Impact of the inhomogeneous current distribution on the turn-off behaviour of BIGT

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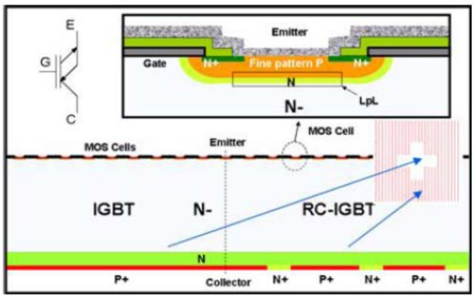
Introduction

- advantage in softness of the turn off behaviour in the BIGT in comparison to a conventional IGBT/diode

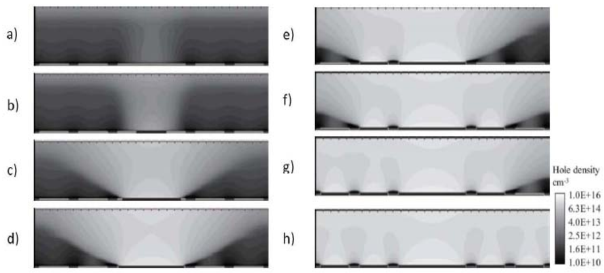
BIGT chip design includes 2 parts:

- pilot-IGBT with a conventional design
- RC-IGBT with shorts on the collector

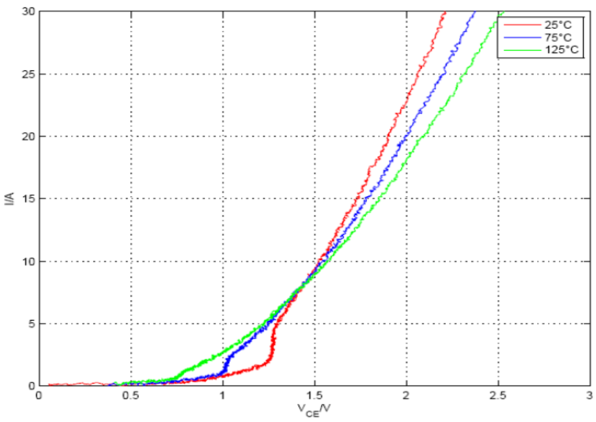


Current distribution during the on-state

- hole density at different current densities in the BIGT



- at low current the RC-IGBT is unipolar, current flows mainly in the pilot-IGBT
- with increasing current the RC-IGBT cells change stepwise into the bipolar operation (secondary snapbacks)
- Inhomogeneous current distribution remains at high current densities



Influence on the turn-off behaviour

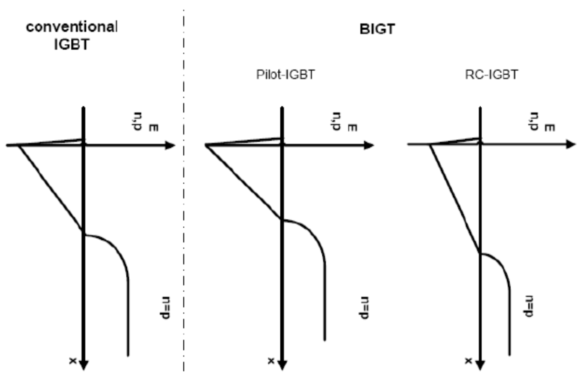
- gradient of the electric field in the space charge region

$$\frac{dE}{dx} = \frac{q}{\varepsilon} \cdot (N_D + p)$$

- hole density

$$p = \frac{j_p}{v_{sat} \cdot q}$$

- same V_{CE} and dv_{CE}/dt for the pilot-IGBT and the RC-IGBT
- high hole density in the pilot-IGBT leads to higher dE/dx and a smaller space charge region



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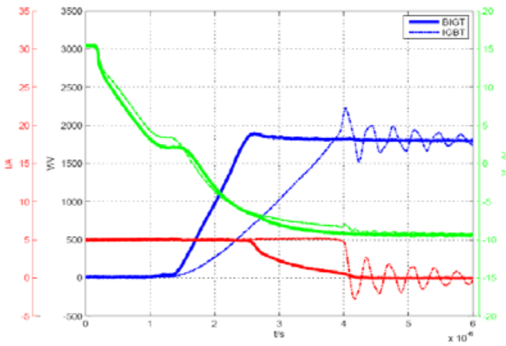
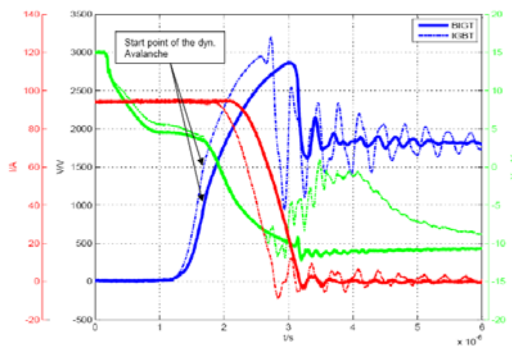
Comparison of the turn-off behaviour in the IGBT-mode

low current



high current



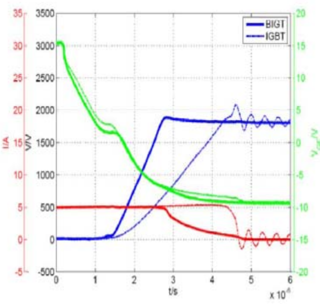
- **IGBT shows high di/dt and overvoltage, as a reason of the low gradient of the electric field**
- **significant higher dv_{CE}/dt and lower overvoltage in the BIGT**
- **higher current density in the pilot-IGBT leads to a higher dE/dx and a decreased space charge region**
- **BIGT shows a tail current**

- **high voltage peak, because the electric field reaches the buffer-layer during the falling edge of current**
- **IGBT shows high di/dt and overvoltage, as a reason of the low gradient of the electric field**
- **both devices show a dyn. Avalanche, but the injection points are different**

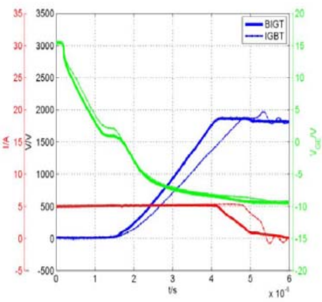
Influence of the temperature on the turn-off behaviour

low current

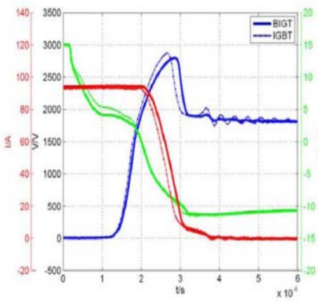
high current



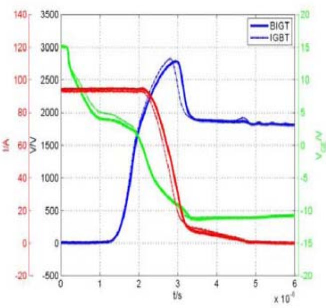
T=75°C



T=125°C



T=75°C



T=125°C

with increasing temperature the current distribution is more homogeneous

- **overvoltage and gradient of the V_{CE} slightly decrease**
- **the dv_{CE}/dt of the BIGT decrease significant with the temperature**
- **smaller tail current in the BIGT, as reason of the smaller dE/dx and longer space charge region**

- **IGBT shows a soft turn-off behaviour at high temperature**
- **injection point of the dyn. Avalanche in the BIGT shows a strong temperature dependency**
- **small difference in the turn-off behaviour at T=125°C**

Conclusion

- **BIGT contains a pilot-IGBT with conventional design and a RC-IGBT with shorts on the collector**
- **higher emitter efficiency of the collector leads to a higher plasma concentration in the pilot-IGBT in comparison to the RC-IGBT**
- **increased hole density leads to a high gradient of the electric field and a short space charge region in the pilot-IGBT**
- **at low current the current flows mainly in the pilot-IGBT , the overvoltage and the dv_{CE}/dt are significant lower**
- **at high current both devices show a dyn. avalanche, but the injection point is in the BIGT at a lower voltage, as a reason of the high electric field in the pilot -IGBT**
- **with increasing temperature the difference in turn-off behaviour between the BIGT and the conventional IGBT are smaller**

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