Xi'an University of Technology

A Trench Gate Reverse-Conducting IGBT with a Shallow Oxide Trench and a Floating P-Region

Cai-Lin Wang, Rong-Hua Cheng, Wu-Hua Yang, Ru-Liang Zhang

Introduction

A Trench Gate Reverse -Conducting IGBT with a shallow oxide trench and a floating p-region (STFP RC -IGBT) is proposed to suppress the snapback phenomenon during the forward conduction. Take 1700 V RC -IGBT for example , the forward , reverse and short - circuit characteristics are analyzed by simulation . The results show that, compared with the conventional RC-IGBT and TFP RC-IGBT, the snapback-free characteristics can be realized in STFP RC-IGBT by cell size of 32 μm. Furthermore , the turn-off energy loss, E_{off}, of IGBT and the reverse recovery peak current density, J_{RM}, of diode are the lowest.

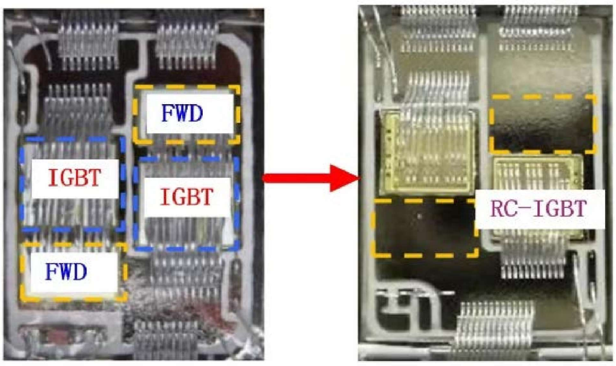

Fig. 1 RC-IGBT

The Conventional RC-IGBT Structure

In practical application circuits, IGBT needs to be connected with the Free Wheeling Diode (FWD) to conduct reverse conduction . Therefore, the RC-IGBT which introduces the n_+ shorted region at the collector side of the IGBT is proposed , and the resulting advantages and disadvantages can be summarized with the following points:

- The resulting advantages:
  Making the chip area, parasitic inductance and the manufacturing cost are greatly reduced, and the power density and reliability of the device are also improved.
- The resulting advantages:
  Due to the introduction of the n+ shorted region, the snapback phenomenon occurs during the forward conduction of the RC-IGBT, which makes it increase the turn-on loss

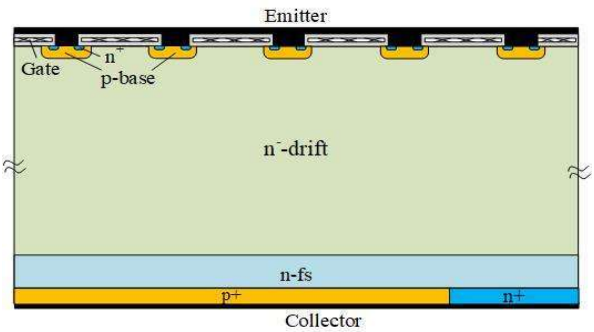

Fig. 2 The conventional RC-IGBT structure

Conclusion

An improved RC-IGBT with a shallow oxide trench and a p-float region is proposed to suppress the snapback phenomenon and reduce process difficulty in this pa-per. As the simulation results show that, the forward conduction has no snapback phe nomenon . In addition , compared with the conventional RC-IGBT and the TFP RC-IGBT, the E_{off} of the STFP RC-IGBT is decrea sed by 7.2% and 5.5%, respectively, and the J_{RM} of the STFP RC-IGBT is decreased by 10.2% and 27.5%, respectively . In addition , the IGBT of STFP RC-IGBT is still able to turn off 10μs after the short-circuit occurs.

The TFP RC-IGBT Structure:

Reverse-Conducting IGBT with an oxide trench placed between the n_+ shorted region and the p_+ collector and a floating p-region sandwiched between the n_- drift regionand the n_+ shorte d region structure.

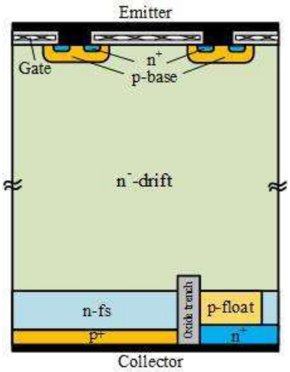

Fig. 3 TFP RC-IGBT structure

And the TFP RC-IGBT increases the collector side short resistor, R_{CS}, by adding oxide trench and p-float region , which suppresses the snapback phenomenon well, but it is difficult to operate the process of deep trench etching and oxide filling.

The STFP RC-IGBT Structure

An improved RC -IGBT with a shallow oxide trench and a p-float region is studied in this paper . And the front of the STFP RC-IGBT adopts the dummy trench which is connected to Emitter and n-carrier storage layer (n-cs), and the ratios of Active Trench Gate (AT) to Dummy Trench(DT) is 1:3, these can obtain lower saturation voltage $V_{CE\ sat}$ without damaging the short-circuit ability of IGBT.

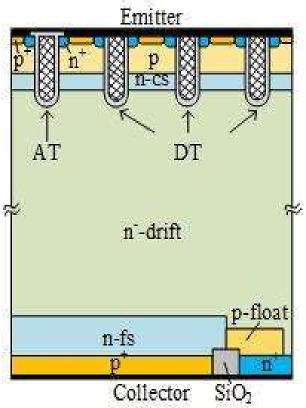

Fig. 4 STFP RC-IGBT Structure

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TCAD Simulation results

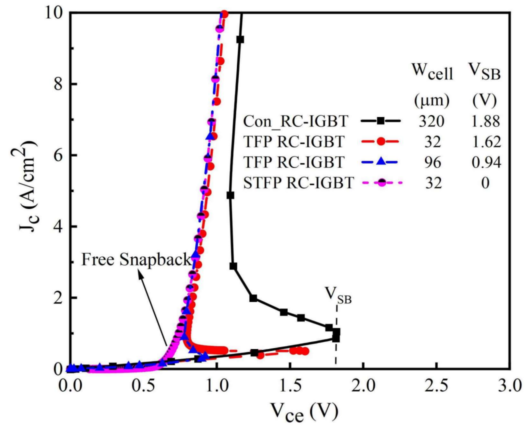

Fig. 4 Forward conduction characteristics of the three types of RC-IGBT

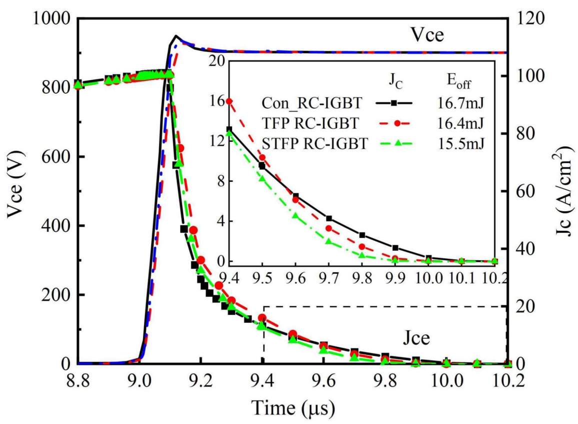

Fig. 5 The IGBT turn-off characteristic of three types of RC-IGBT

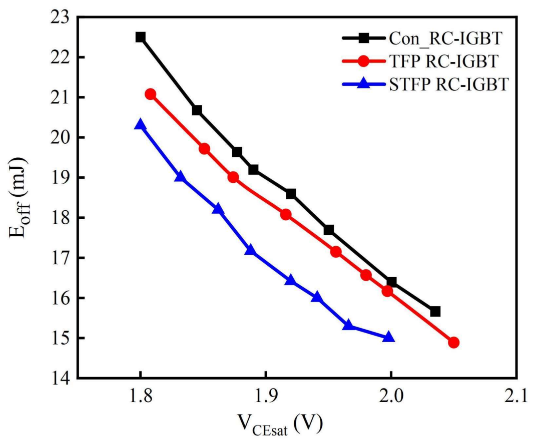

Fig. 6 V_{CEsat} and E_{off} trade-off relations of IGBT of STFP RC-IGBT

TCAD Simulation results

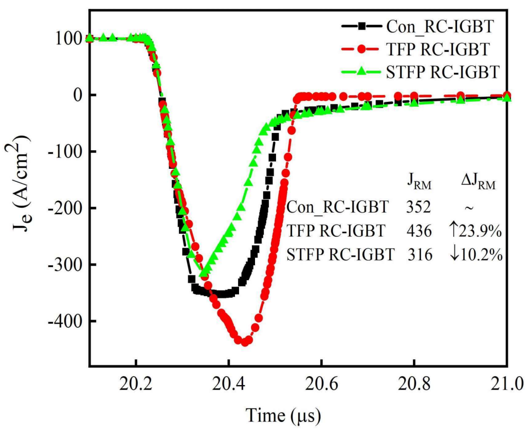

Fig. 7 The diode reverse recovery characteristics of three types of RC-IGBT

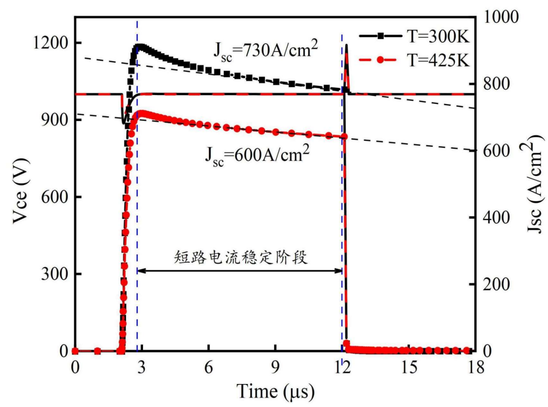

Fig. 8 The short-circuit characteristics of STFP RC-IGBT

Results

STFP RC-IGBT:

- Snapback -free forward conduction characteristic with smaller cell size
- Lower switching energy loss, Eoff, of IGBT
- Superior V_{CEsat}-E_{off} compromise relationship
- Lower reverse recovery peak current density, J_{RM}, of integrated Diode
- With 10μs tsc of short-circuit