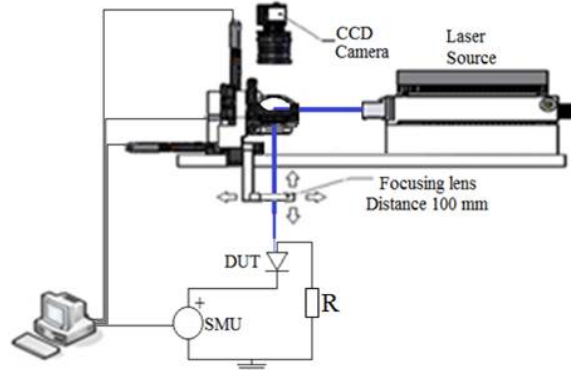


Fig. 3: Schematic view of OBIC bench.

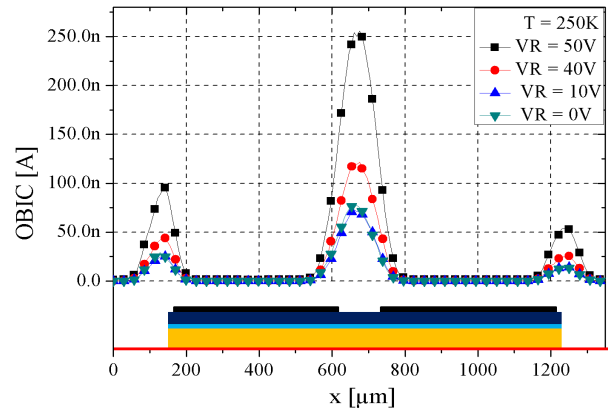


Figure 4: OBIC signal vs. Beam position for several reverse voltages at 250K.

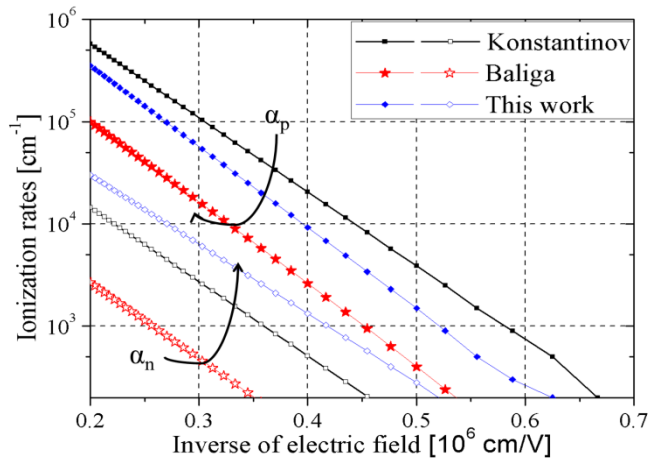
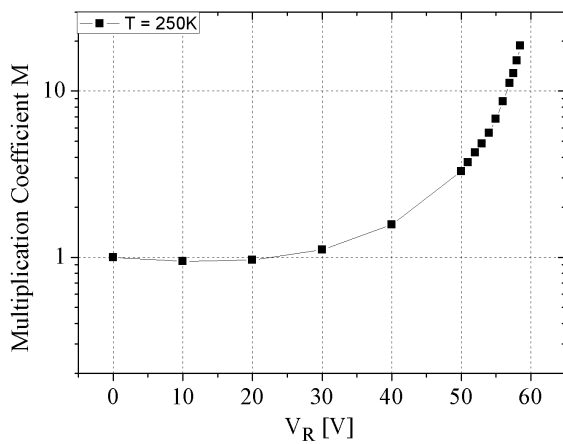


Fig. 5: (a) Curve of multiplication coefficient vs. Reverse voltage at 250K, (b) Ionization rates of 4H-SiC vs. the inverse of electric field at 250K for this work.