

Silicon Carbide specific components for power electronics system protection

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The paper addresses the potentialities of silicon carbide as the material for protection components in Power Electronics. It may be a series protection and its operation is then to limit the current. It may be a parallel protection clamping over-voltages. In any case, the protection component must sustain large power densities when operating. Silicon components are available but they can not dispose of the overload energy alone. They require an association with other components as discharge tubes for example. Indeed Silicon Carbide features characteristics adequate with the realization of protection components. A brief introduction lists different types of protection devices. The specifications of a current limiter are then detailed. Following these specifications, a controllable and a non-controllable device have been manufactured and tested. The measured ratings meet the specifications and thus they enlighten the potentialities for SiC with regard to protection components. Particularly it has been verified that power densities larger than 100 kW per cm² are sustained over more than minutes, under 320 V of operating voltage and with a package temperature less than 200°C.

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To protect power electronic circuits against over-current or over-voltage both serial protection (SP) or a parallel protection (PP), respectively as shown in figure 1, can be used. For the parallel protection some components can be used as varistances, gas discharge tubes or silicon devices as trisil or transil. For the serial protection the components are fuses, superconductors or polymers. In all cases it is necessary to dissipate the overload energy through the protection device which has to sustain high voltage and high current simultaneously. These constraints imply a very fast temperature increase. So, when the protection device is active it has to sustain high junction temperature. All these constraints will globally define the electrical specifications of this kind of device. The full paper will show how silicon carbide is able to satisfy the requirements in comparison with silicon.

Samples will be presented ($V_{BR} = 690$ V; $I_N = 1$ A). As an example a current limiting device has been developed. Figure 2 shows the vertical JFET structure with all parameters to be optimised by simulation with ISE TCAD. Simulation results produce the device structure given in figure 3. Figures 4 and 5 present the mask layout respectively of a matrix and of an interdigitated structure. The first one has an overall area of 2.8×10^{-3} cm² and a source area of 10^{-3} cm² with channel width of 13.8 mm. The areas of the second structure are respectively 1.2×10^{-2} cm² and 5×10^{-3} cm² and the channel width is 17.4 mm.

Samples were manufactured at Centro Nacional de Microelectronica in Barcelona. Technological steps will be briefly described in the full paper. Experimental set-up and additional measurements will be detailed to illustrate short-circuit protection efficiency and over-voltage clamping using a SiC current limiting device. Experimental validation of serial protection was made using a packaged matrix device. As shown in figure 6, the current limiting device is able to react in a very short time (less than 1 μ s). The ability of this SiC device to dissipate power density larger than 100 kW cm⁻² for several minutes under 320 V and a maximum temperature close to 200°C with only small heat sink is demonstrated. The results show the interests in SiC material for the realisation of specific devices for power circuit protection.

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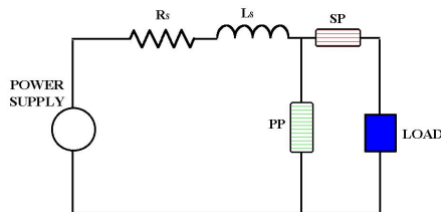


Fig. 1. Schematic view of a power system

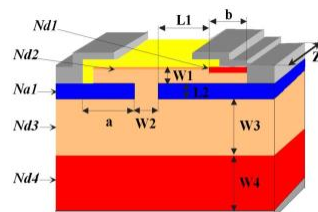


Fig. 2. JFET parameters structure

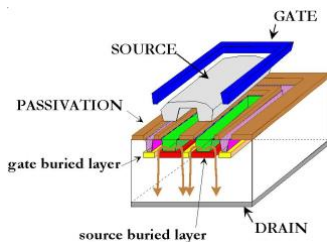


Fig. 3. 3D view of JFET structure



Fig. 4. Matrix device

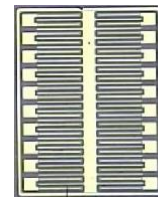


Fig. 5. Interdigitated device

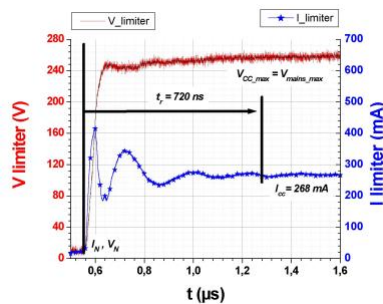


Fig. 6. Sample switching behaviour