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A Novel Dynamic Avalanche Free Super-Junction Trench Clustered IGBT for High Power Applications

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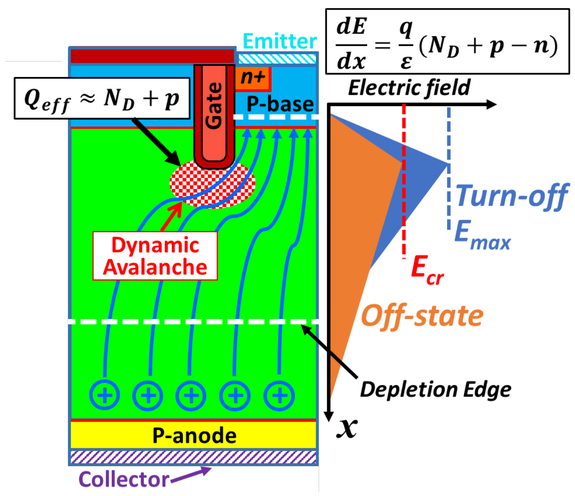
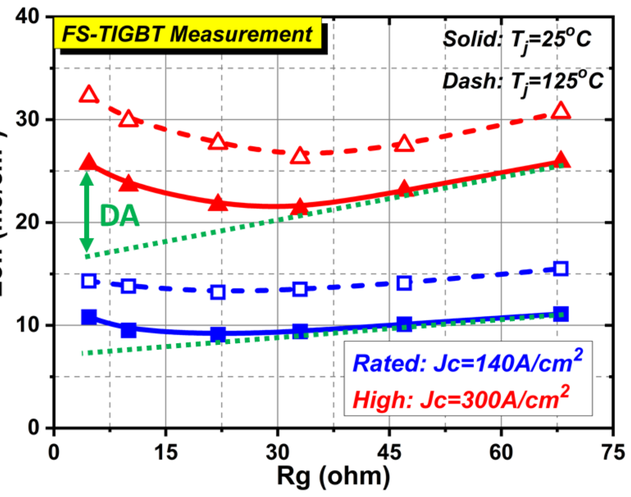
Introduction to Dynamic Avalanche (DA)



DA during switch-off of TIGBTs

- DA can be triggered by:
  - High current density
  - High dV/dt
  - Current filamentation
- DA poses a fundamental limit on:
  - Operating current density
  - Turn-off energy loss
  - dV/dt controllability
- Therefore DA must be eliminated.

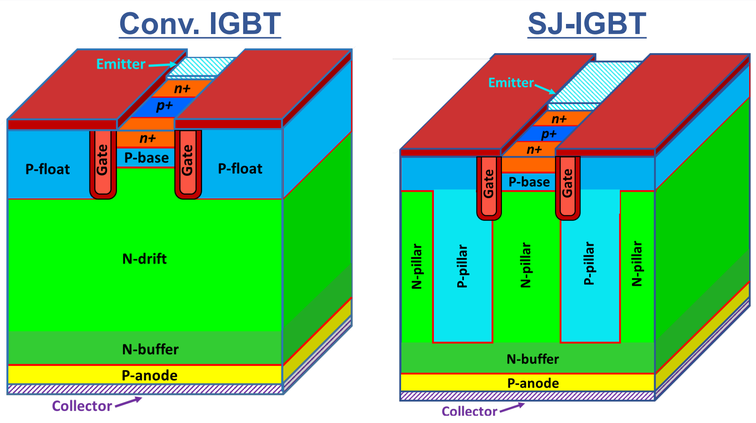
DA in Trench IGBT



(Source: P. Luo, et al, "Evaluation of Dynamic Avalanche Performance in 1.2-kV MOS-Bipolar Devices," in IEEE Trans. on Electron Devices, Sep. 2020.)

- DA limits the reduction of Eoff in trench IGBTs.
- DA is enhanced at high current density operation.

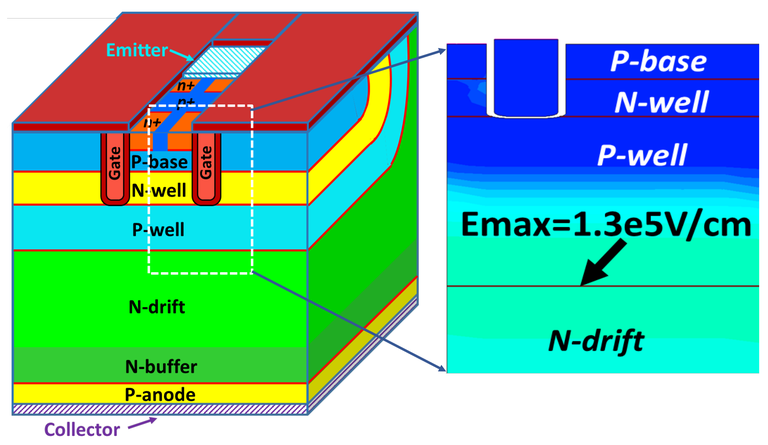
DA in Super-Junction IGBT



Comparison of Hole Density during turn-off

Comparison of Electric Field during turn-off

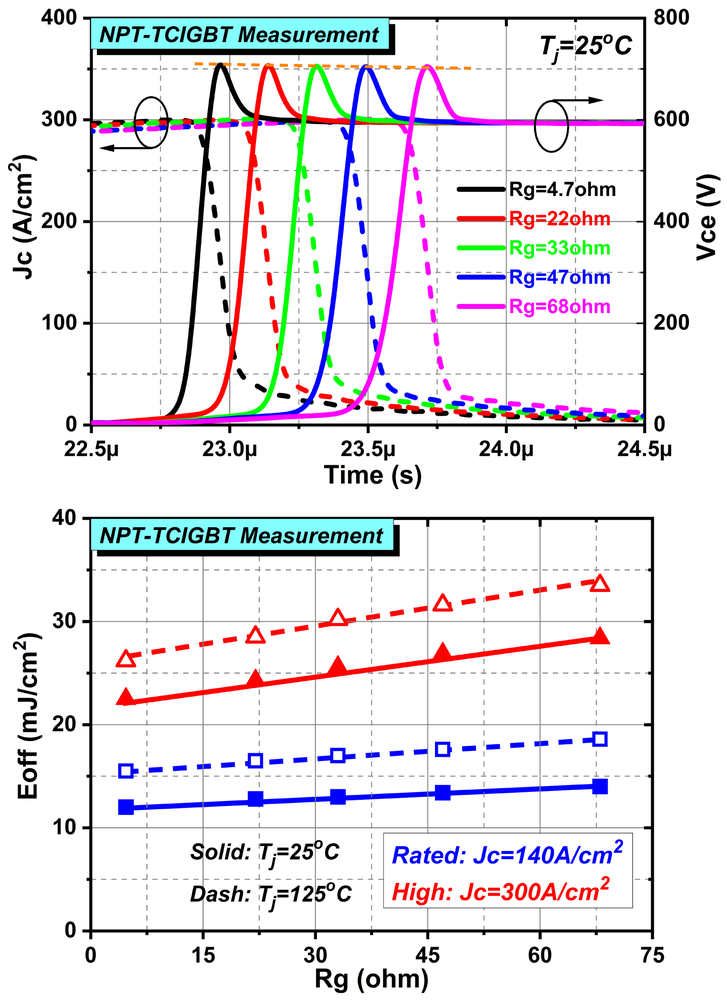
DA Free Design Trench CIGBT



Cross-section view of the TCIGBT

- No electric field crowding in the **TCIGBT**.
- Trench gates are protected from peak electric field.

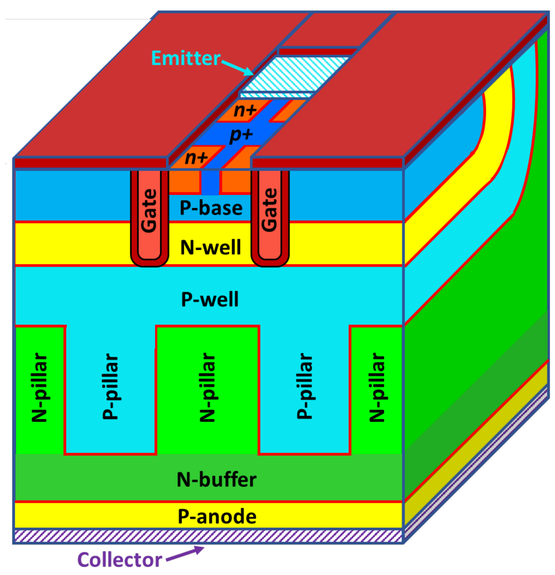
TCIGBT-High Current Density Operation



(Source: P. Luo, et al, "Evaluation of Dynamic Avalanche Performance in 1.2-kV MOS-Bipolar Devices," in IEEE Trans. on Electron Devices, Sep. 2020.)

- Experiments confirm that **TCIGBTs** remain DA free even operated at 300A/cm².

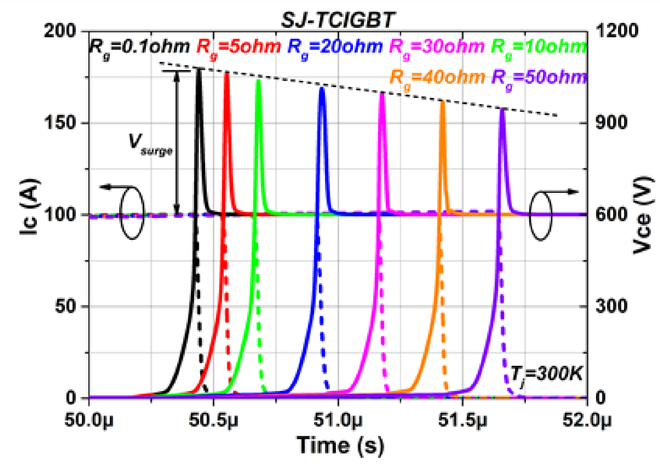
Super-Junction TCIGBT

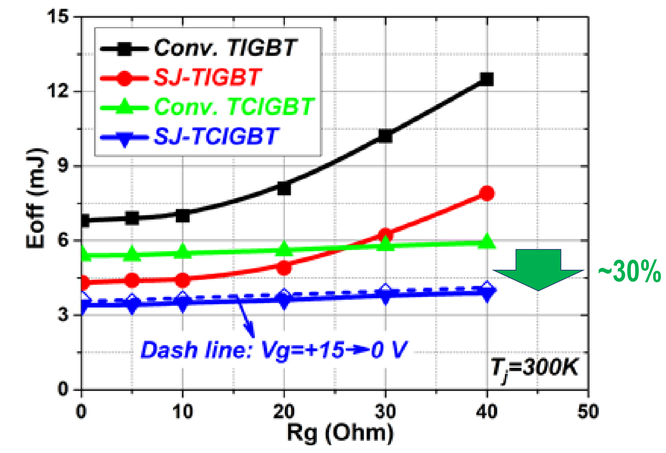


Cross-section view of the SJ-TCIGBT

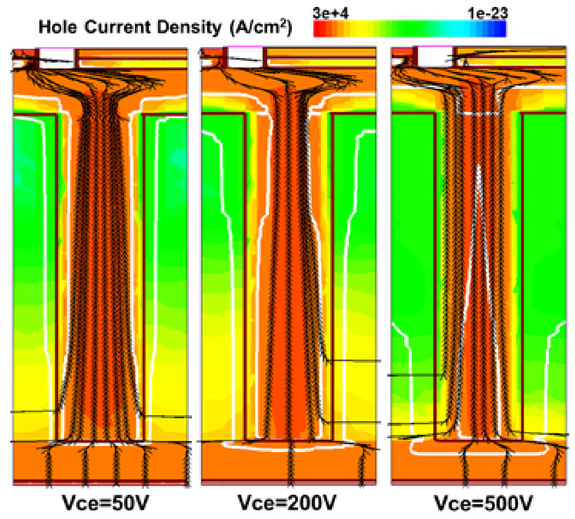
- SJ structure can further enhance the PMOS effect in **TCIGBT**. Therefore, the Eoff can be further reduced.

Simulation Study on SJ-TCIGBT



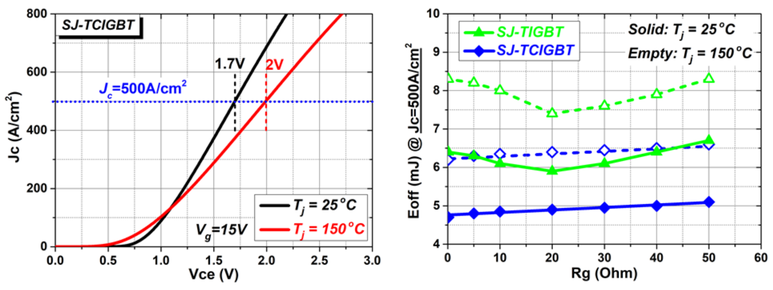


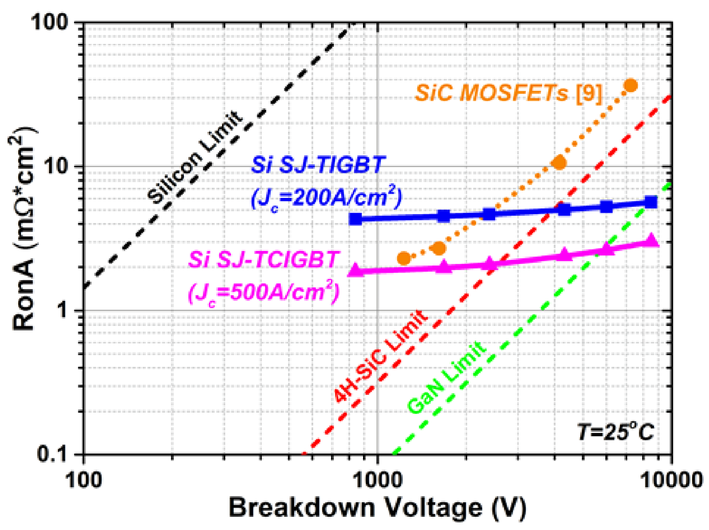
PMOS Actions in SJ-TCIGBT



Hole current flowlines during turn-off

SJ-TCIGBT: High Power Density Operation





Conclusions

- The DA limits the electrical performance of IGBT and SJ-IGBT.
- The SJ-TCIGBT remains DA free performance and low energy loss at Jc=500A/cm².
- Therefore, the SJ-TCIGBT device is well suited for high power applications.