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Characterization of 4H-SiC junction barrier Schottky diodes by admittance vs. temperature analyses

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Junction barrier Schottky (JBS) diodes are of great interest for high voltage applications because they joint the advantages of i) bipolar diodes in reverse bias i.e. low leakage current ; ii) the low barrier of Schottky diodes in forward bias, and iii) the minority carrier injection from bipolar operation at high voltages or high temperatures in forward bias, resulting in lower on-resistance. This paper reports first admittance spectra on JBS diodes.

Description of the devices and techniques

Schottky (SBD) and Junction Barrier Schottky (JBS) were fabricated on a 5 μm n-type epilayer with a doping value in the $2 \times 10^{16} \text{cm}^{-3}$ range. For defining P⁺ regions of the JBS diodes an Al multi-implantation was performed. JTE is used as the termination technique for high voltage capability also defined by Al implants. The anode metal for SBD and JBS rectifiers is Nickel annealed at 500°C (Fig.1). This paper reports on admittance spectroscopy (AS) of these 4H-SiC junction barrier diodes. AS is a technique that has been developed in early 80's on Schottky barrier [1] and pn junction [2].

Experimental results and discussion

From C-V measurements doping level and barrier height can be extracted by plotting $1/C^2$ vs. V (Fig.2). For lower temperature, due to the freeze-out of carriers, the extracted doping concentration (from the slope of $1/C^2$ vs. V) slightly varies with temperature (Fig.3). In contrast, above room temperature, C-V curves are virtually independent of temperature. A barrier height of 0.95 eV is extracted from Current-Voltage measurement in forward bias from the thermoionic-emission theory. However, SBD and JBS both exhibit large built-in potential V_{bi} derived from the value of the intercept with x-axis. This is due to the depletion of the P⁺ ring which is located at the edge of the devices alongside the JTE. For this reason JBS and SBD C-V curves are like as the one from p-n junction based devices, with large V_{bi} (Fig.4).

AS has ever been used to determine activation energies of the dopant in Schottky diodes [3] and bipolar diodes [4]. AS is now used on JBS and compared with results on SBD (Fig. 5 and Fig. 6). In each case, conductance spectra show three peaks, with a maximum depending on frequency. First analyses seem to indicate that the energy of all these peaks are closed values ~ 0.2 eV, possibly due to aluminium levels.

The difference between SBD and JBS structures is the emergence of a 4th peak in JBS structure, located close to peak B. This difference can be due to the presence of the p⁺-type region under the anode. To extract activation energy of the 3rd and 4th peak, it is necessary to fit the spectra by a Gaussian functions.

Final paper will present detailed results of activation energies and capture cross section of these defects, possibly related to Aluminium in regions of different doping level. They will also be compared with results obtained on similar Schottky diodes without p⁺-type rings.

References

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 [3] C. Raynaud et al. Mat. Sci. and Technol., 12, 94 (1996).
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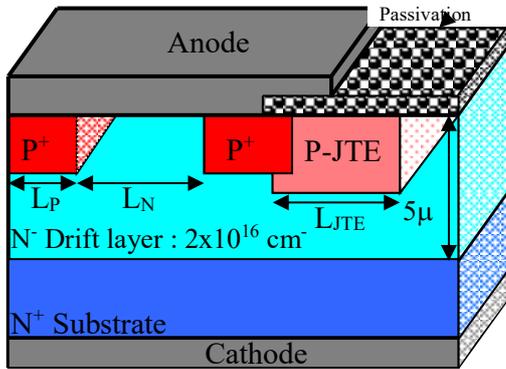


Figure 1 : Cross sectional view of the JBS structure. SBD is similar without the P+ region of L_p length.

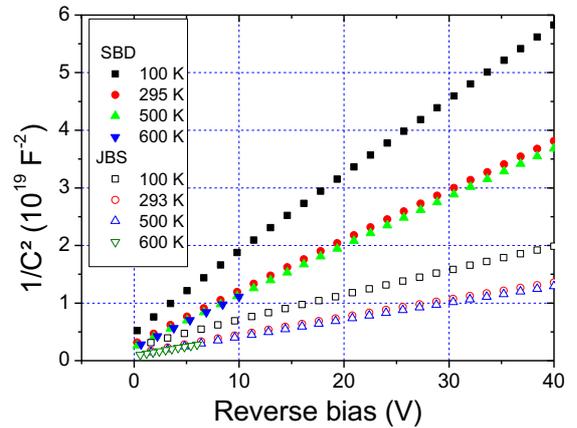


Figure 2 : C-V measurements on Schottky diodes performed at 100 kHz.

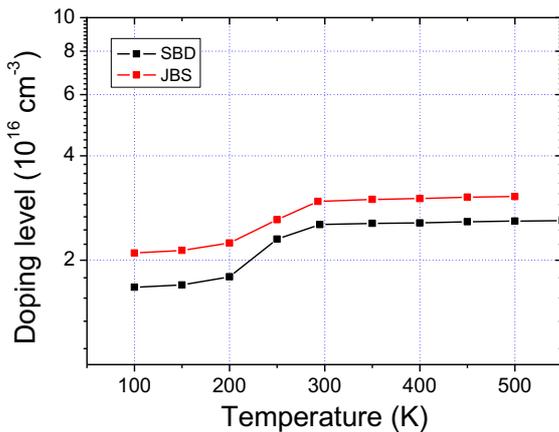


Figure 3 : Doping level extracted from C-V measurements on Schottky and JBS.

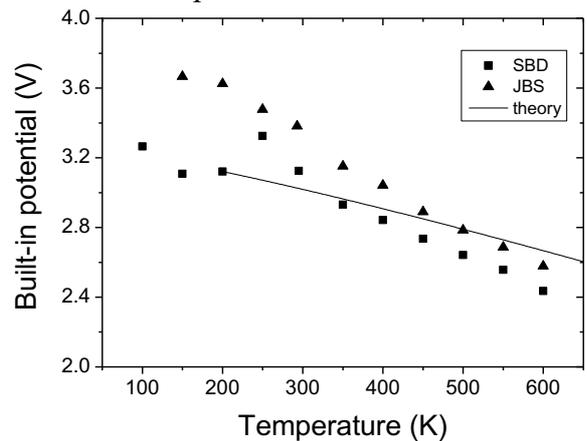


Figure 4 : Experimental and theoretical built-in potential for Schottky and JBS.

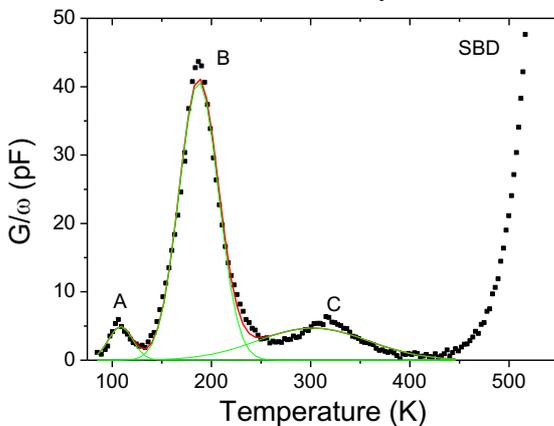


Figure 5 : Conductance spectra obtained at 1.9 kHz on SBD.

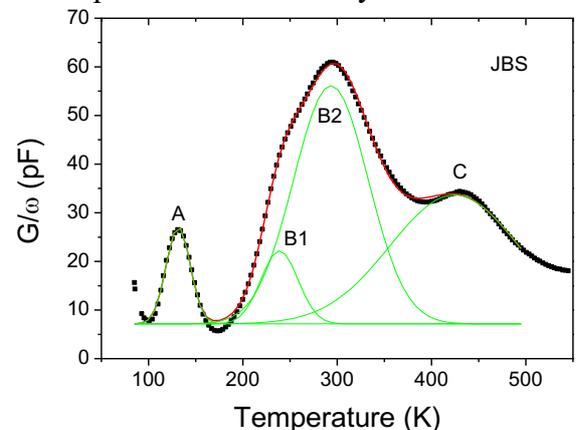


Figure 6 : Conductance spectra obtained at 187 kHz on JBS diodes fitted by 4 Gaussian curves.