Advances in IGBT and Packaging Technologies for Next Generation High Power Applications

Evgeny Tsyplakov, ABB Switzerland Ltd, Semiconductors, Switzerland, evgeny.tsyplakov@ch.abb.com
Franc Dugal, ABB Switzerland Ltd, Semiconductors, Switzerland, franc.dugal@ch.abb.com
Munaf Rahimo, ABB Switzerland Ltd, Semiconductors, Switzerland, munaf.rahimo@ch.abb.com
Arnost Kopta, ABB Switzerland Ltd, Semiconductors, Switzerland, arnost.kopta@ch.abb.com
Fabian Fischer, ABB Switzerland Ltd, Semiconductors, Switzerland, fabian.fischer@ch.abb.com
Samuel Hartmann ABB Switzerland Ltd, Semiconductors, Switzerland, samuel.hartman@ch.abb.com
Makan Chen, ABB Switzerland Ltd, Semiconductors, Switzerland, makan.chen@ch.abb.com

Introduction - Power semiconductor devices are the key components, facilitating the continuous strive to increase the level of regenerative power sources in our energy mix . As part of this change, the new power sources have to be both affordable and reliable, which are directly reflected in the required total system cost, losses and reliability. Power semiconductor device are today present in all parts of the energy chain, starting Power Generation, through the GW range transmission and distribution (T&D) down to low power applications in computers and mobile phones. Innovation in both device and packaging technologies enables the power electronic systems along the chain to utilize energies from renewable generation in the most efficient way, making them affordable and competitive with the traditional sources. In this paper, we will focus on applications and devices in the highest power range used in grid applications like HVDC and FACTS

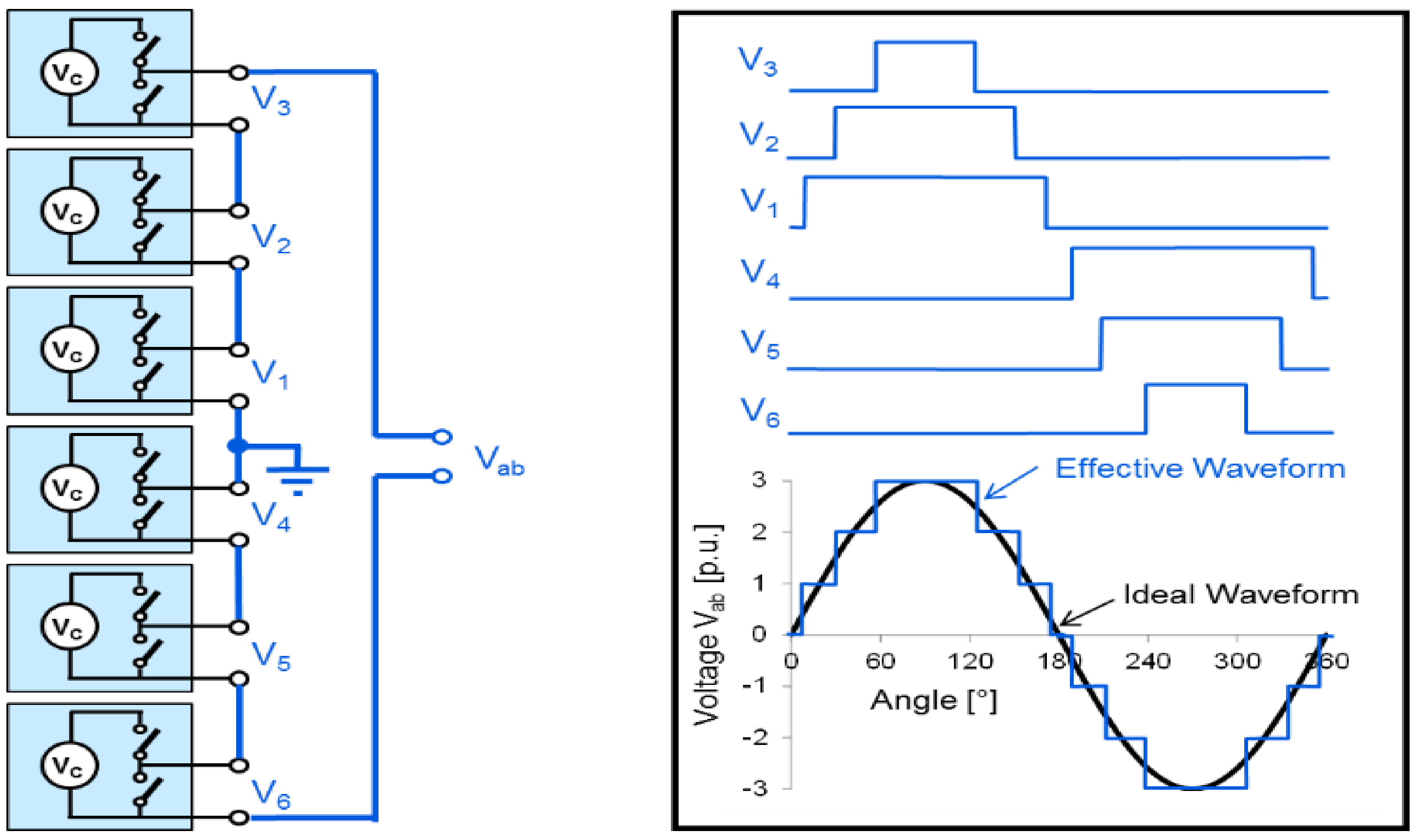

Fig. 1 MMC Conveter

General power device trends

The general device development trends, which are valid for both IGCTs and IGBTs can be summarized with the following four points:

- Loss reduction by optimizing the device structure and design.
- Increasing the power density for a given footprint/silicon area via integration.
- Increasing the converter output power by improving the thermal design.
- Where applicable, increasing the single device footprint to increase the total current capability of a single device.

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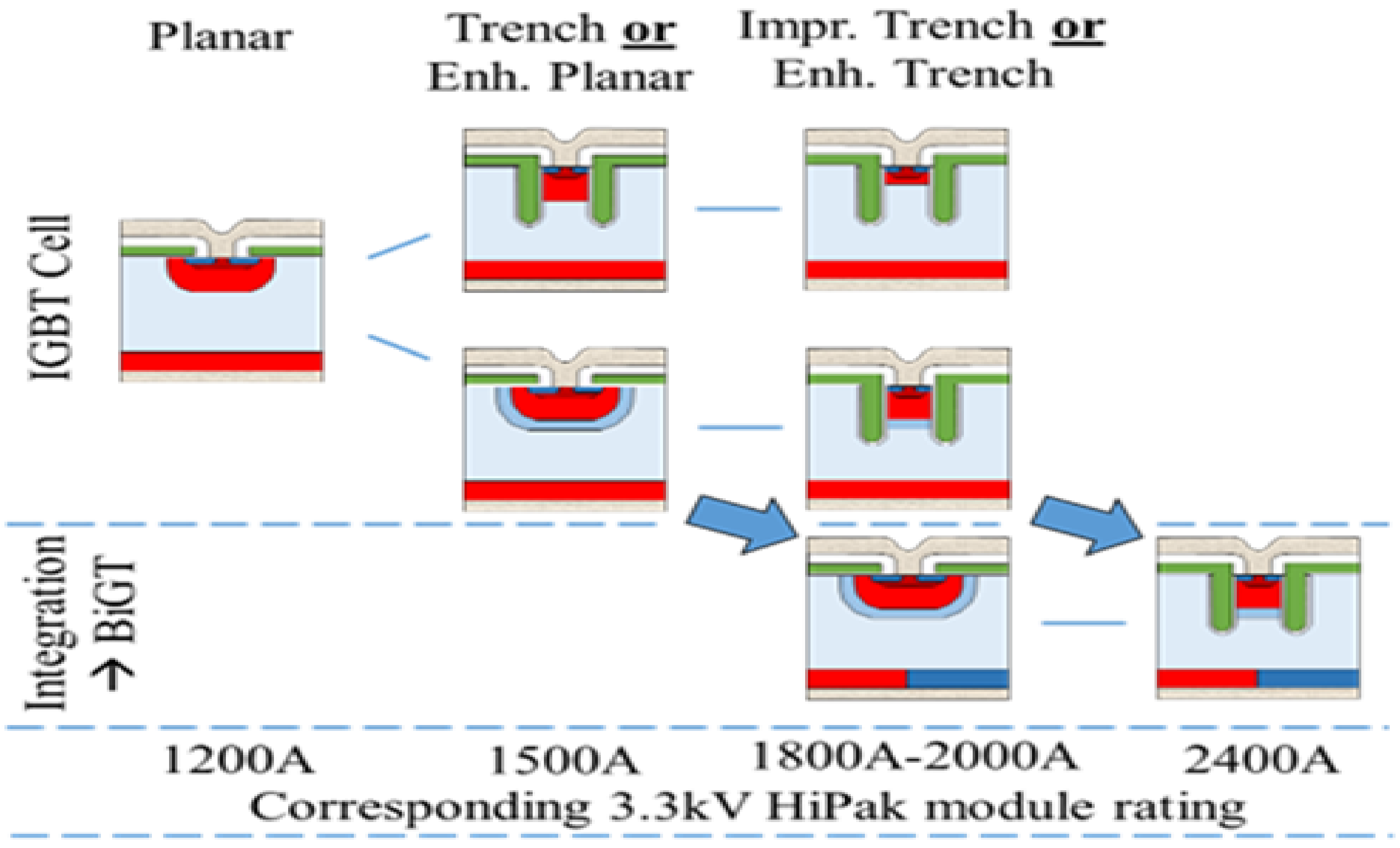

Fig. 2 IGBT development steps. The corresponding ratings of a 3.3kV HiPak2 module (footprint 190*140mm) are shown.

BiGT: Integration of the diode into the IGBT structure

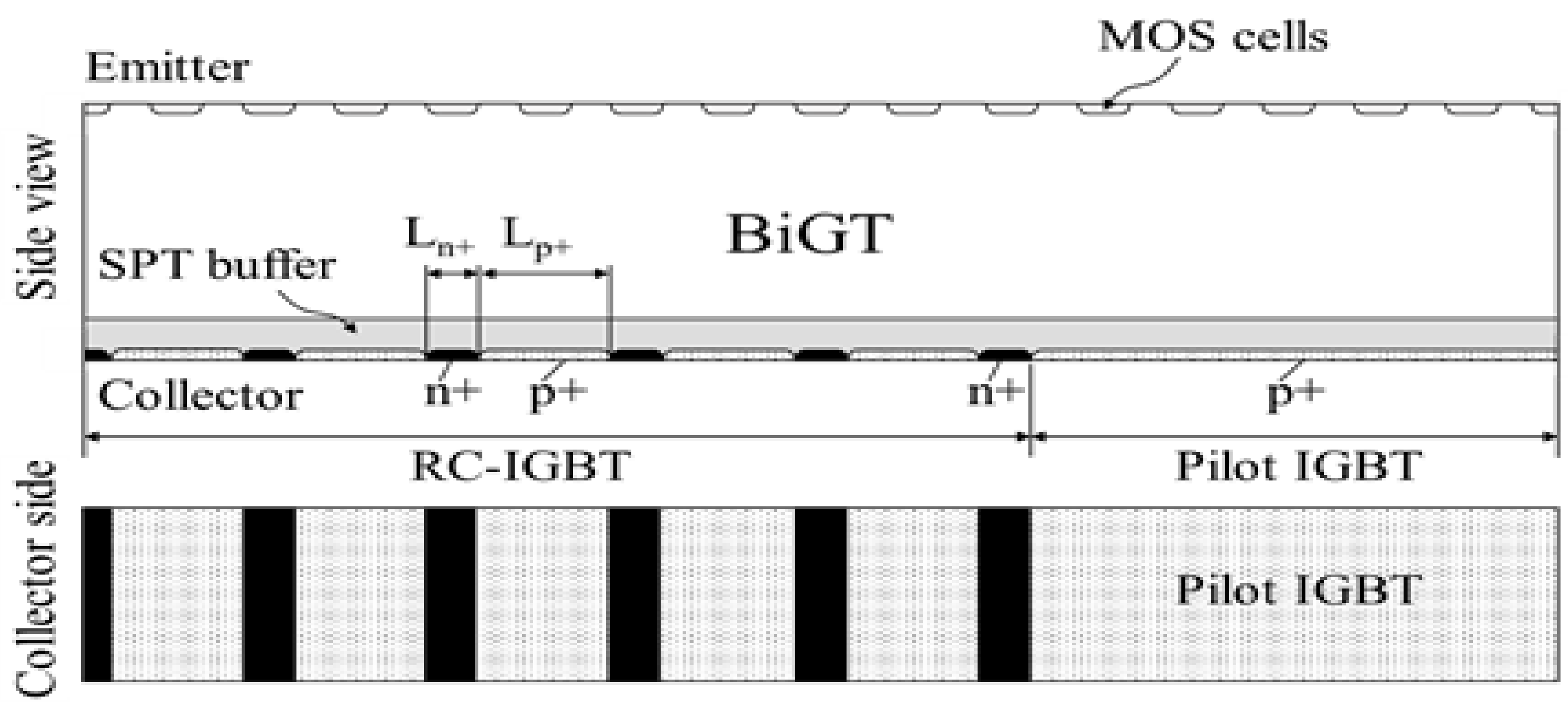

Figure 3 BiGT (Bi-mode Insulated Gate Transistor), an advanced reverse conducting IGBT. Cross section and collector design.

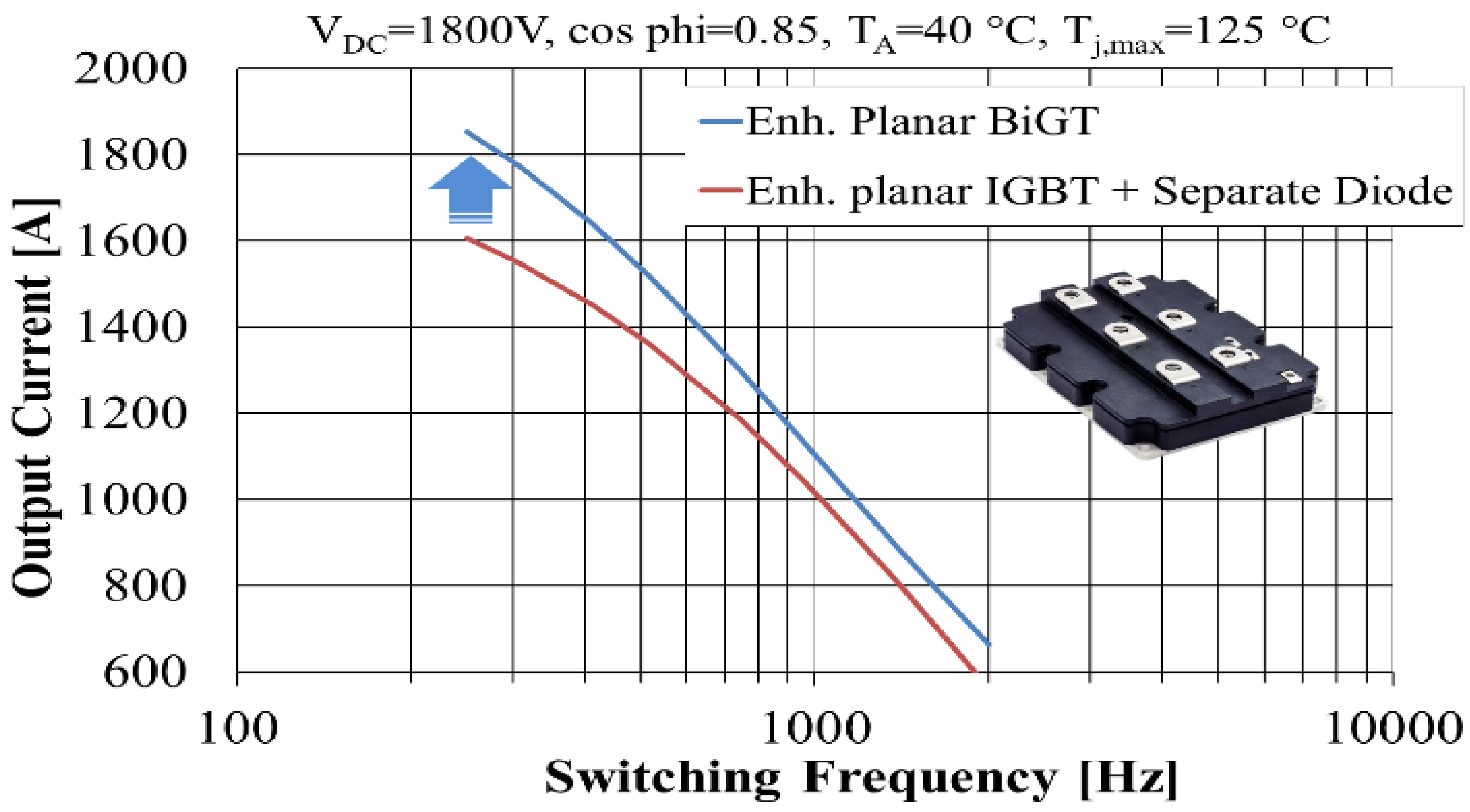

Fig. 4 Calculated RMS current for 2-level PWM converter (T_{case} = 80 °C)

The Plug-In PI-BIGT Concept

The diode can be made fully independent of the gate bias during the freewheeling phase. The losses can still be reduced by applying MOS-control, but the diode has its full functionality including a high surge current capability independently of this possible feature.

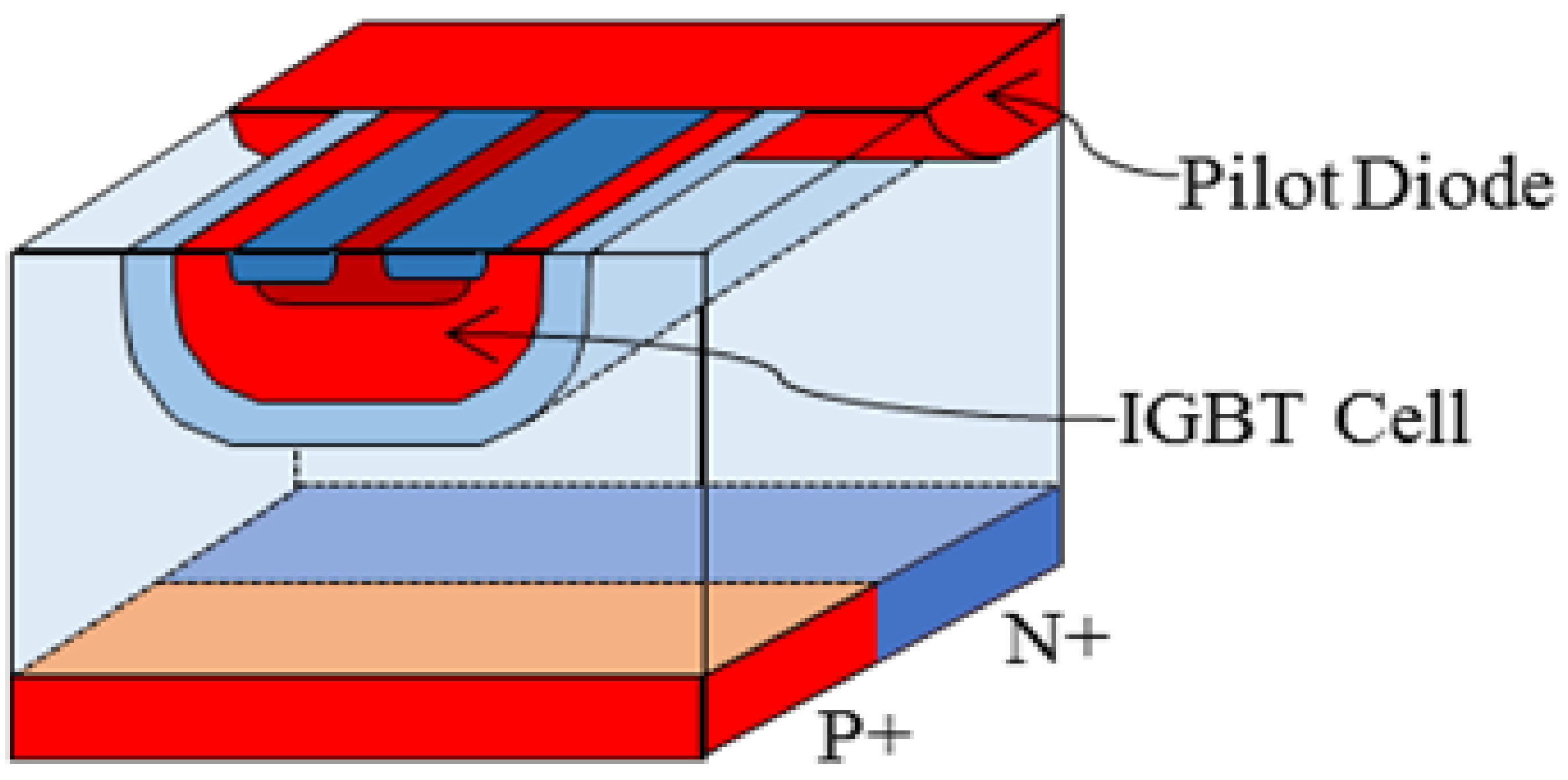

Figure 5 Schematic view of the enhanced planar BiGT cell with the pilot diode

The basic target of the PI-BiGT is to reduce the diode mode V_F with an applied positive gate single, i.e. without MOS-control. For reference a 6500 V/600 A BiGT HiPak1 (130 x 140) mm was previously reported with the output characteristics shown in Fig. in both IGBT and diode mode at 25 °C and 125 °C.

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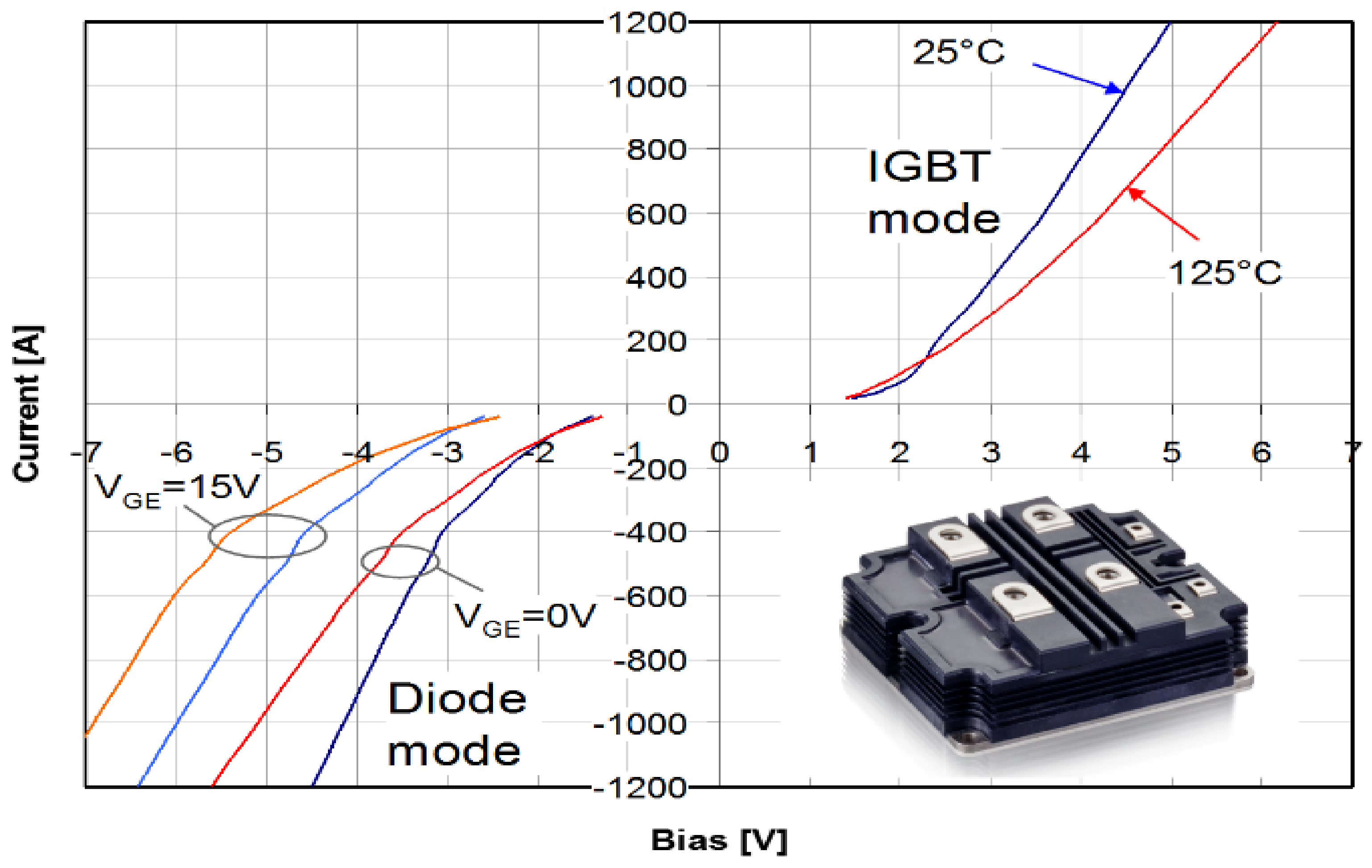


Figure 6 6500V/600A BIGT HiPak1 (130 x 140) mm output characteristics in IGBT and diode modes at 25° C and 125 °C

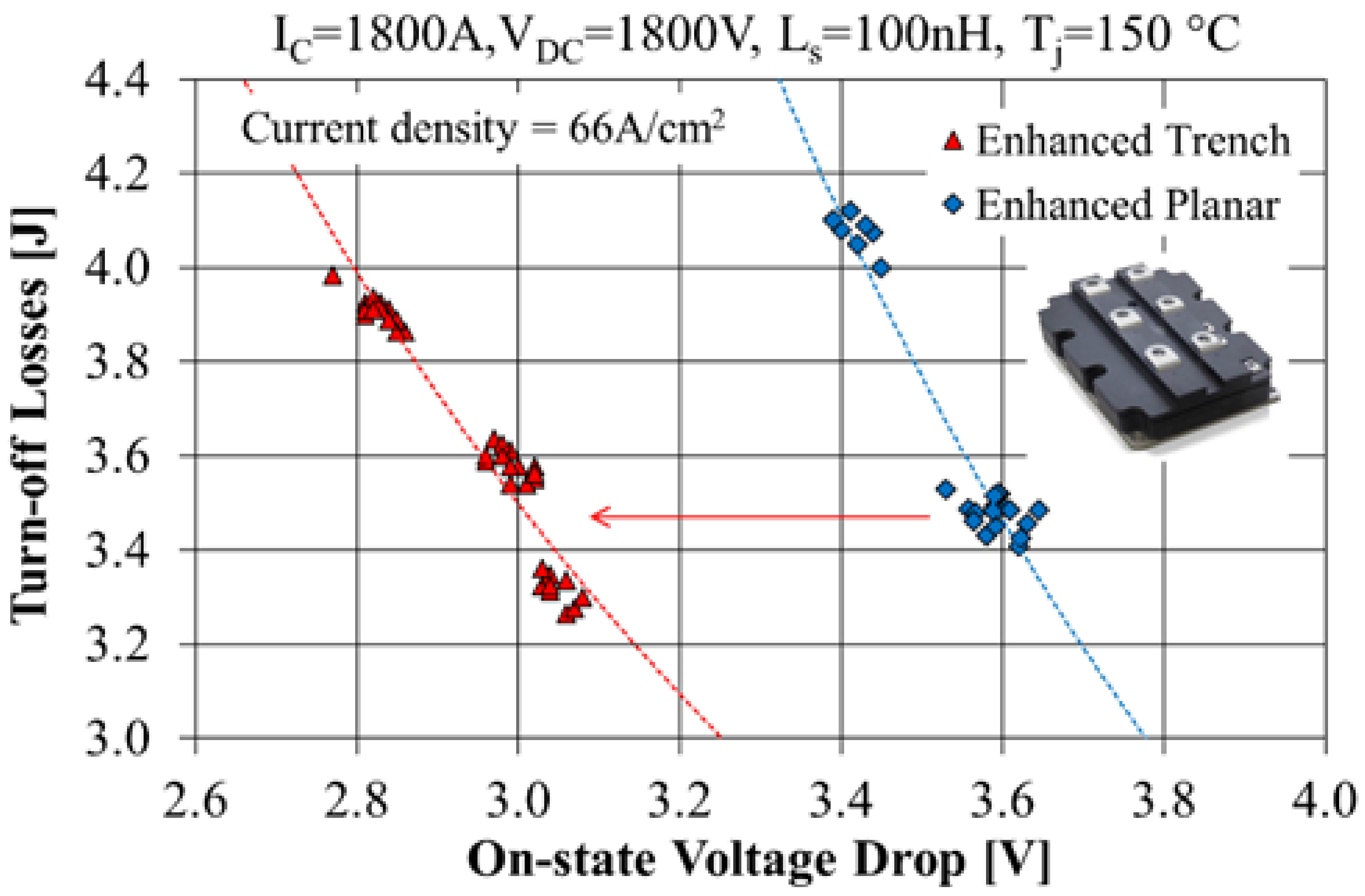
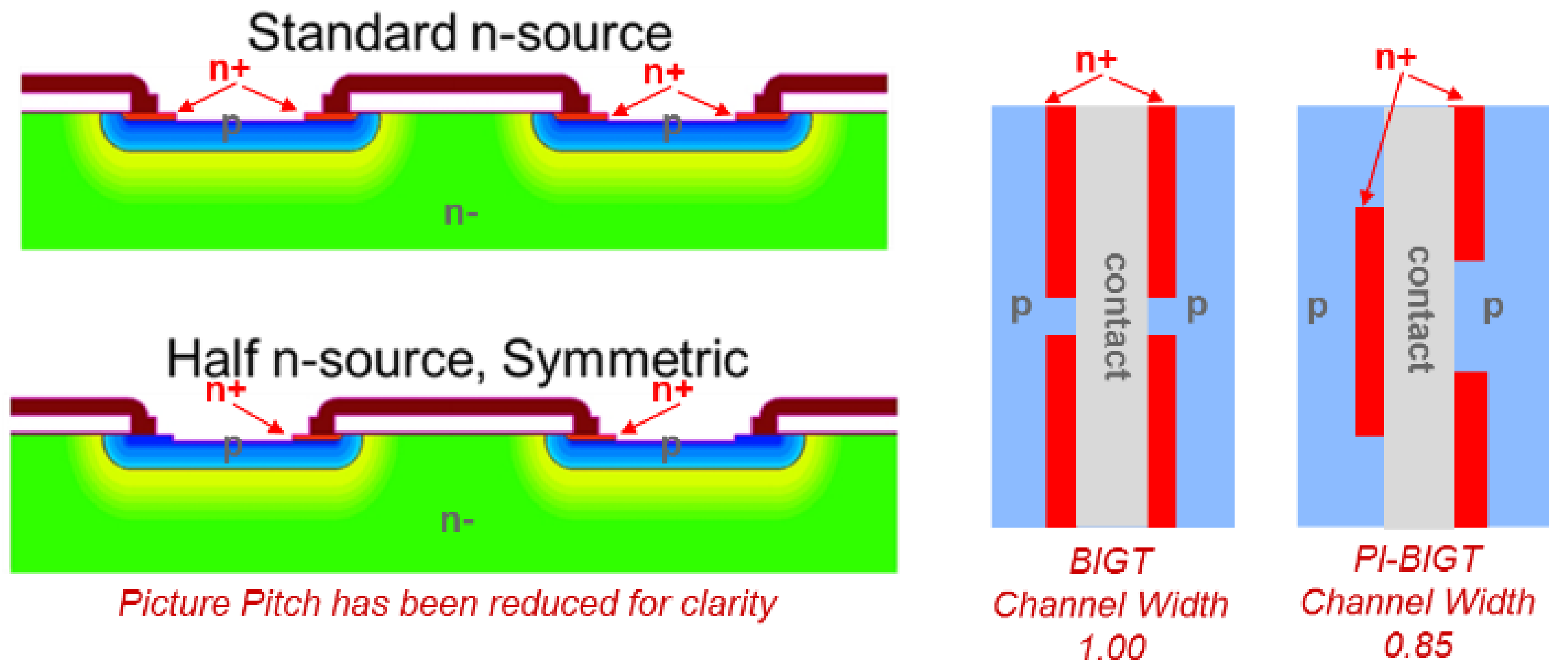


Figure 10 E_{off}/ $V_{CE,}$on trade-off curve comparison between the 3.3kV enhanced trench and the enhanced planar IGBT. For HiPak module.



2D MOS Cell Model

MOS Cell Top View

Figure 7 *PI-BIGT n+ source adaptations for lowering the MOS channel effect on the diode conduction mode.*

New package for next generations of power converters

Fig.11 LinPak module

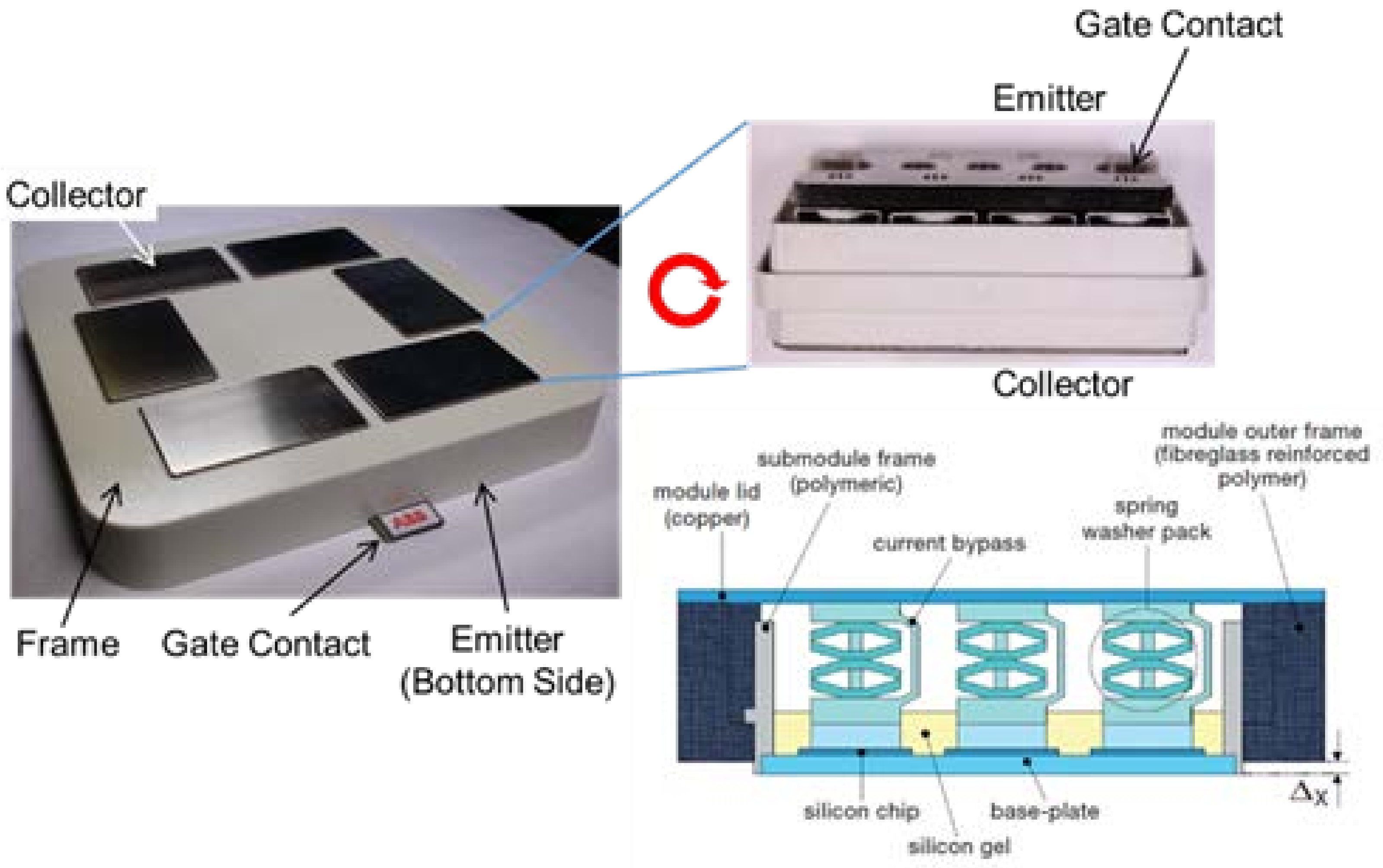
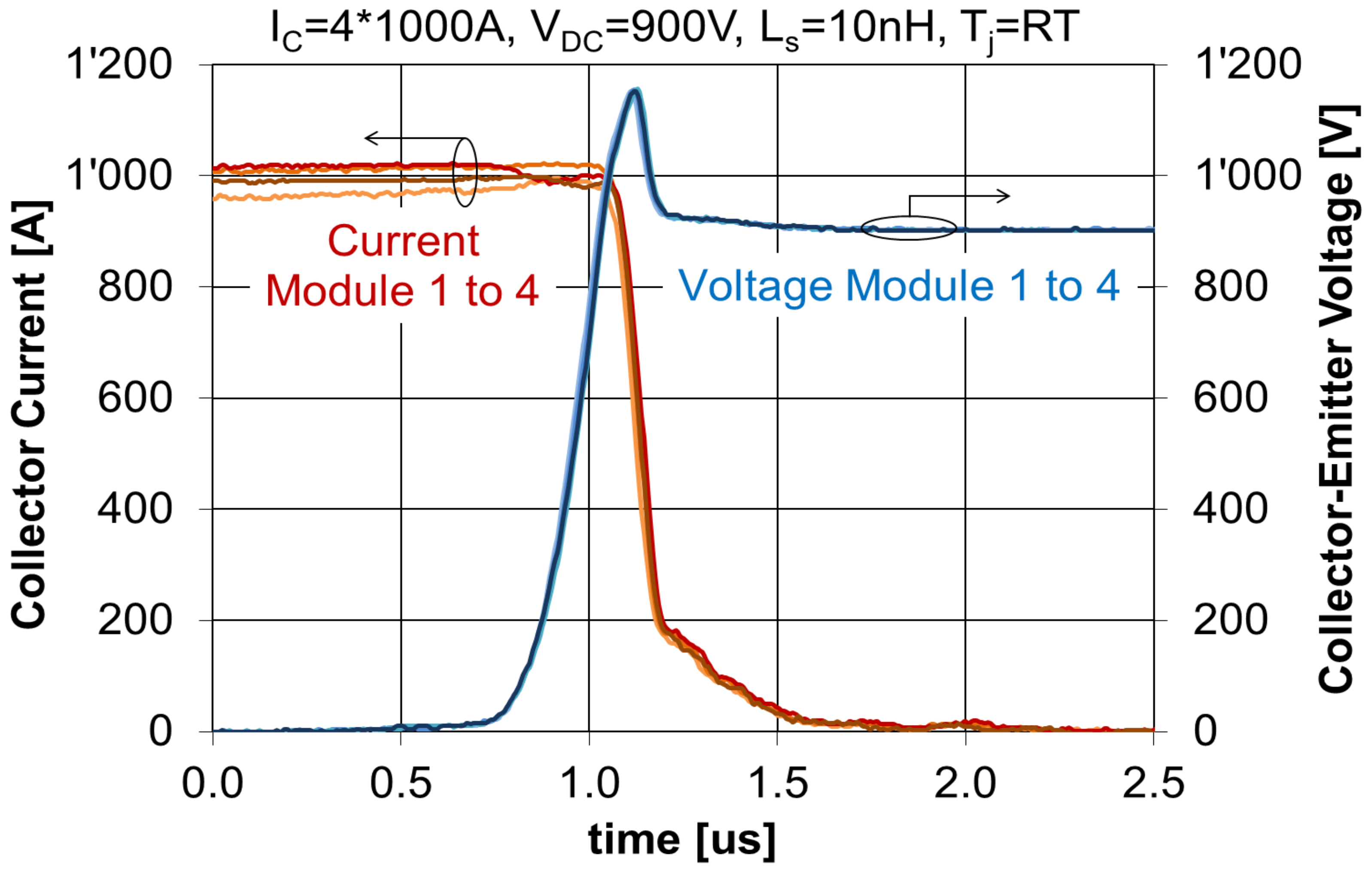


Figure 8 4500 V/3 kA StakPak module with BiGT chips

Cell improvement: the Enhanced Trench IGBT



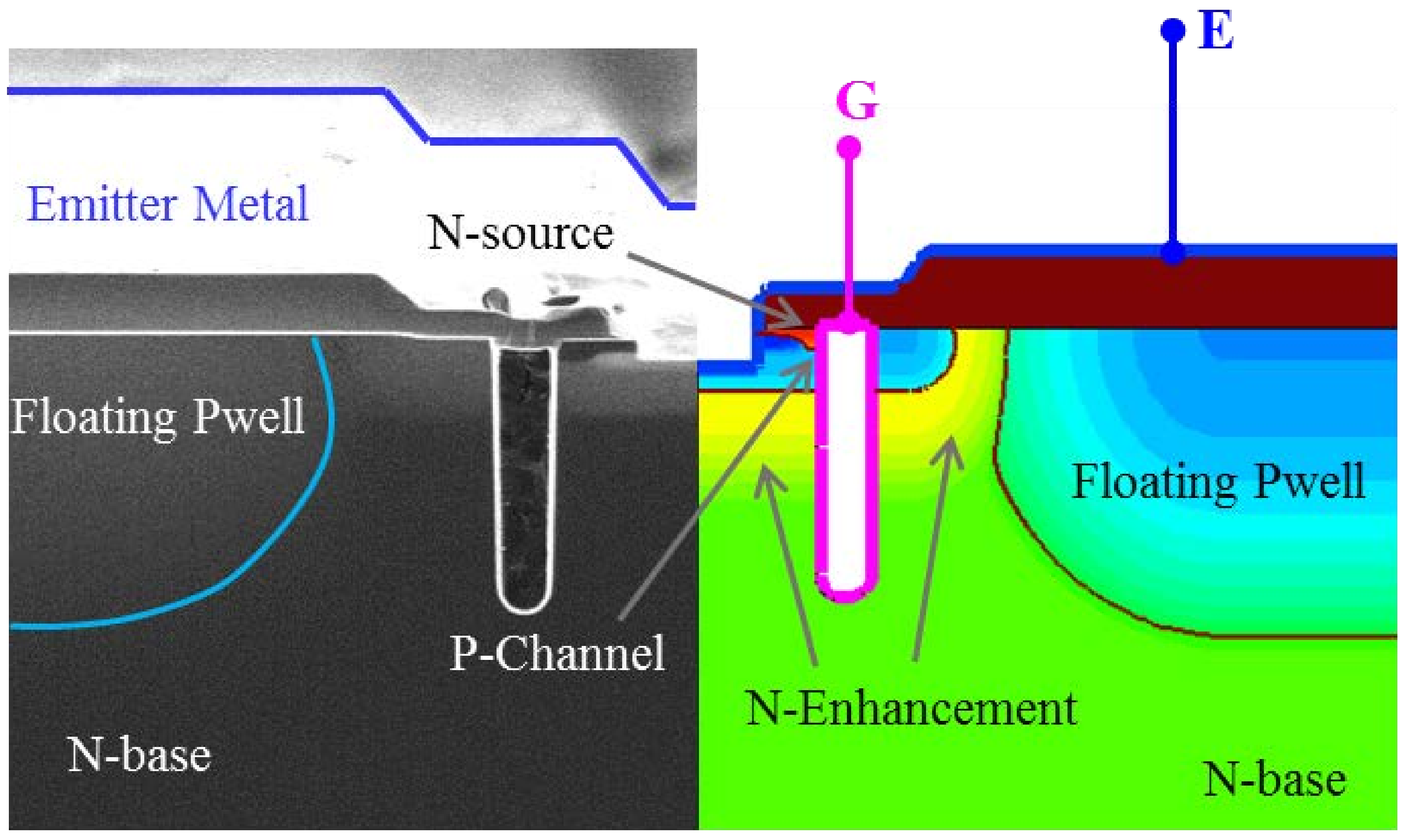


Figure 9 Cross-section of the enhanced trench IGBT cell. Left SEM im age, right simulation model

Figure 12 Turn-off at nominal conditions of 4 parallel connected LinPak