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Novel 1300V Trench IGBT Optimized for Automotive Applications with Bus Voltage above 900V

Lixiao Liang[1,2], Zhenhua Tan[1,2], Wei Hu[1,2], Di Li[1,2], Pengfei Liu[1,2], Rongzhen Qin[1,2], Qiang Xiao[1,2], Haihui Luo[1,2]

[1] State Key Laboratory of Power Semiconductor and Integration Technology, China
[2] Zhuzhou CRRC Times Semiconductor Co. Ltd, China

Corresponding author: Lixiao Liang, lianglx1@csrzic.com
Speaker: Lixiao Liang, lianglx1@csrzic.com

Abstract

A new 1300V Trench IGBT is introduced in this paper. For higher bus voltage, etc., 900V or more, the performance of device is limited by application constrains. An optimized chip design is adopted to reduce the turn-off loss while the short circuit capability has no degradation. Meanwhile, the turn-on loss is reduced by optimized capacitance design. The proposed 1300V trench IGBT is achieved and packed in 600A/1300V S3+ module. Compared with traditional 1200V device tested at 900V, the new 1300V device has enhanced short circuit capability and 15% lower total power consumption during inverter at 10kHZ.

1 Introduction

In automotive applications, the higher bus voltage, the lower conduct current and lower stray loss. In order to improve the power density, the bus voltage of 1200V IGBT is set from 800V to 900V or move. When the bus voltage is increased, the power loss of device is increased simultaneously. Specially, the device speed is limited by the application constrains like turn-off peak voltage, recovery dvf/dt and short circuit capability, the final switching loss is further increased due to higher driving resistance. Consequently, the IGBT device should be specially optimized for higher bus voltage applications.

It is well known that the direct design rule of reducing switching loss is improving the turn-on and turn-off speed. However, the turn-off peak voltage and the recovery dvf/dt will be increased simultaneously.

Fig.1a showed the turn-on waveform of 1200V IGBT tested at 800V and 900V separately, as can be seen the turn-on loss is increased due to higher power integration. Fig.1b showed the reverse-recovery waveform tested at 10% rated current, the reverse-recovery dvf/dt and peak voltage are increased observably. In order to reduce the reverse-recovery peak voltage, the turn-on driving resistance must be increased and hence the turn-on loss is increased higher.

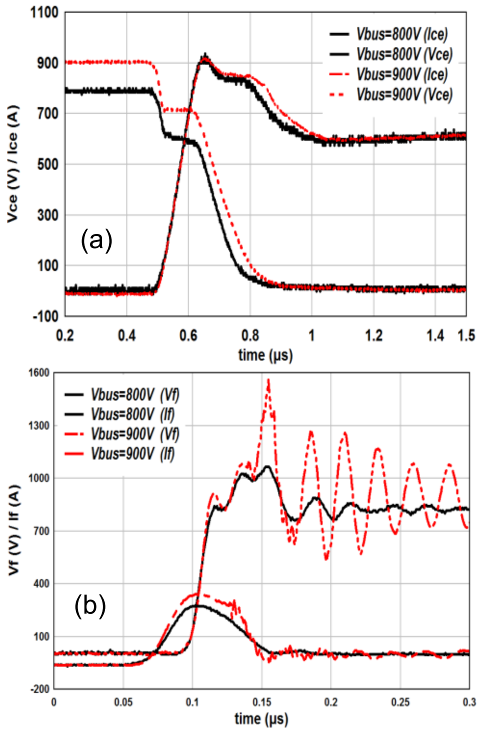

Fig. 1. Tested switching waveform between 800V and 900V (a) turn-on and (b) reverse recovery at 10% rated current.

Due to the same reason, when the bus voltage is increased from 800V to 900V, the turn-off loss is increased and the turn-off peak voltage is also increased. Besides, at higher bus voltage, the short

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circuit capability will be degraded. As shown in Fig.2, the device occurs failure when tested at 900V.

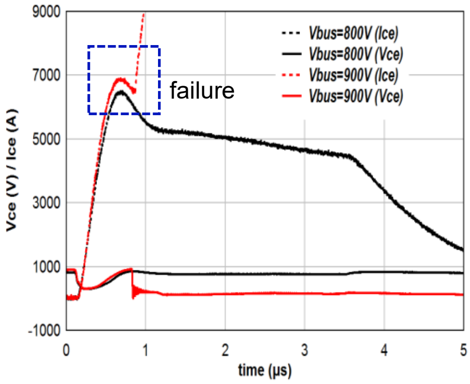
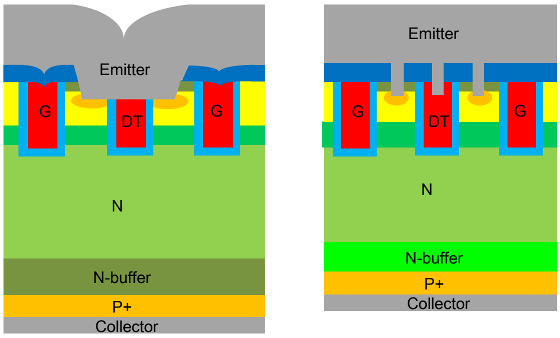


Fig. 2. Tested short circuit waveform.

As noted above, when the bus voltage is increased, not only the power is increased but also the driving resistances are increased due to higher reverse-recovery dvf/dt, turn-off peak voltage and degraded short circuit capability.

2 7th generation IGBT technology

As shown in Fig. 3, due to the progress of fabrication platform, the new device is verified using the 7th IGBT technology.



(a) (b)

Fig. 3. Schematic cross-section of (a) 6th IGBT and (b) 7th IGBT technology in CRRC.

In order to reduce the total switching loss, the 1200V IGBT device is extended to 1300V IGBT device with higher blocking voltage and specially optimized chip design to improve the dynamic trade-off. The following tested bus voltage is set as 900V.

Fig.4(a) and Fig.4(b) showed the compared turn-on and reverse-recovery waveform of 1200V module and the new 1300V module. In the new 1300V IGBT chip, the ratio of capacitance Cgc over Cge is adjusted, which results in a soft reverse-recovery at 10% Icn test. Due to such optimization, the Fast-Recovery Diode can be designed faster and the turn-on driving resistance is reduced at the same time, finally a lower turn-on loss is achieved.

Different from the Split-Dummy-Active CSTBT[1], capacitance of the proposed 1300V device is achieved by an optimized trench layout owing to the 7th IGBT technology. As a result, the new 1300V device gets a better balance between performance and cost.

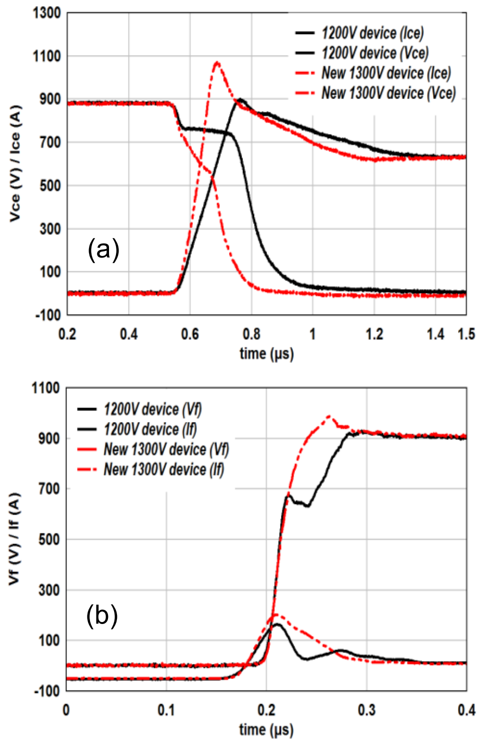
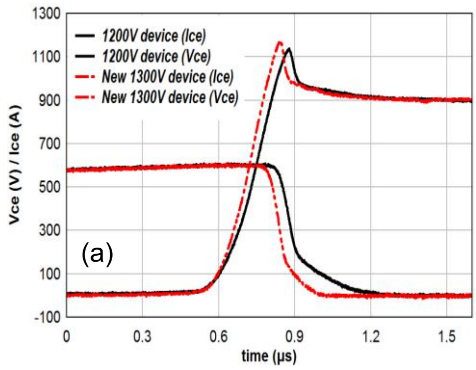


Fig. 4. Tested switching waveform between 1200V and proposed 1300V IGBT (a) turn-on and (b) reverse recovery at 10% rated current.

Fig.5a and Fig.5b showed the compared turn-off and short circuit tested waveform. In order to reduce the turn-off loss, the new 1300V device is designed with a smoothed carrier distribution and back electric field optimization during short circuit. Due to higher block voltage and chip design, the turn-off loss is reduced and the short circuit capability is also enhanced.

In the new 7th generation IGBT, an obvious progress of technology is achieved. The chip is endowed with higher design freedom, which resulted in an adjustable capacitance between Cgc and Cge, hence a controlled switching behavior can be realized.



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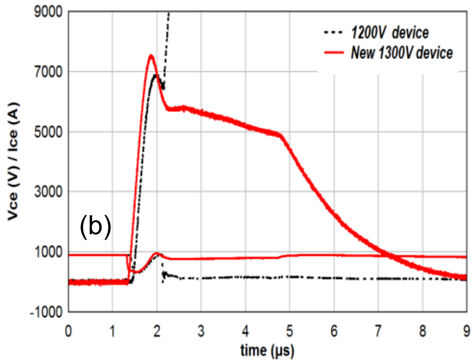

Fig. 5. Tested switching waveform between 1200V and proposed 1300V IGBT (a) turn-off and (b) short circuit.

3 IGBT module performance

As shown in Fig.6, the new 1300V device is verified and packed in a 600A/1300V S3+ module[2].

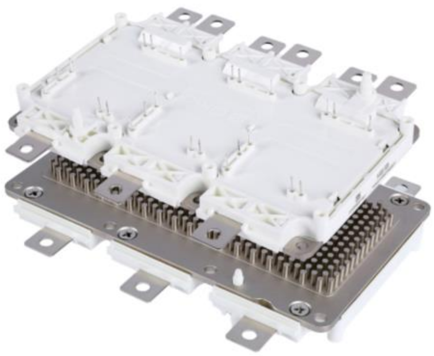

Fig. 6. Demonstrated 600A/1300V S3+ module.

Fig.7 showed the simulated power loss distribution during inverter at 10kHZ. Owing to the optimized design in 1300V IGBT, the total power loss is reduced by 15%, and the output current of the module can be increased.

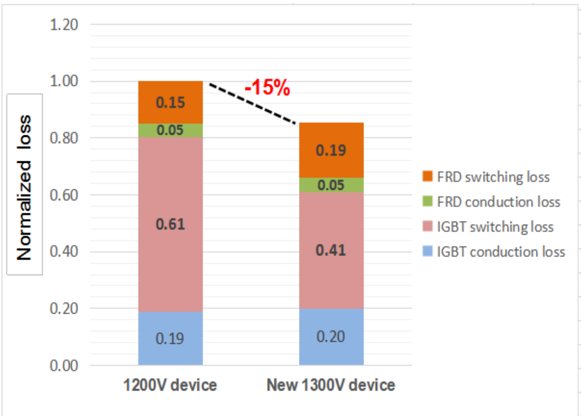

Fig. 7. Normalized loss distribution at 10kHZ by simulation.

4 Conclusion

In this paper, a new 1300V IGBT device is proposed and verified in a 600A/1300V S3+ module for bus voltage above 900V. Owing to the 7^{th} IGBT technology in CRRC, the proposed IGBT is verified by a new design concept. A flexible trench layout design is adopted to change the ratio of capacitance Cgc over Cge, which resulted a lower turn-on loss by optimization of reverse-recovery dvf/dt under 10% normal current test. Besides, a smoothed carrier distribution and back electric field optimization are also adopted to reduce the turn-off loss with higher short circuit capability. Due to the chip optimization, the output power of module is improved by a 15% lower total switching loss during inverter at 10kHZ.

5 References

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