Characterization of Schottky SiC Diodes for Power Applications

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Abstract: The performance of a 600V, 4A Silicon Carbide (SiC) Schottky diode (Infineon SDP04S60) is experimentally evaluated and compared with an ultra-fast, soft-recovery, silicon power diode (Fairchild RURD460). A substantially negligible recovery current is observed for the SiC Schottky diode with expected great advantage on EMI generation; on the other hand, the forward voltage drop is larger than that of Si diodes with not easily predictable behavior in power applications efficiency.

The first Silicon Carbide (SiC) power diodes only recently become commercially available: the high electrical breakdown field and the very high thermal conductivity of this material make it particularly suited to the manufacturing of power devices. The diodes have been initially characterized to compare their basic parameters, as forward voltage drop, reverse recovery time and the reverse recovery current. The results, comparing SiC diode to RURD460 Si diode, are shown in Fig.1 and Fig.2. As can be seen in Fig.1, the dc forward voltage drop of the SiC-based diode is considerably higher than that of the Si diode. Fig.2, instead, shows the recovery behavior of the two diodes for different case temperatures. Notice that recovery time for SiC Schottky diodes is only 6ns for every case temperature: in fact, while the effect of temperature variation is invisible for SiC-based diode, Si-based diode shows a peak recovery current increase until about 29%. Correspondingly, its reverse recovery charge Q_{rr} increases until 77%. Being a Schottky diode, the SiC device presents instead an almost negligible recovery current, mainly determined by its junction capacitance. It is worth noting that we tested the diodes at 400V reverse voltage and 10A forward current, selecting a 400A/µs di/dt. These are quite demanding operating conditions, which explains the relevant peak recovery current of the Si diode. It is also possible to note the soft-recovery behavior of the Si diode, which requires to get the current to zero about 54ns at room temperature until about 74ns at 125°C. From these measurements, it is possible to expect the power losses on the SiC diode to be predominantly conduction losses, while the conduction losses of the Si-based diode to be considerably lower than those of the SiC diode, cause of the difference in the forward voltage drop. On the other hand, the Si diode is expected to have considerably higher switching losses, because of its slower commutation time, and to cause a higher current peak on converter switch at turn-on. A key application for this type of rectifiers is Boost Power Factor Corrector (PFC), whose basic scheme is shown in Fig.3: a 300W, universal input range Boost PFC with input voltage 90-260Vrms, output voltage 380V and switching frequency 70kHz has been developed and used to evaluate performances with different diodes, measuring overall efficiency, switch and diode losses, and conducted EMI noise. We initially evaluated the effect of the diode recovery current on the switch current at turn-on. As can be seen in Fig.4, the current peak at moment of turn-on is considerably reduced by the use of the SiC diode. This is promising to considerably reduce the commutation losses of the switch and to show a significant reduction of the generated EMI. The impact of the above described phenomena on the overall efficiency of the converter is difficult to estimate and requires a careful examination: virtual absence of recovery current and performance stability in SiC-based diodes with increasing operating temperature, it becomes interesting to quantitatively evaluate possible advantages of its adoption in typical applications, especially in terms of efficiency improvement. The same can be said for the EMI generation reduction because the absence of the recovery current peak may have an appreciable effect.

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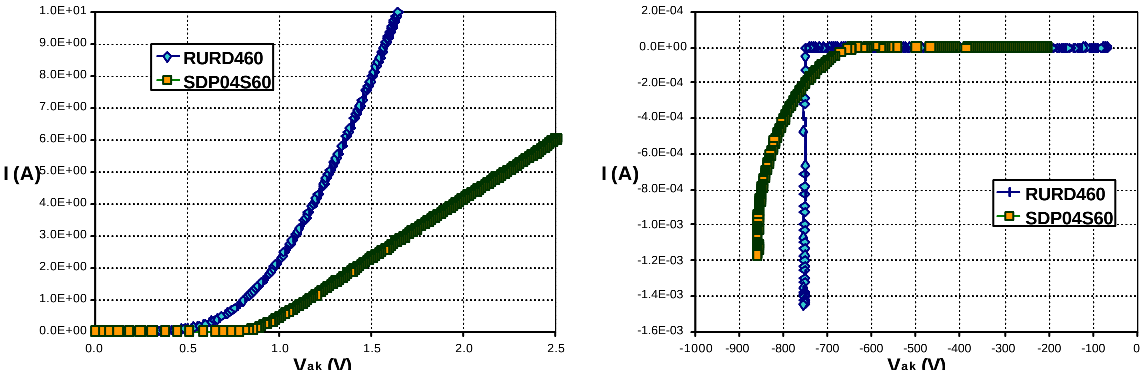

Fig.1 - Measured forward and reverse I-V curve for Si-based and SiC-based diodes.

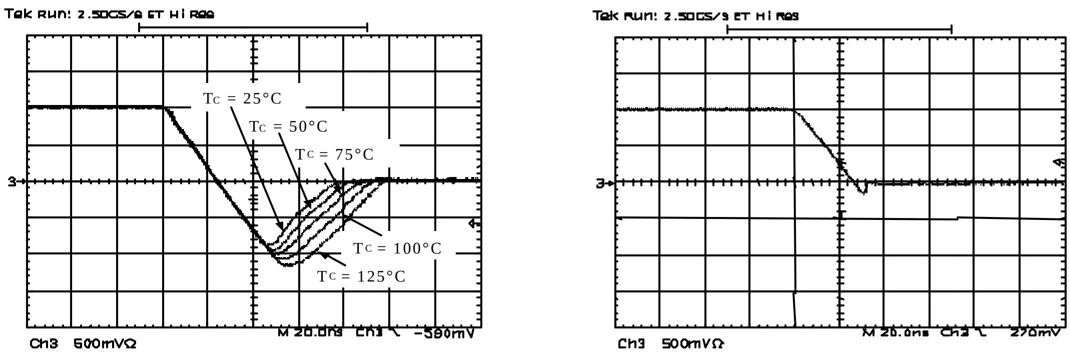

Fig.2 - Reverse recovery behavior for different case temperatures of the RURD460 diode (a) and of the SiC diode (b), measured at 400V reverse voltage and 10A forward current (5A/div). Timebase is 20ns/div. SiC diode reverse current keeps unchanged!

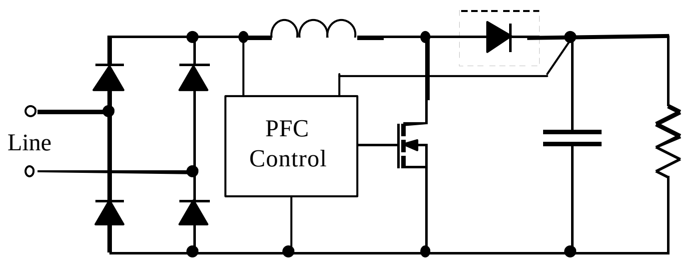

Fig.3 - Basic scheme of the Boost PFC

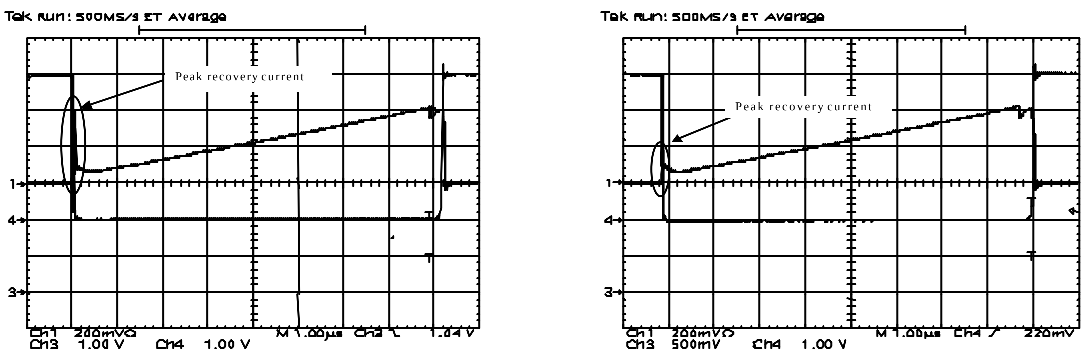

Fig.4 - Effect of recovery current on the switch turn-on (a) for RURD460 diode and (b) for SiC diode