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Silvaco-based electrothermal simulation of 10 kV 4H-SiC p-i-n diode under pulsed condition

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Power p-i-n diodes are well known for their high-voltage and high-current capability which makes it a viable candidate for pulsed power circuits. The breakdown mechanism of a p-i-n diode enables high blocking voltage capability whereas, conductivity modulation due to high level injection drastically reduces the ON-state resistance during high forward current. Even though it is possible to develop silicon-based p-i-n diode with very high blocking voltage, the device characteristics, both steady state and transient, are adversely affected primarily due to the large drift region thickness which is in the order of several hundred microns. The application of silicon carbide technology in p-i-n diode has facilitated the development of p-i-n rectifiers up to several kV blocking voltage with a much thinner drift region thickness as compared to its silicon counterpart. This research is focused on the 2D electrothermal simulation of a 10 kV 4H-SiC p-i-n diode model developed using Silvaco ATLAS TCAD software. The p-i-n diode structure was designed for 100 A/cm² forward current density with a cell pitch of 16 956m and an active area of 10 956m². Physics-based models were included to account for low-field mobility, carrier-carrier scattering, carrier generation-recombination, avalanche breakdown, and lattice heating. The device model was simulated under steady state and transient conditions. Pulsed simulation of the p-i-n diode was carried out using an RLC ring down circuit to generate a 5 956s wide pulse with peak current densities up to 5000 A/cm². The reverse recovery characteristics of the diode was analyzed for a forward current density of 100 A/cm² and varying turn-off di/dt to assess the limitation on usable switching frequency. Thermal profile of the p-i-n diode was generated by including heat generation models during transient simulation to identify thermal hot spot formation and areas of possible failure during pulsed operation.

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