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The role of the ion implanted emitter state on 6H-SiC power diodes behaviour. A statistical study

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Following a simulation work on design 6H-SiC p^+n power diodes, two device runs were fabricated with Al ion implanted emitter and JTE periphery. The implantation temperatures of the emitter were different: room temperature (RT) and 300°C. A systematic characterisation in forward (up to 5V) and reverse bias (down to -50V) was performed. Breakdown voltages were also measured on a part of diodes. The emitter state after implantation and annealing seems to be important for the diode behaviour in forward and in reverse polarisation also. For the 300°C implanted wafer higher current densities (200 $A.cm^{-2}$ at 5V) are obtained in forward bias, with a better distribution, more homogenous, showing better doping activation and layer quality. For the 300°C implanted diodes, fewer diodes with high leakage currents is obtained and those with the smallest emitter and the longest JTE sustain more than 1100V, with a breakdown voltage value close to the simulated value and independent on the testing ambient. This indicates a breakdown in the bulk, confirmed by its voltage value decrease for the RT implanted diodes. This is due to the presence of an amorphous layer after implantation and thus residual defects at the emitter-epilayer junction interface.

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Realisation of silicon carbide (SiC) power devices and integrated power systems, requires local doping. Due to the very low diffusion coefficients of the dopants in SiC, ion implantation is needed, followed by a high temperature annealing. To avoid amorphous layers creation and thus residual defects presence, ion implantation has to be performed at high temperature (300-600°C) which is an impediment in industrial SiC devices development, utilising silicon standard equipment. In this paper we compare the features of two fabricated runs of 6H-SiC bipolar power p^+n diodes implanted at 300°C and room temperature (RT).

Two commercially 6H-SiC wafers with n-type epilayers (~10^{16}cm^{-3}, 10µm) on n-type substrates were Al ion implanted, to realise the p-type emitter and the Junction Termination Extension (JTE) periphery protection. The parameters (energies, doses) were preliminary determined by Monte-Carlo ion implantation simulations and by entering the doping profile obtained into Medici software. The diode design, the JTE geometry (doping, length and depth), were thus determined to obtain a maximum breakdown voltage in the bulk with efficient lateral protection of the JTE. 1.3×10^{13} cm^{-2} total doses were implanted at room temperature simultaneously in the two wafers to form the JTE. For the emitter 1.75×10^{15} cm^{-2} total doses were implanted forming box profiles of ~4×10^{19} cm^{-3} on 0.45µm, using different temperatures for the two wafers (300°C and RT). The post-implantation annealing (1700°C/30min) was performed in a rf-induction furnace specially dedicated for this SiC technological step [1]. The ohmic contacts were formed employing an Al/Ti alloy on the p-type emitters and Ni on the whole substrate backside.

Current-voltage characterisation of the fabricated diodes were systematically measured in forward (up to 5V) and reverse voltage (down to –50V) with an automatic probe-stage with four K237 source measurement units. A current density of more than 200 A.cm^{-2} is obtained at 5V in forward bias for the diodes with the emitter implanted at 300°C and about 150 A.cm^{-2} for the RT implanted ones. In reverse bias at –50 V leakage currents as low as 10^{-8}A.cm^{-2} are obtained.

Figure 1(a, b) presents current density histograms obtained on 160 µm diameter emitter diodes from the two wafers. A better distribution, more homogenous and with higher current density is obtained for the 300°C implanted diodes, showing better dopant activation and layer qualities. RBS/C (Rutherford Backscattering Spectroscopy in the Channeling mode) measurements [2] on similar implanted layers have shown a recrystallised state close to the virgin non-implanted state, after annealing, in the case of non-amorphous as-implanted layers. The layers implanted at RT, amorphous on 0.3µm depth, are after annealing recrystallised with a residual damage quantified to 6% dechannelling yield. Increasing the emitter size (Figure 1c) the histograms are translated towards lower current density ranges, the emitter surface becoming more sensitive to the material quality, i.e. to the eventual presence of micropipes or dislocations. This last remark is also valid for the histograms obtained in reverse bias at –50V. Comparing the two wafers, the diodes have almost the same distribution. A less number of diodes with $|J|>10^{-4}$A.cm^{-2} is obtained for the 300°C implanted. However we have attained as low as 10^{-9} A.cm^{-2} only for the RT implanted.

Measurements in reverse bias down to –1100V with a K238 are presented in Figure 2. The role of the JTE is proved comparing the diodes protected and not, the breakdown voltage increasing with the JTE length. All the diodes with the smallest emitter implanted at 300°C and the longest JTE sustain more than 1100V. The breakdown voltage on these diodes measured with a 12.5kV FUG power supply, increases up to 1270V which is very close to the value predicted by Medici simulator (1300V).

The JTE being realised in the same conditions and the epitaxial doping being lightly superior for the 300°C implanted wafer (Cree^{TM} data sheet), the emitter state after implantation and annealing seems to be also important for the diodes behaviour in reverse polarisation. Relating the decrease of the breakdown voltage for the RT implanted diodes to the residual defects due to the presence of an amorphous layer before the annealing, i.e. to the defects presence at the emitter-epilayer junction interface, indicates a breakdown in bulk volume. That is confirmed by the non variation of the breakdown voltage when the diodes with the longest JTE are testing in different ambient (air, oil, SF_6), and by the absence of arcing at the surface.

In the final paper the comparison of the two wafer diodes will be developed taking into account the electrical tests realised on the emitter like formed Van-der-Paw structures and the contact resistance on p-type emitter. The emitters layers resistance has a radial distribution decreasing from the centre to the periphery due to the temperature distribution on the post-implantation furnace [1]. Nevertheless the diode current does not follow this distribution, the series resistance of the implanted layer being a negligible term in the total measured series resistance [3].

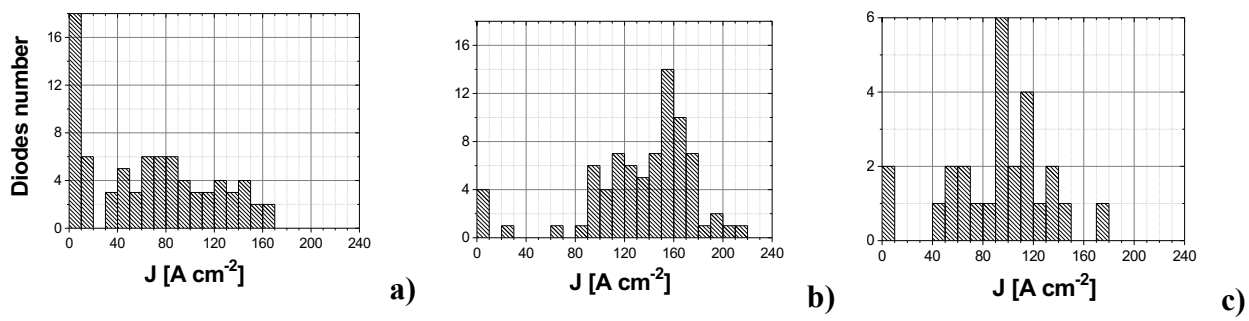

Fig1. Current density histograms of diodes under forward bias of 5V. The y-left axis range is proportional to the number of each type of diodes: a) RT implanted, 160 µm diameter emitter, b) 300°C implanted, 160µm diameter emitter, c) 300°C implanted, 250 µm diameter emitter

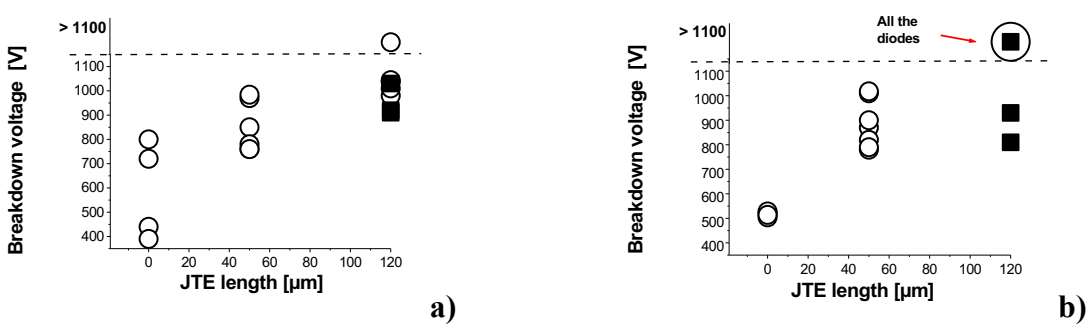

Fig2. Blocking voltage vs. JTE length on wafer diodes with the emitter implanted at RT (a) and 300°C (b). Open circles correspond to diodes with 160 µm diameter emitter and full squares to 250 µm diameter.

[1] M. Lazar, C. Raynaud, D. Planson et al., Mater. Sci. Forum Vol. 389-393 (2002), p. 827.
[2] M. Lazar, C. Raynaud, D. Planson et al., submitted to J. Appl. Phys.
[3] R. Nipoti, F. Moscatelli, A. Scorzoni et al., MRS Proceedings Vol. 742 (2002), K6.2, in press.