실리콘 카바이드와 실리콘 MOSFET의 단락회로 특성비교

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SiC MOSFET Compared to Si Power Devices during Short Circuit Test

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ABSTRACT

Higher power density, higher operational temperature, lower on state resistance and higher switching frequency capabilities of Silicon Carbide (SiC) technology devices compared to Silicon (Si) devices makes it has higher promising market. One of the most developed SiC devices is the power MOSFET. This study tests the SiC MOSFET under short circuit conditions taking into account the effect of gate voltage characteristics. The results will be compared to IGBT and MOSFET Si devices with similar ratings. A tester circuit was designed to perform the short circuit operation.

1. Introduction

High power discrete SiC devices such as Thyristors, JFETs and MOSFETs are commercially available after decades of research on device physics and manufacturing technology [1]. SiC material offers a number of advantages compared to Si. It has ten times the dielectric breakdown field strength, three times the band gap, and three times the thermal conductivity [2]. These properties make SiC an attractive material that can far exceed the performance of their Si counterparts. The higher critical electric field strength is used to design faster switching devices with lower power losses compared Si-based devices. Many papers in the literature studied normal operating switching characteristics of SiC MOSFET. However, up-normal operating characteristics outside the safe operating area of the device were rarely studied.

In this paper, the SiC MOSFET has been studied under short circuit condition compared to Si MOSFET and Si IGBT power devices with very similar ratings. The objective of the test is to investigate the performance of the SiC MOSFET during short circuit taking into account change in gat-source voltage (V_{GS}). Section 2 will descript the design processes of the tester circuit. The experiment results and discussions will be presented in section 3. Finally, the conclusion and future work will be proposed in section 4.

2. Tester circuit design

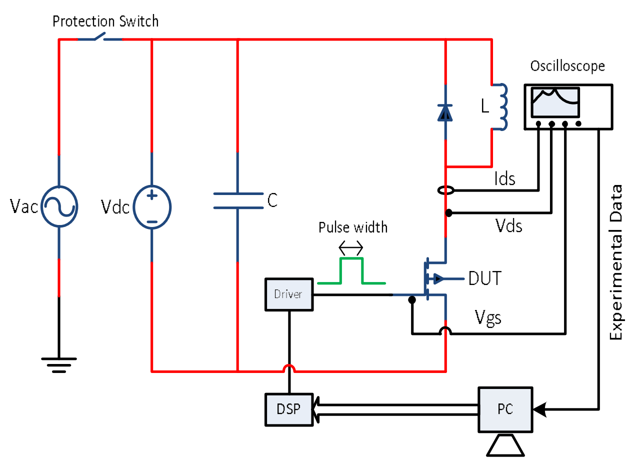

Figure 1. Schematic of the short circuit test for power semiconductor devices

Figure 1 shows the high power clamped inductive load tester for semiconductor power devices. A photo for the proposed tester is shown in Figure 2. A 3.3kV transformer is connected to the main grid through a variable AC voltage (VARIAC) to provide the AC power source. The VARIAC is used to manually control the voltage level. A high power rectifier is connected to the secondary high voltage terminal of the transformer to provide the required DC voltage level on the capacitor bank at rated 1.8 kV and 1200µF. A TI28335 DSP controller is used to control the gate driver PWM signal. A protection switch is used to separate out the power stage of the tester circuit and the electrical grid to prevent the circuit damage during failure.

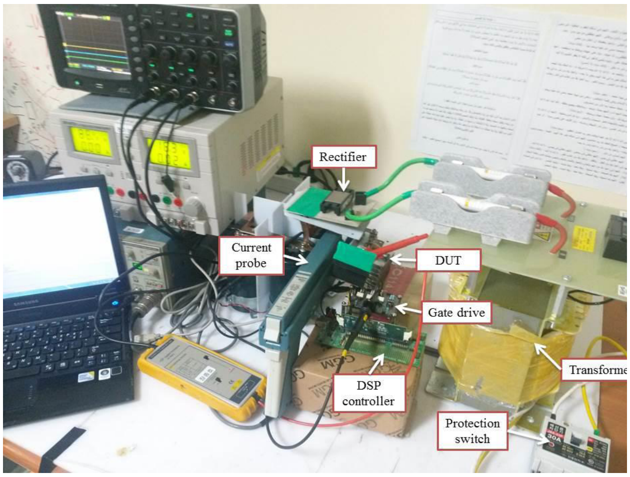

Figure 2. Experimental set up

3. Experimental results and Discussion

Figure 3 shows the waveforms during the short circuit operation for the three devices under test Si MOSFET, Si IGBT and SiC MOSFET. The devices were tested with V_{GS} = 15V and V_{DS}= 500V. A single pulse width of 20µs was applied. A small inductance of 0.36µH was used to limit dI/dt in the circuit.

Looking to the I_{DS} profile through the three devices, it increases to very high values of around 7 times its rated value with dI/dt limited only by the small inductance in the circuit. Subsequently, the current gradually reduce due to the internal increase in the device temperature.

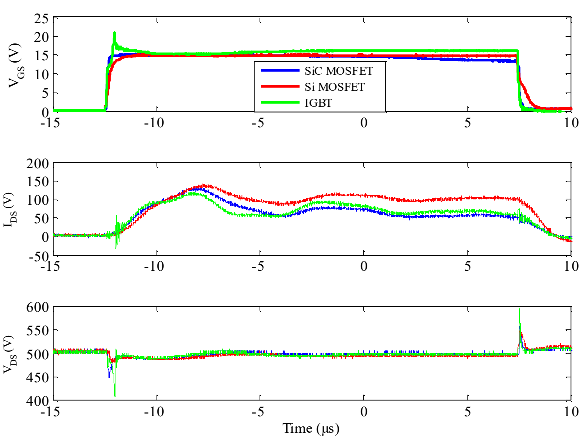

Figure 3. Short circuit operation of SiC MOSFET, Si MOSFET and IGBT

A reduction on the V_{GS} for the SiC MOSFET was observed in Figure 3 compared to Si MOSFET and IGBT. A more detailed figure for this phenomenon is shown in Figure 4 while the devices were tested at V_{DS} = 500V and pulse width = 15µs with different V_{GS} values. It is clear that the reduction occurs only with SiC MOSFET, and as V_{GS} increases more reduction occurs.

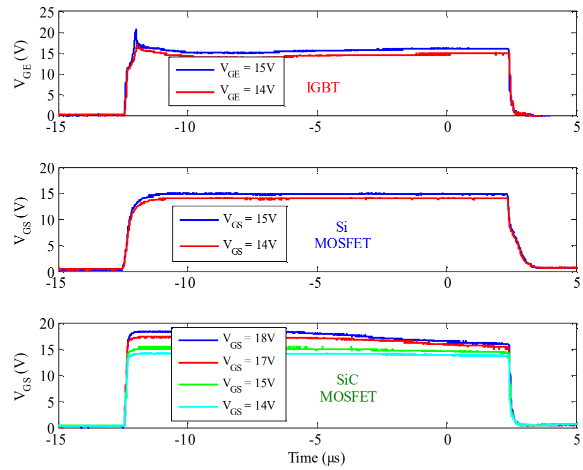

Figure 4. Comparison between gate voltages of the devices

4. Conclusion

In this paper, a commercially available 1200V/24A SiC MOSFET was tested for short circuit operation. The test results were compared to 1000V/22A Si MOSFET and 1200V/20A Si IGBT. A gradual reduction on V_{GS} was detected in case of SiC MOSFT. However, this is not happening with Si devices with the same testing conditions. It is well known that the SiC devices have smaller gate thickness which might affect the gate reliability. This also would cause degradation of the gate characteristics. A further investigation for this phenomenon will be given in future study.

References

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[2] Guannan Wei; Liang, Y.-C.; Samudra, G.S., "Realistic simulation on reverse characteristics of SiC/GaN p-n junctions for high power semiconductor devices," *Power Electronics and ECCE Asia (ICPE & ECCE), 2011 IEEE 8th International Conference on* , vol., no., pp.1464,1468, May 30 2011-June 3 2011