

# 4.5 kV Module for various applications

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## 4.5 kV 1500 A module for various applications

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POWERING GOOD FOR SUSTAINABLE ENERGY

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## About myself



**Speaker:** Evgeny Tsyplakov

**Company:** HITACHI ABB POWER GRIDS

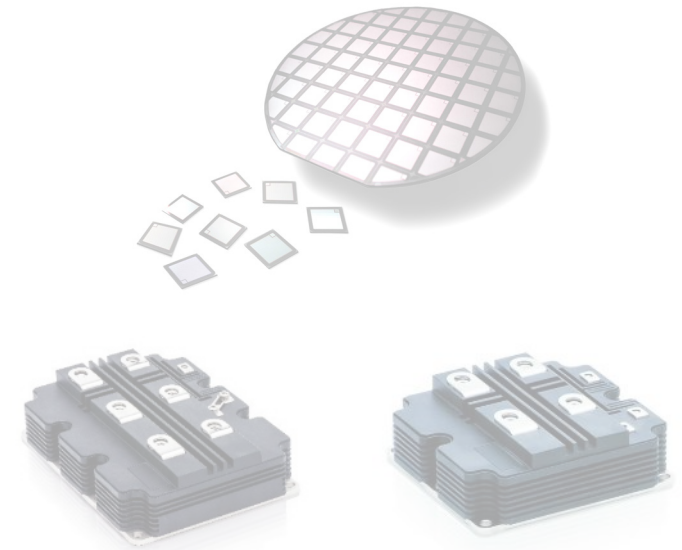
**Department:** Product Management

**Position:** Global Product Specialist



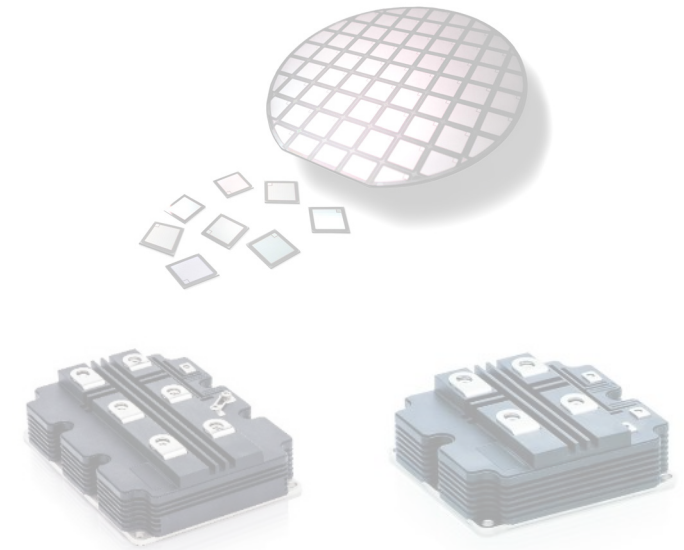
## 4.5 kV Module for various applications

1. Motivation and application requirements
2. Chipset technologies
  - New enhanced planar 4.5kV IGBT chip
  - New field charge extraction 4.5kV diode
3. SPT++ HiPak2 4.5kV 1500A module
  - Electrical characteristics
  - Maximum ratings
4. Summary and conclusion



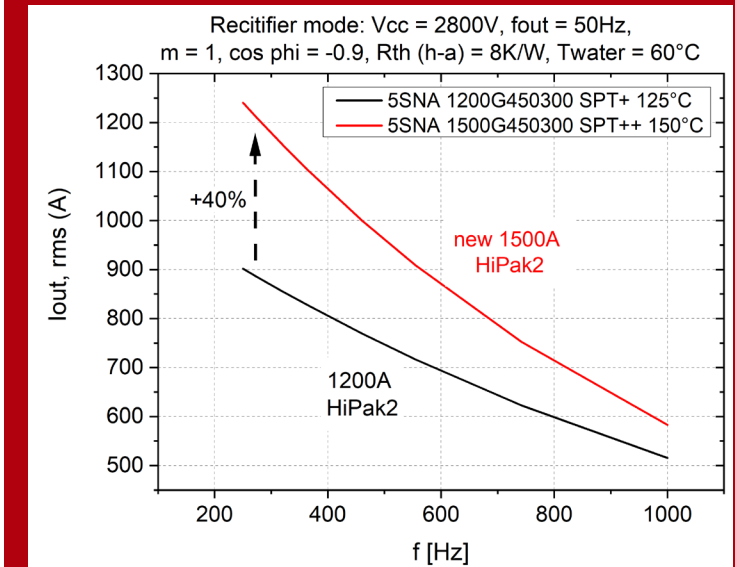
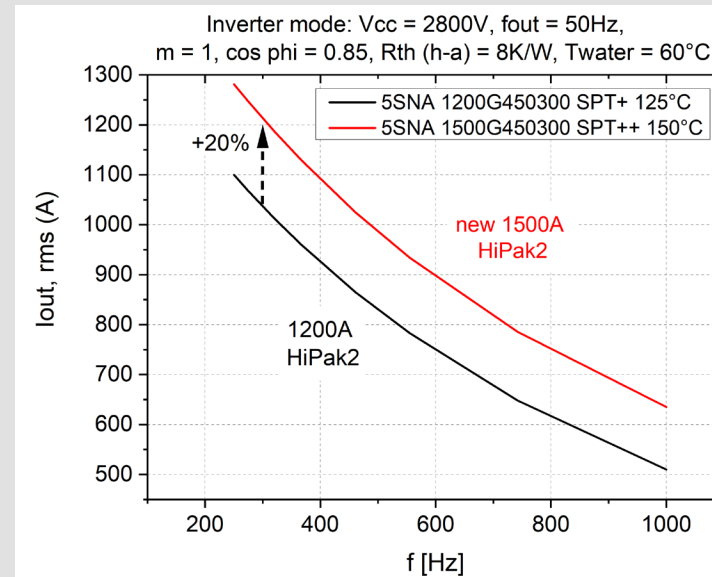
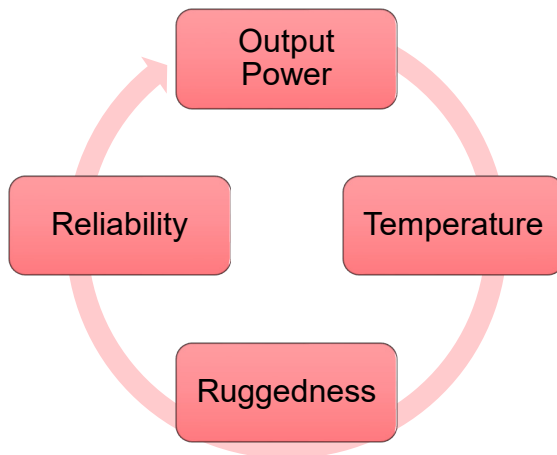
## 4.5kV 1500A HiPak module for various applications

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## 4.5kV 1500A HiPak module

- Higher power density demands, as trigger for our new 4.5kV 1.5kA HiPak2<sup>1</sup> 150°C
- New IGBT and diode chip design for increased current and temperature capabilities
- Increased reliability with improved humidity protection with the new Hitachi ABB Power Grids passivation concept<sup>2</sup>

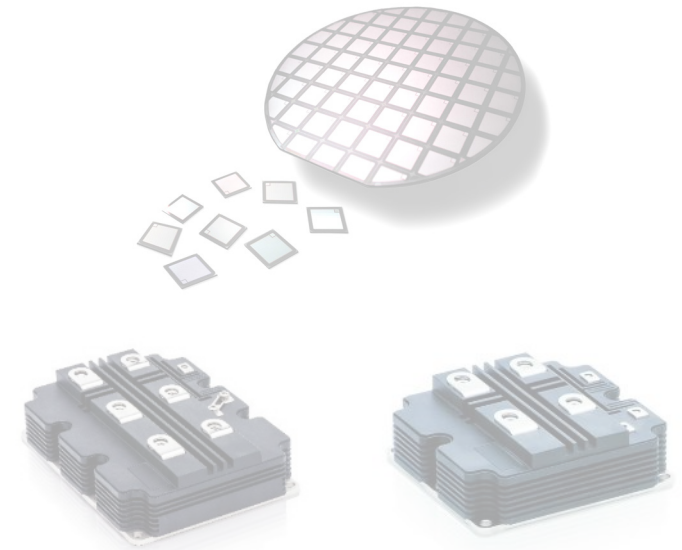


References:  
 1: "A new HiPak Module Platform with Improved Reliability", G. Pâques et al., PCIM 2014  
 2: "Humidity Robustness of IGBT Guard Ring Termination", C. Papadopoulos et al., PCIM 2019



# 4.5kV 1500A HiPak module with 150°C capability

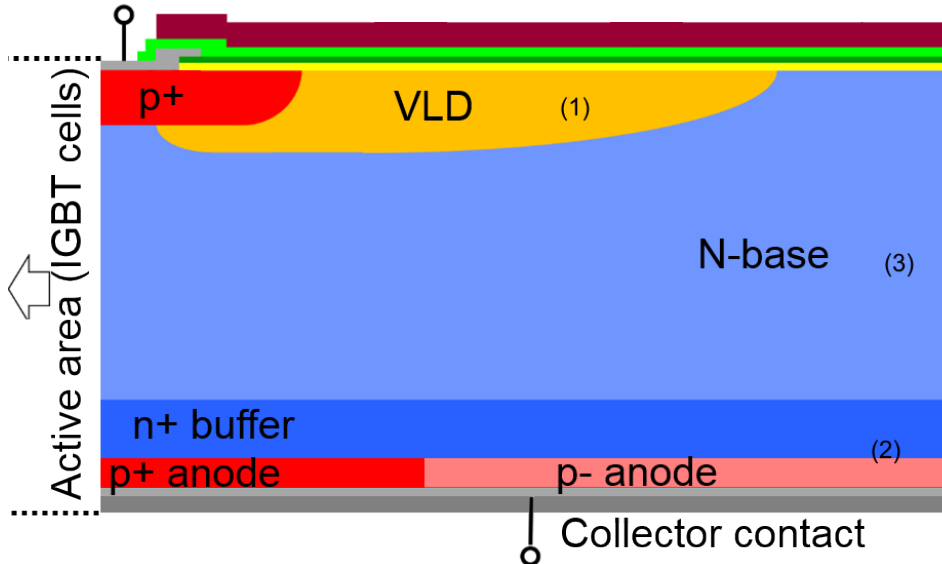
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## IGBT schematic and key highlights

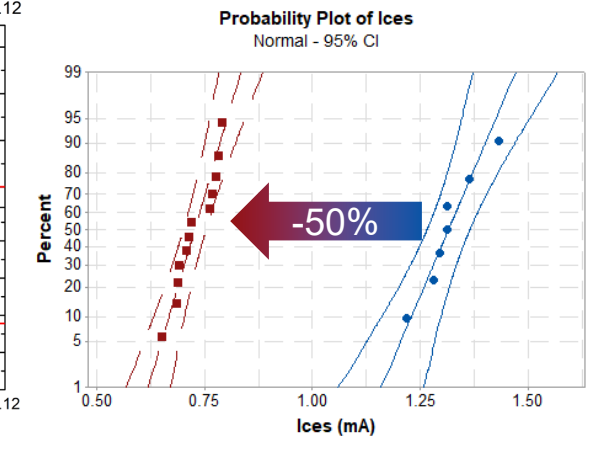
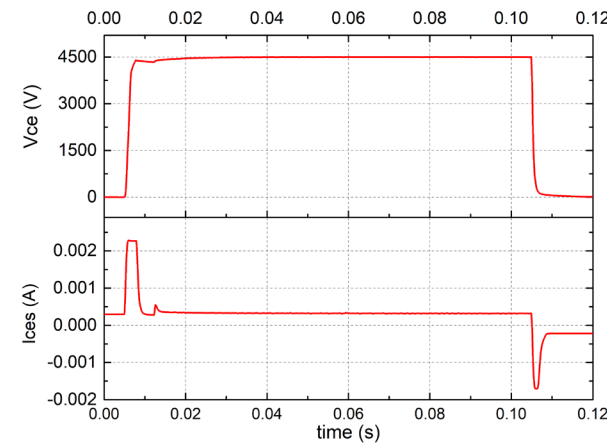
- Lower leakage
- Lower on-state voltage losses (at the same turn-off energies)

Emitter contact



## New features

1. New Variable Lateral Doping (VLD) termination design, resulting in 25% smaller dimensions
2. Introduction of the “partial p-collector” concept1
3. New buffer and n-base design with 10% reduced thickness



Same chip area of previous 4.5kV rugged enhanced planar IGBT generation

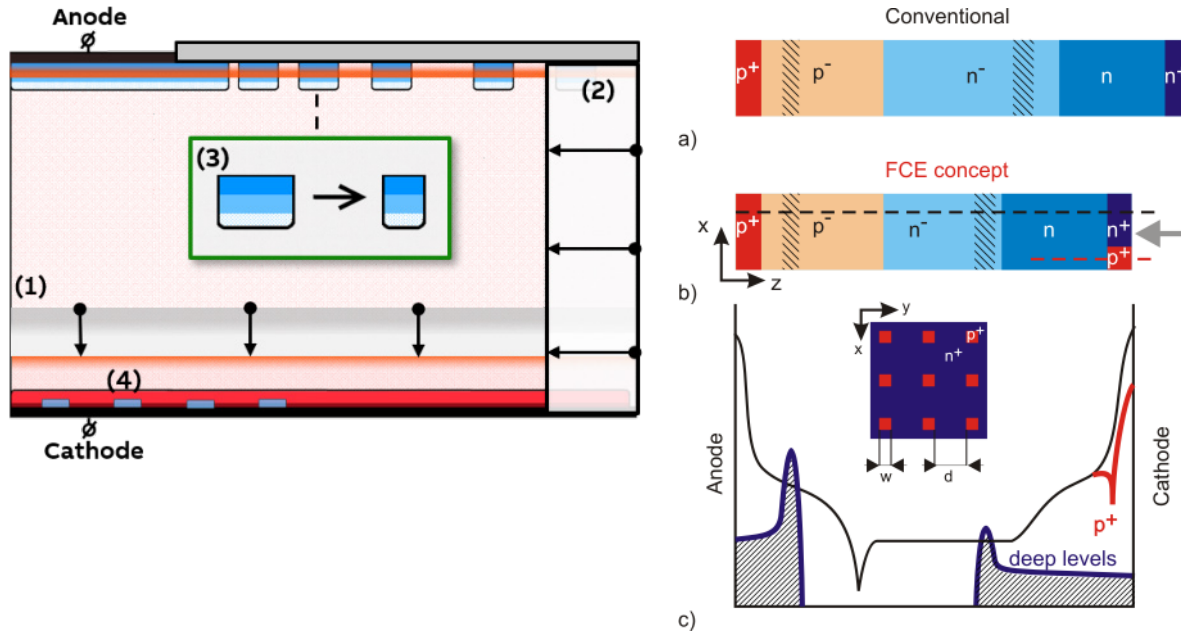
Reference:  
1: "Reduction of Temperature dependence on leakage current of IGBTs by Field-Stop design", H.-J. Schulze, ISPSD 2011





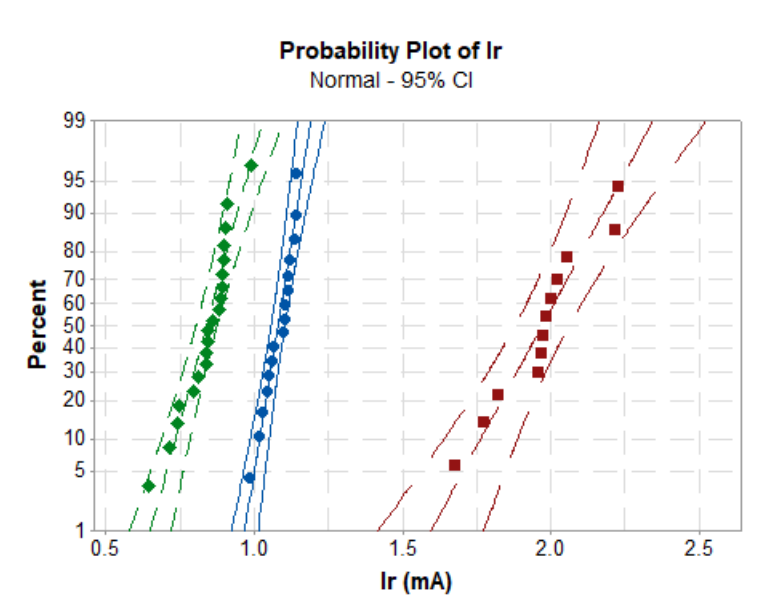
# The new 4.5kV Field Shielded Anode (FSA) Field Charge Extraction (FCE) diode

## Diode schematic and new features



## Key highlights

1. Backside irradiation depth optimization
2. New termination design
3. Optimized silicon

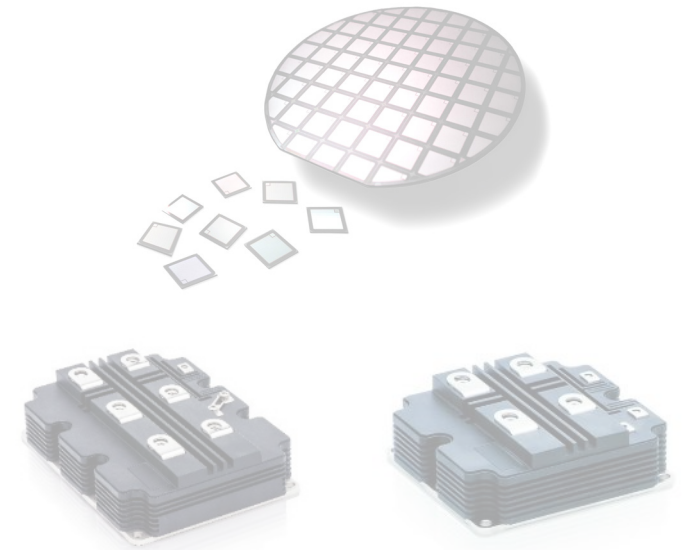


20% larger chip area w.r.t. the previous 4.5kV diode generation

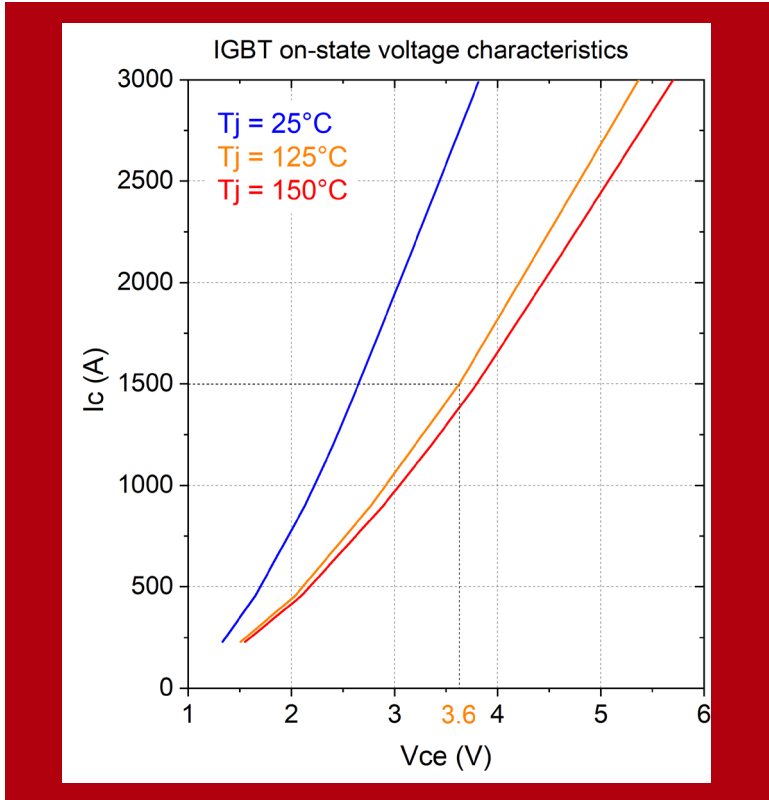


# 4.5kV 1500A HiPak module with 150°C capability

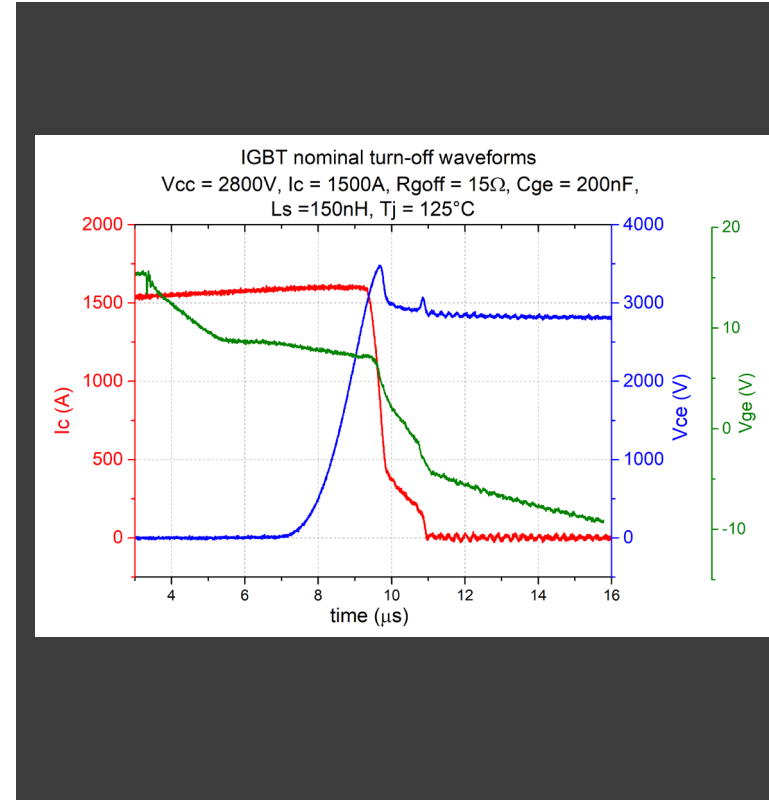
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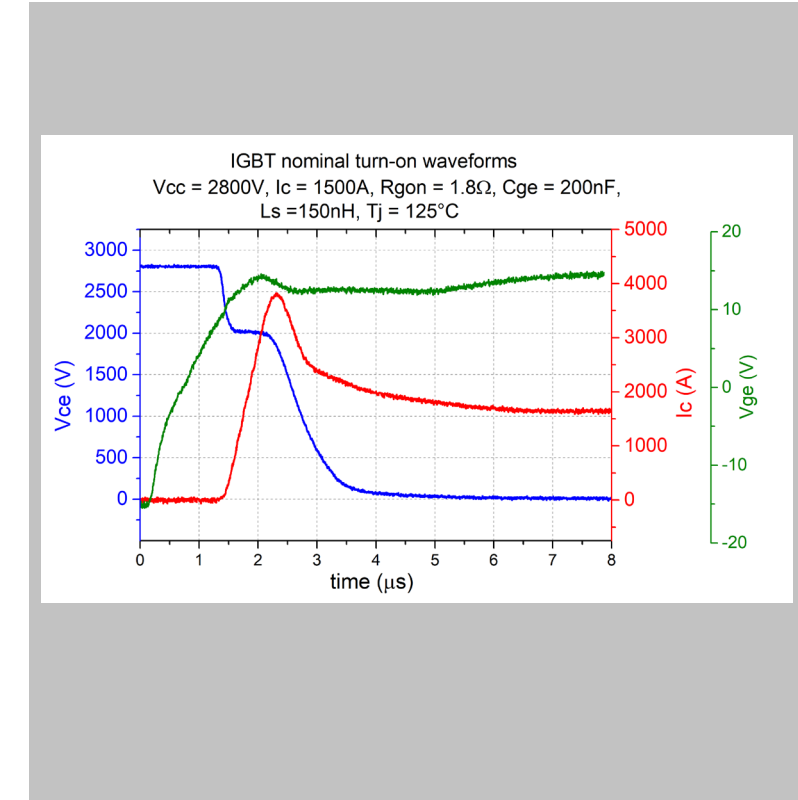
## IGBT on-state characteristics



## IGBT turn-off nominal switching



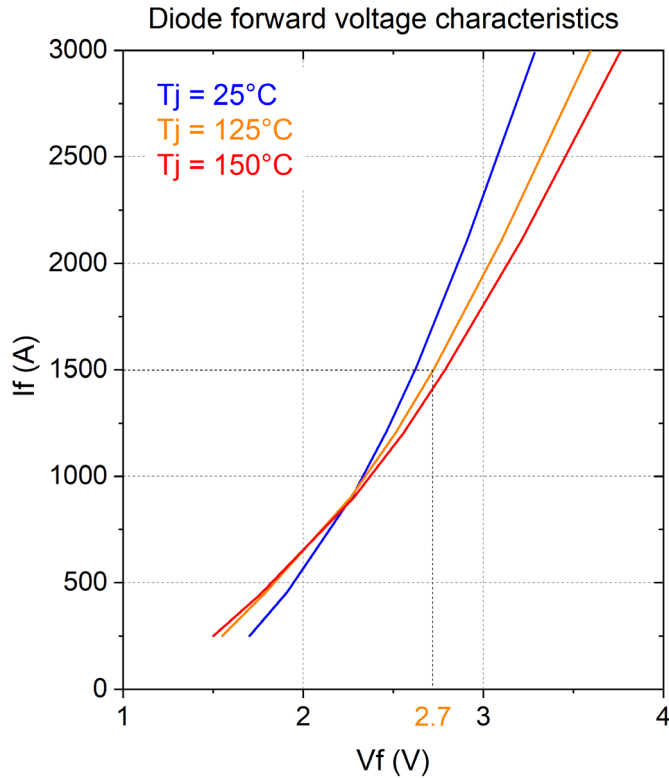
## IGBT turn-on nominal switching



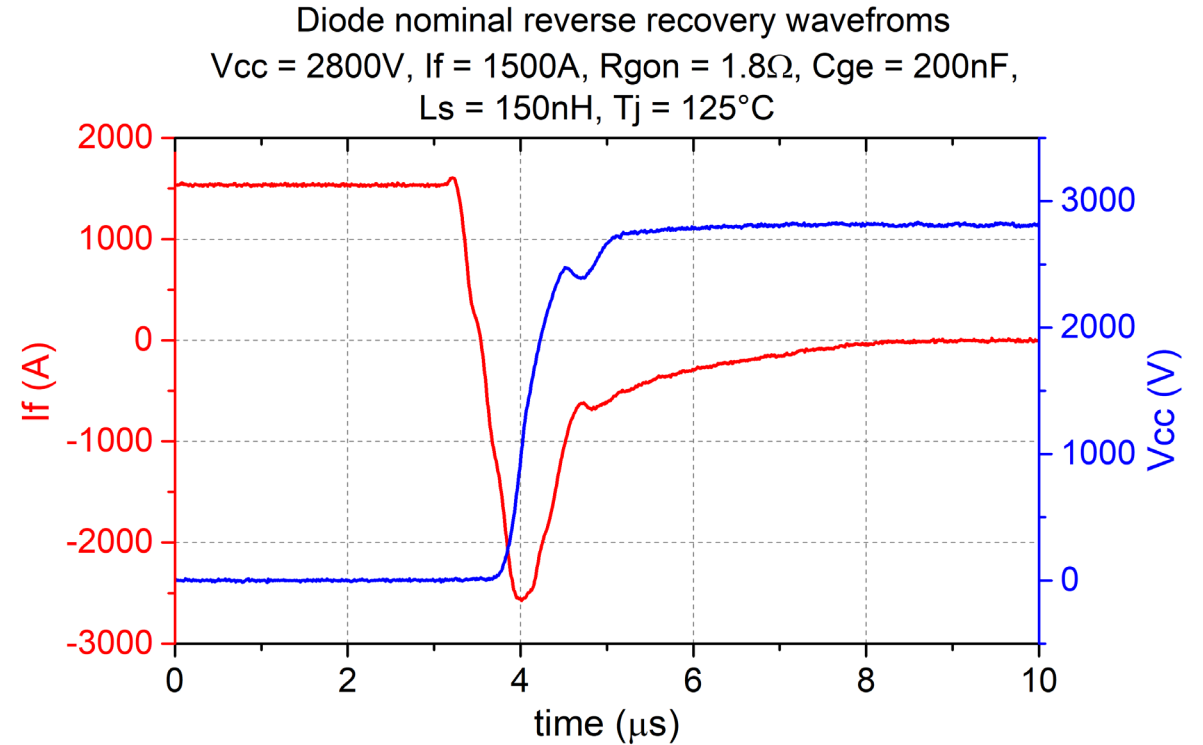
New 4.5kV 3<sup>rd</sup> generation HiPak2, 1500A



## Diode characteristics



## Diode reverse recovery

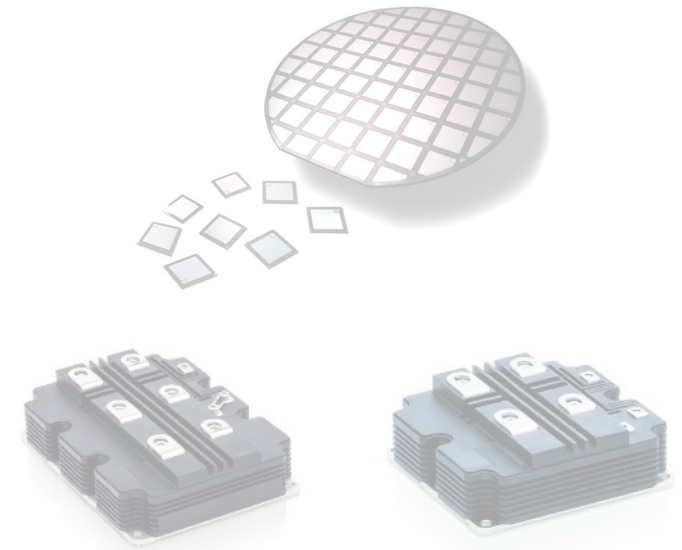


New 4.5kV 3<sup>rd</sup> generation HiPak2, 1500A



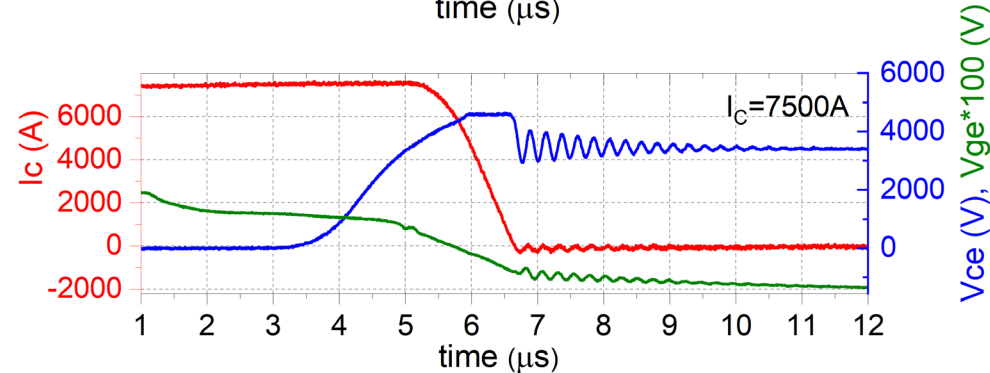
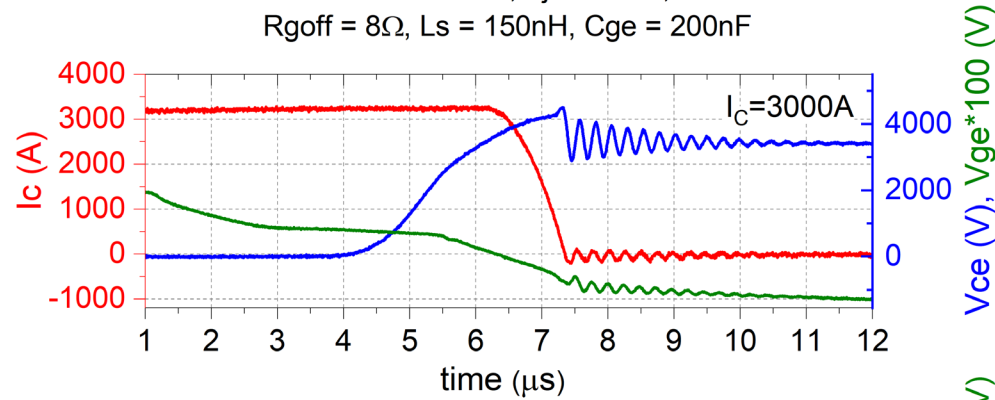
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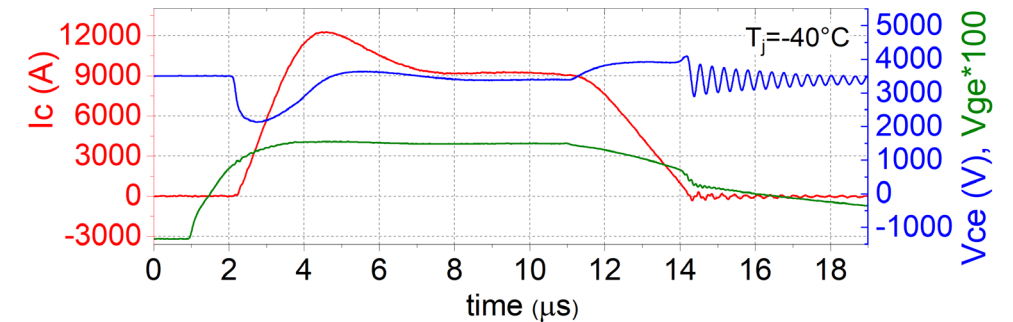
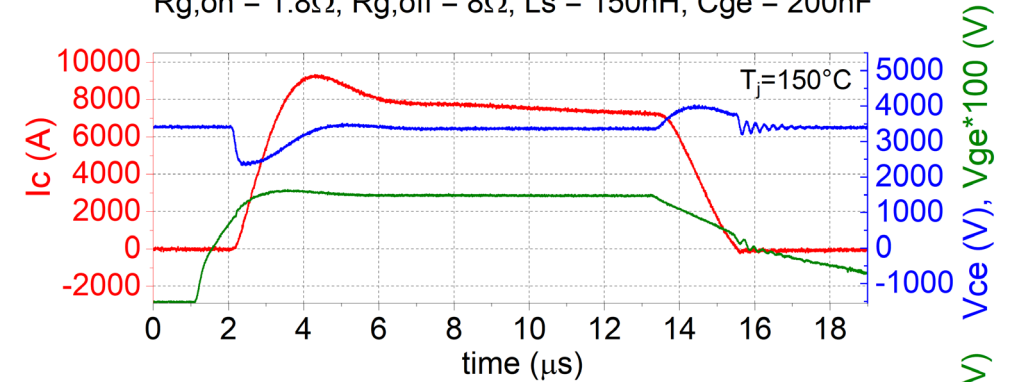
## IGBT RBSOA switching waveforms

$V_{cc} = 3400V$ ,  $T_j = 150^\circ C$ ,  
 $R_{goff} = 8\Omega$ ,  $L_s = 150nH$ ,  $C_{ge} = 200nF$



## IGBT short circuit switching waveforms

$V_{ce} = 3400V$ ,  $t_p = 12\mu s$ ,  $V_{ge} = 15V$   
 $R_{g,on} = 1.8\Omega$ ,  $R_{g,off} = 8\Omega$ ,  $L_s = 150nH$ ,  $C_{ge} = 200nF$

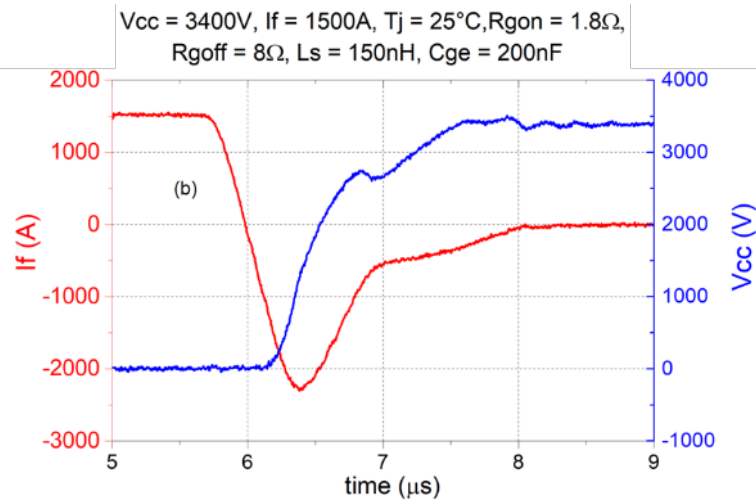


Very rugged and robust 3<sup>rd</sup> generation 4.5 kV 1500 A HiPak2 module

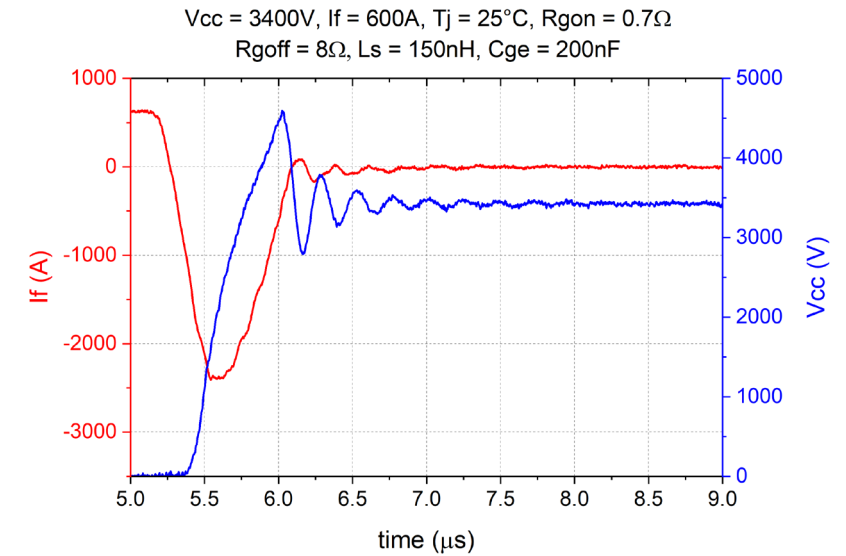
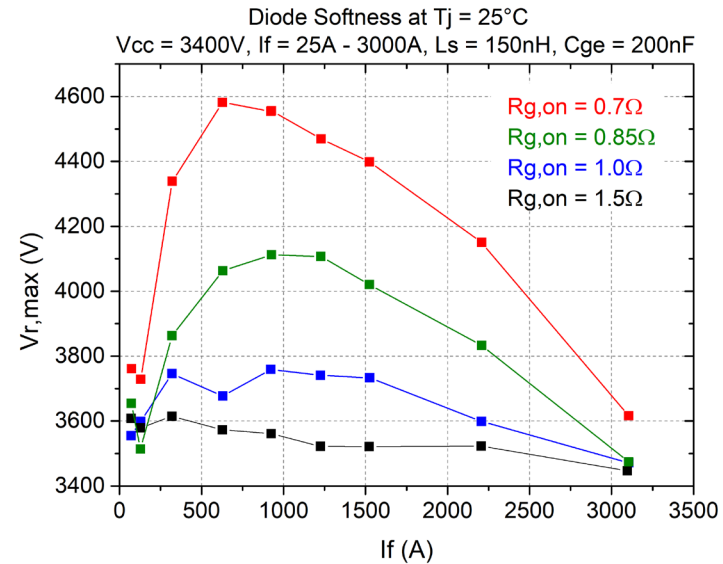


# Diode mode: Safe Operating Area (SOA) and softness performances

## Diode reverse recovery waveform (SOA)



## Diode softness under different IGBT switching speeds



Very soft diode enabling full flexibility to balance between IGBT turn-on and diode turn-off losses



- Simulation with Hitachi ABB simulation tool SEMIS, available online

Steady state

DC voltage 2800 V

Switching frequency 450 Hz

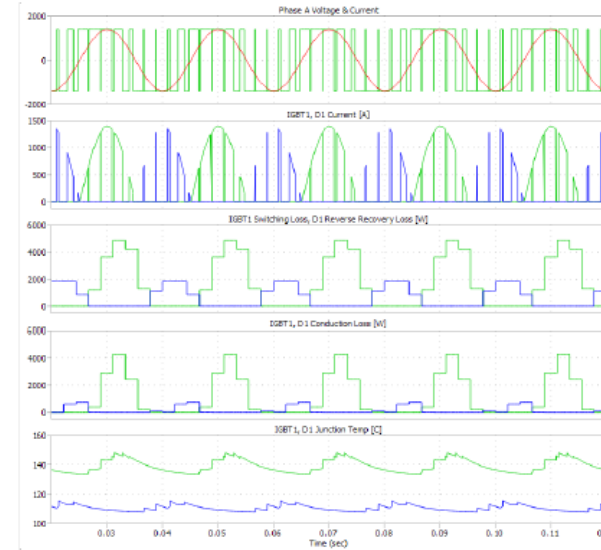
Sinusoidal PWM

Inverter and rectifier operation mode

Power factor 0.85

Modulation index 1

Cooler Rth should be selected to reflect application conditions



Device Losses & Temperatures						
	Switching	Conduction	Combined Losses	TvjAvg	TvjMax	TvjBLS
per IGBT	1.695 kW	1.129 kW	2.824 kW	139.14 °C	147.98 °C	146.79 °C
per Diode	631.65 W	163.58 W	795.23 W	110.44 °C	115.47 °C	111.37 °C
Converter Losses	13.96 kW	7.76 kW	21.72 kW			
% Losses			0.87 %			

AC Parameters						
	Real Power	Reactive Power	Phase Voltage (RMS)	Phase Current (RMS)	Output Frequency	Power Factor
	2.474 kW	1.533 kVAR	990 V	980 A	50 Hz	0.85

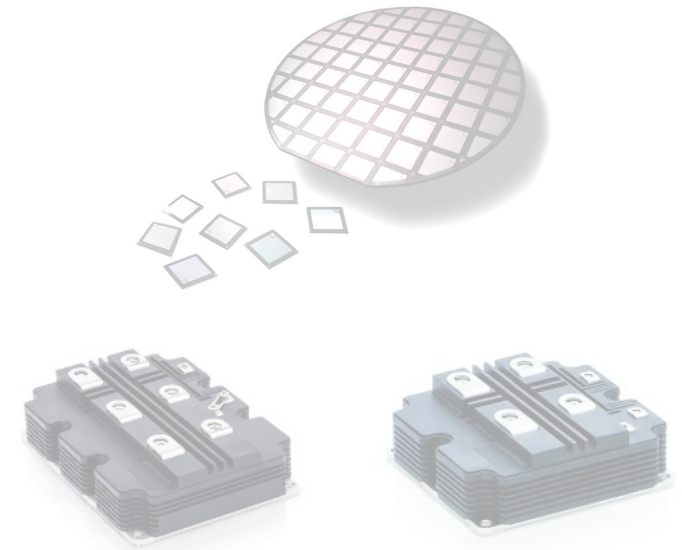
DC Parameters & Control Parameters				
	DC Power	DC Voltage	Switching Frequency	Modulation Index
	2.495 kW	2.800 kV	450 Hz	1.00





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- **New 4.5kV IGBT and diode 150°C capable chipset has been presented**
  - **New 3<sup>rd</sup> generation 4.5kV**  
**HiPak2 (1500A) and 4.5kV**  
**HiPak1 (1000A)**
- **High safe operating area**
- **High reliability with improved passivation for enhanced humidity protection**
- **The module is therefore suitable for wide application range from MMC HVDC to traction and industrial drives.**

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