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Research on the Full Temperature Range Characteristics of IGBT

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Introduction

- The temperature of the IGBT varies significantly during repeated switching, which can affect its electrical characteristics and lead to failure or fatigue effects.
- It is necessary to study its electrical characteristics under working conditions across the entire temperature range. The junction temperature can be indirectly obtained using the temperature sensitive parameter (TSP) method.
- In this paper, we propose an automatic testing platform to provide data on various electrical characteristics and status parameters of the IGBT across the entire temperature range.

The Establishment of Automated Testing Platform

- The gate driver used in the test experiment is a totem pole driver composed of two MOS devices.
- The double-pulse test is performed on the inductive load IGBT half-bridge circuit.
- Utilize Python to develop a host computer that interacts with the FPGA. After setting the temperature to the temperature control platform, the FPGA applies the double-pulse signal to the IGBT gate driver

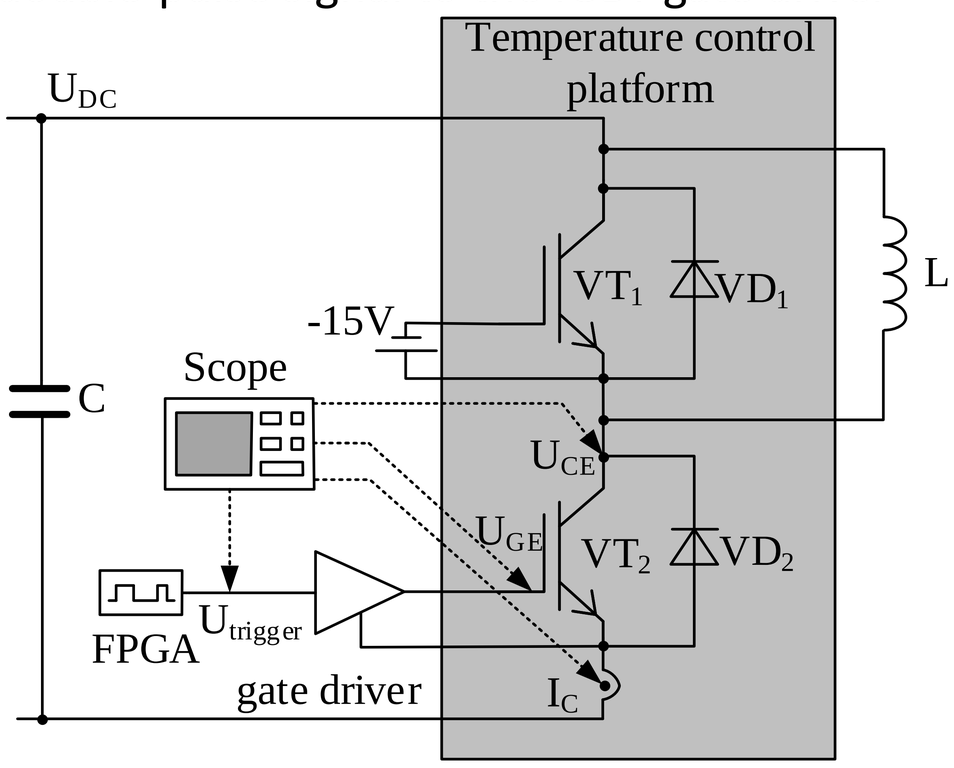

Fig. 1. Automated testing platform.

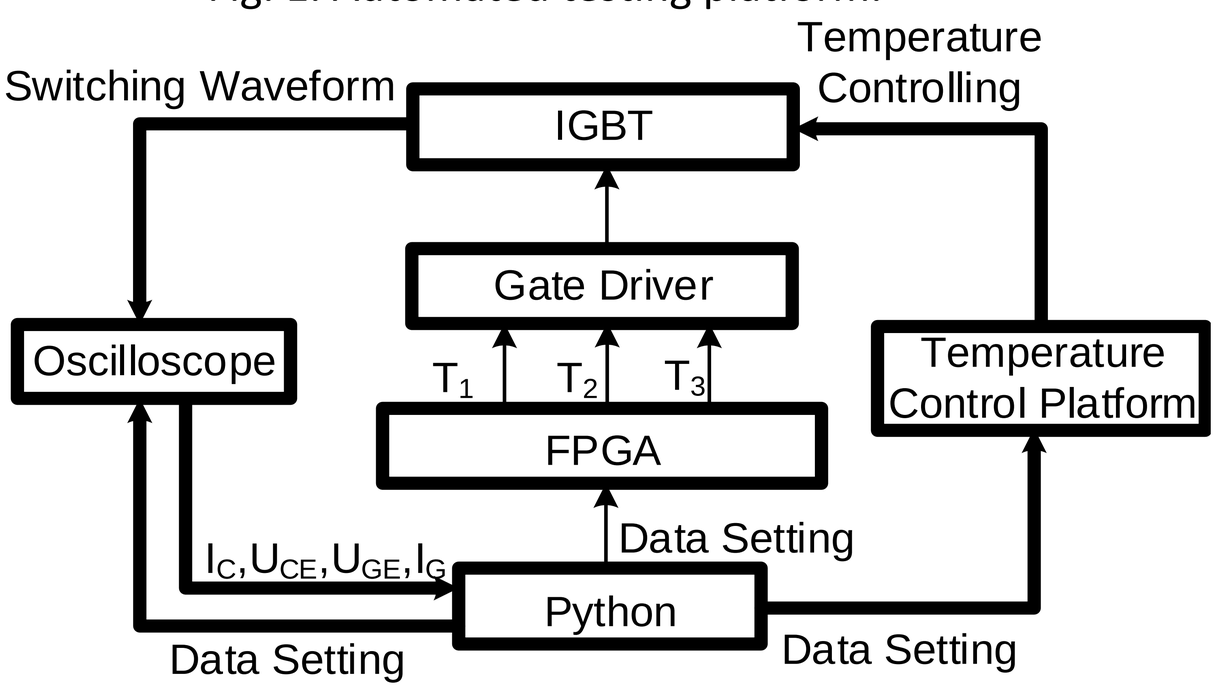

Fig. 2. Dual Pulse Testing Flowchart.

Experimental Waveform

- dI_C/dt with increasing temperature.
- dU_{CE}/dt decreases as the temperature increases.
- the switching time significantly increased
- the switching loss significantly increased

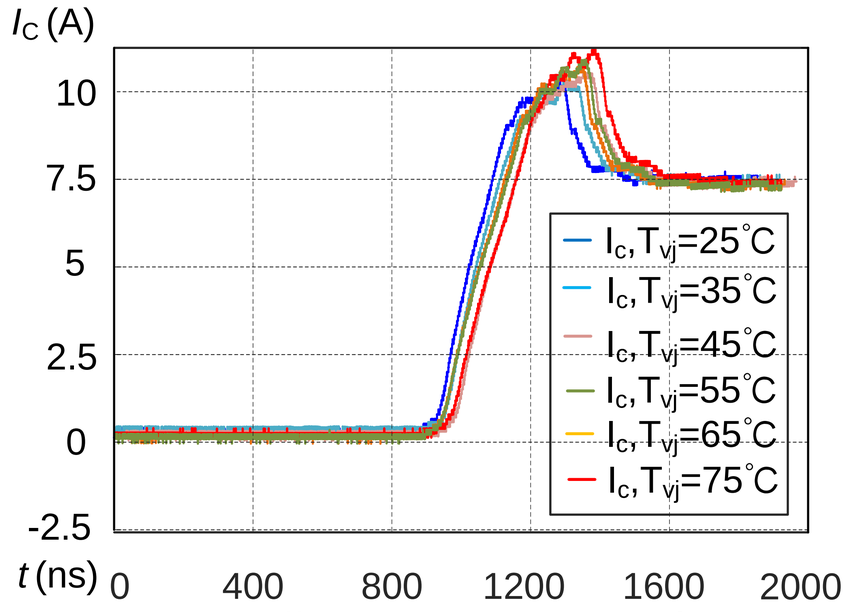

Fig. 3. Collector current waveform at 25℃~75℃ when IGBT is turned on.

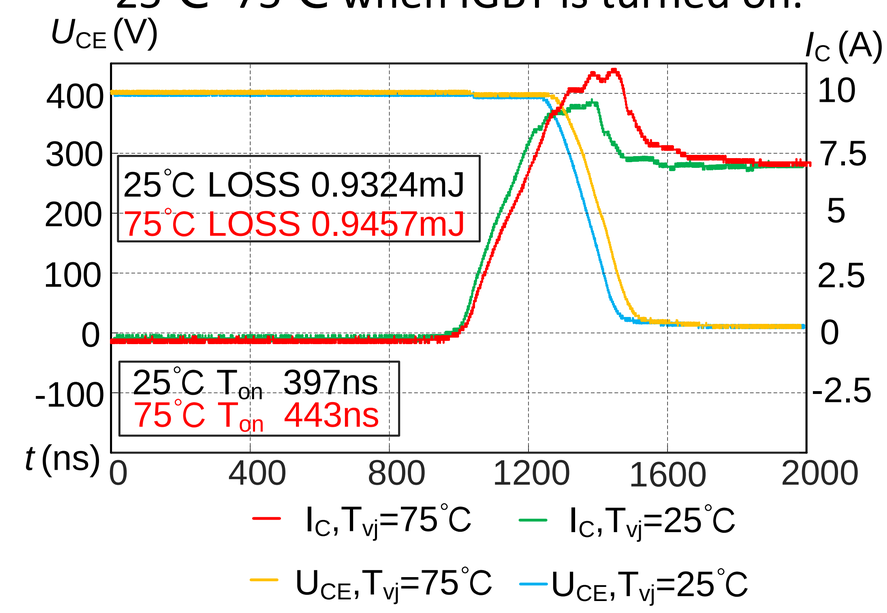

Fig. 4. The turn-on waveform of the IGBT at 25°C and 75°C.

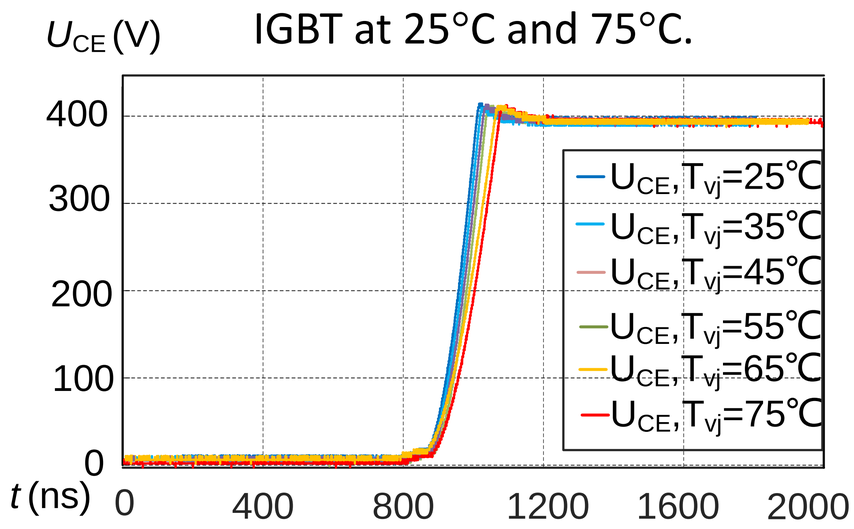

Fig. 5. The collector-emitter voltage waveform during IGBT turn-off from 25°C to 75°C.

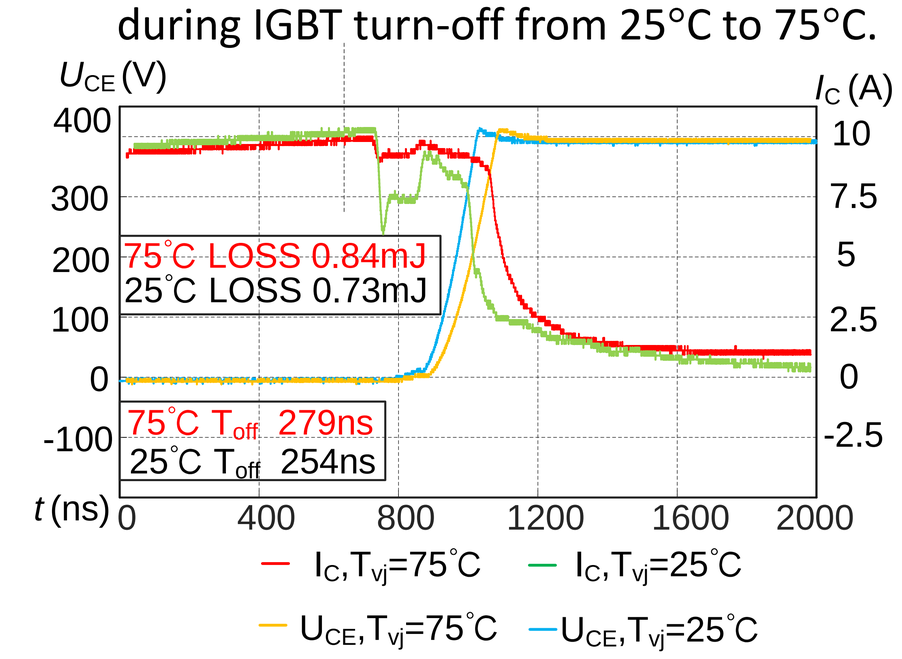

Fig. 6. The turn-off waveform of the IGBT at 25°C and 75°C.

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Theoretical Analysis

- The intrinsic carrier concentration increases with increasing temperature.
- The mobility decreases with temperature following a proportionate decrease of $T^{-1.5}$.

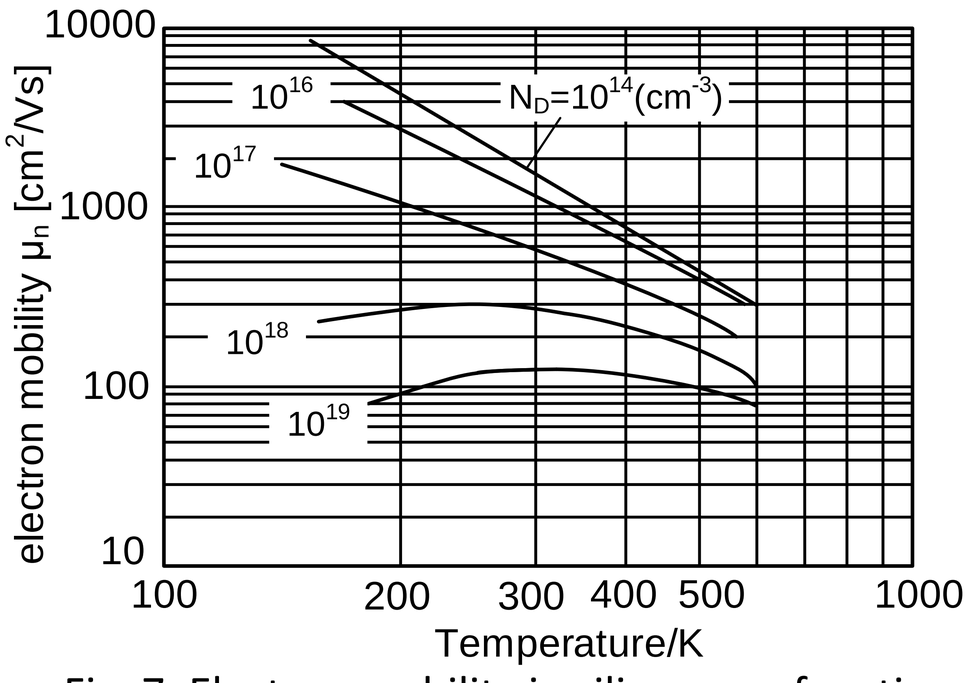

Fig. 7. Electron mobility in silicon as a function of doping and temperature.

- With increasing temperature, both recombination life-time and generation lifetime increase, indicating an increase in carrier lifetime.

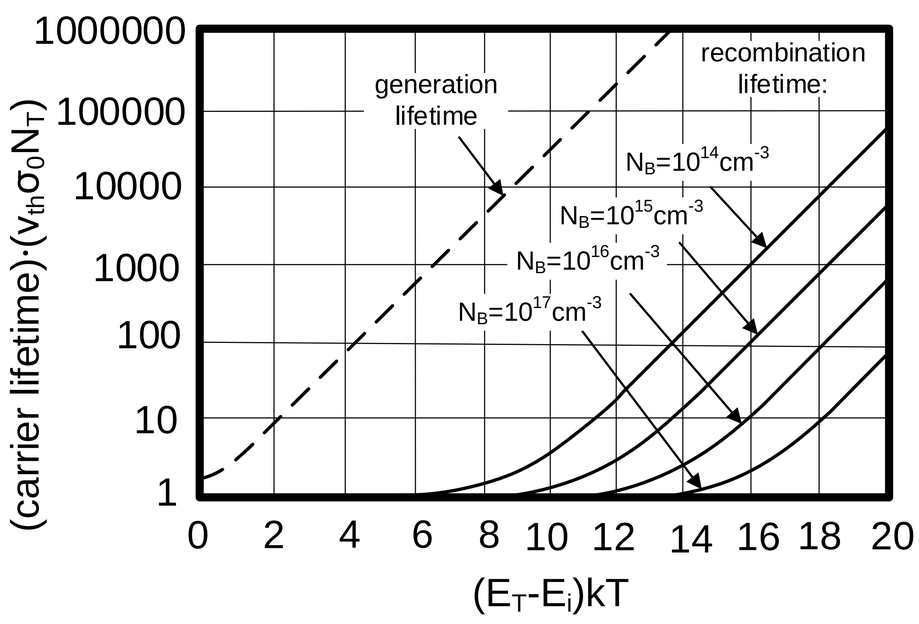

Fig. 8. The curve depicting the variation of carrier lifetime with temperature and the position of recombination centers within the energy band gap.

Experimental Environment and Double-pulse Testing Standards

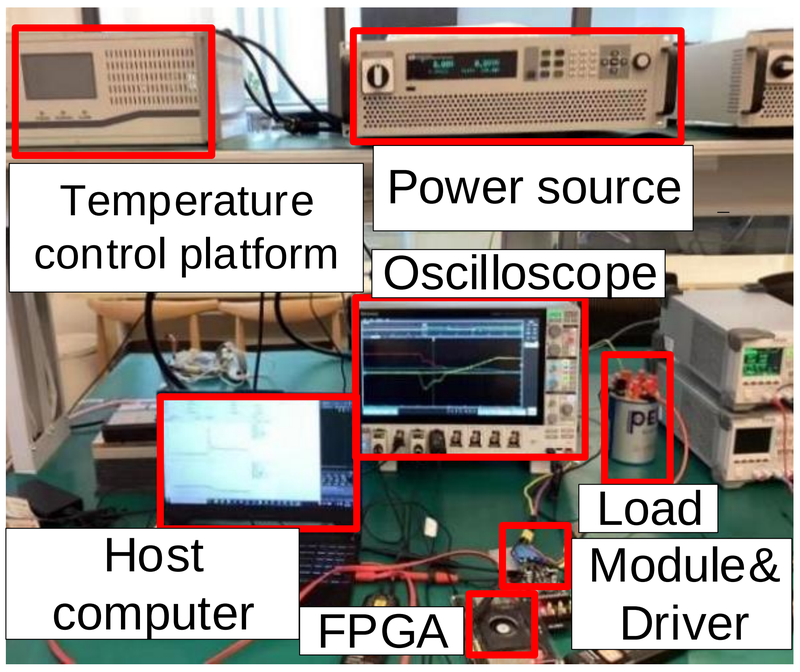

Fig. 9. The photograph of test platform.

- di/dt represents the slope of the load current from 50% to 90% during I_C turn-on and from 90% to 50% during I_C turn-off.
- du/dt represents the slope of U_{CE} from 90% to 50% during U_{CE} turn-on and from 50% to 90% during U_{CE} turn-off.
- t_{on} refers to the time taken from the gate voltage to reach the threshold voltage to for I_C to rise to 90% of the load value during IGBT turn-on.
- t_{off} represents the time taken from the voltage to rise to 10% to the current to decrease to 10% during IGBT turn-off.

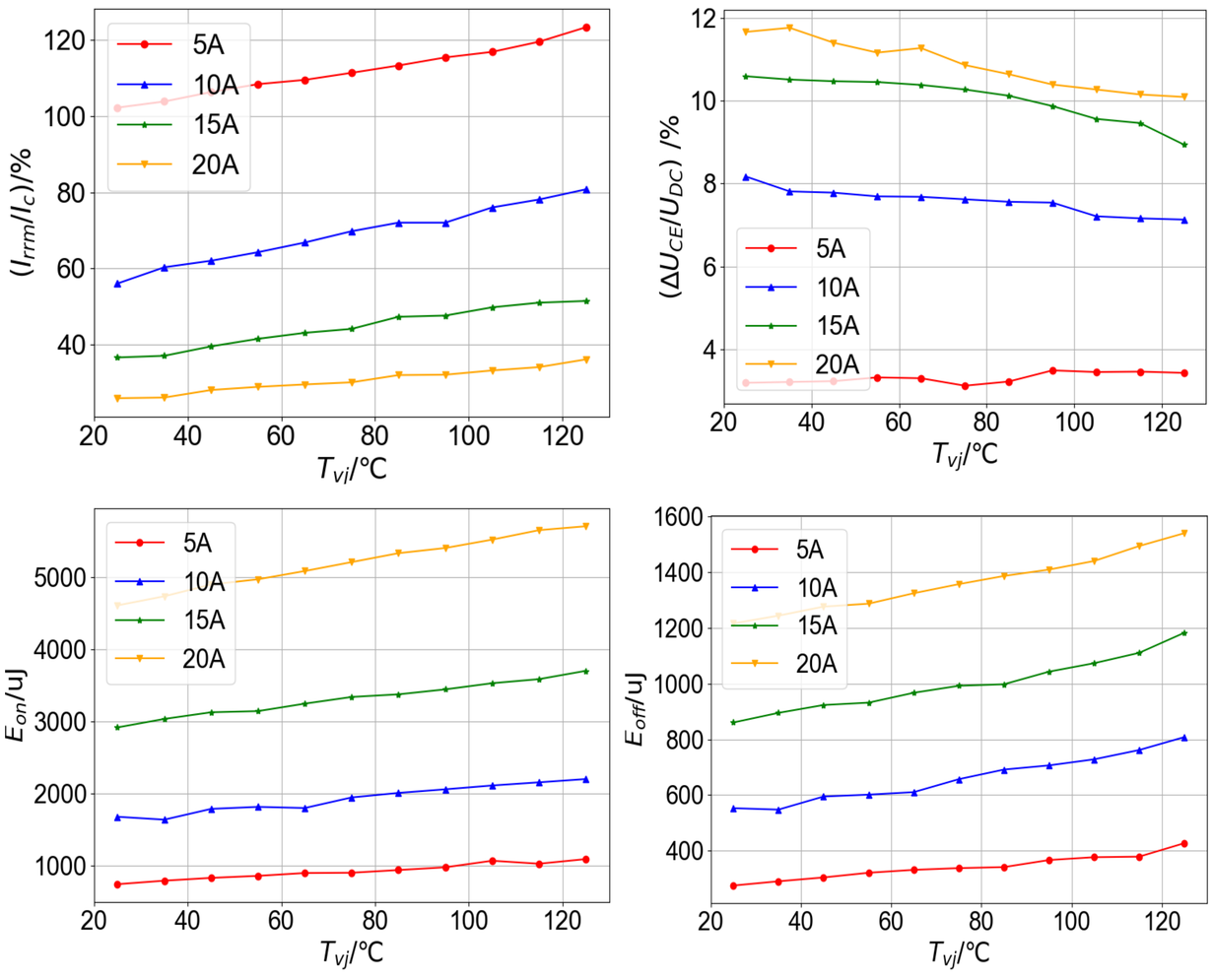

Fig. 10. The curve depicting the variation of dynamic electrical characteristics of the IGBT over the entire temperature range.

Conclusion

Through experimental verification, it is demonstrated that this platform can accurately and rapidly test the dynamic electrical characteristics of IGBTs over the entire temperature range. By combining semiconductor physics knowledge with experimental waveform analysis, it was determined that the variations in IGBT electrical characteristics with temperature are attributed to the changes in internal device parameters and the semiconductor physical constants of the materials. The experimental results can serve as a basis for the temperature-sensitive parameter method and the optimization of IGBT driver circuits.

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