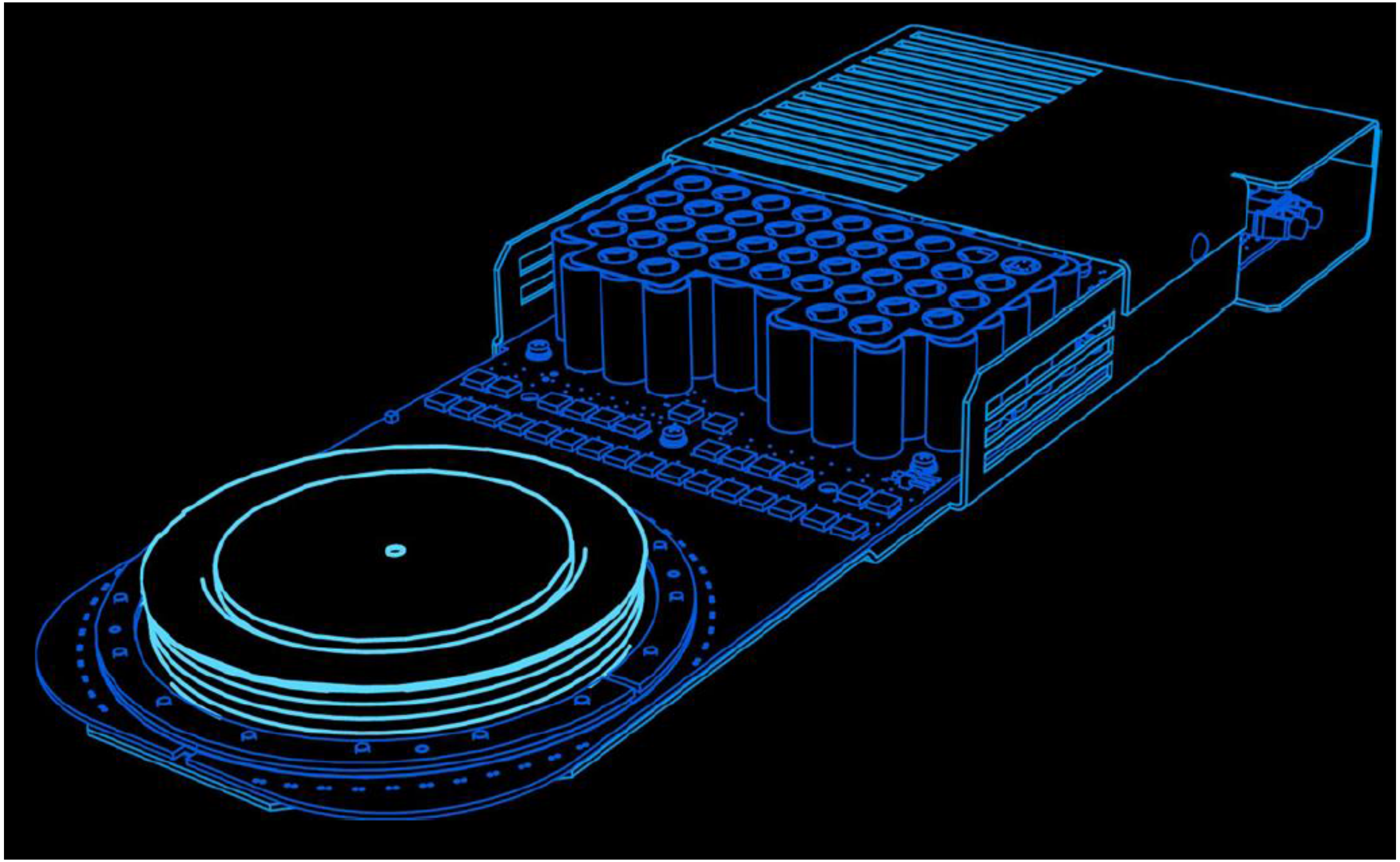
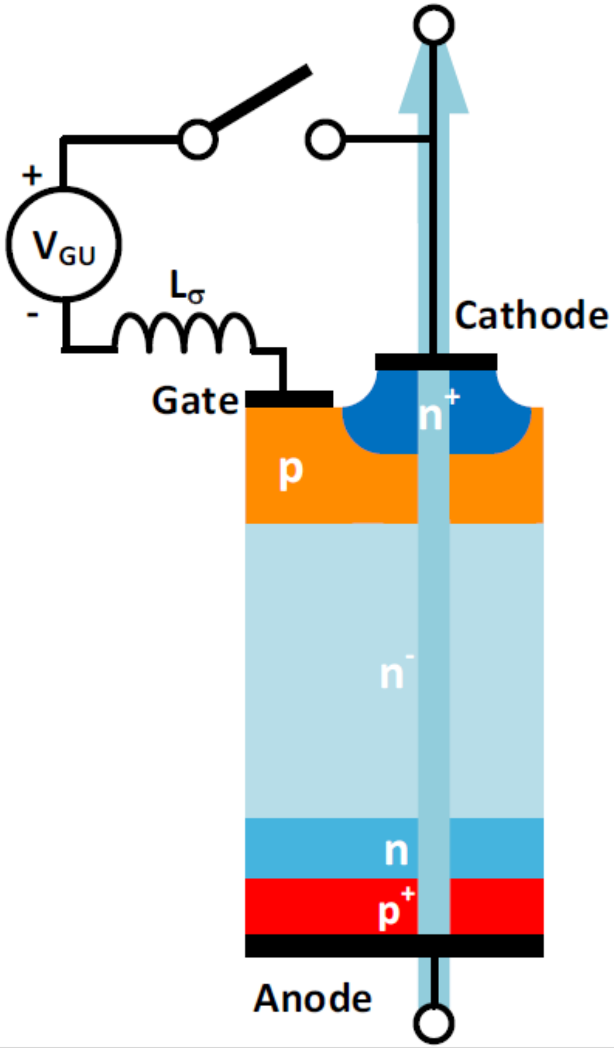


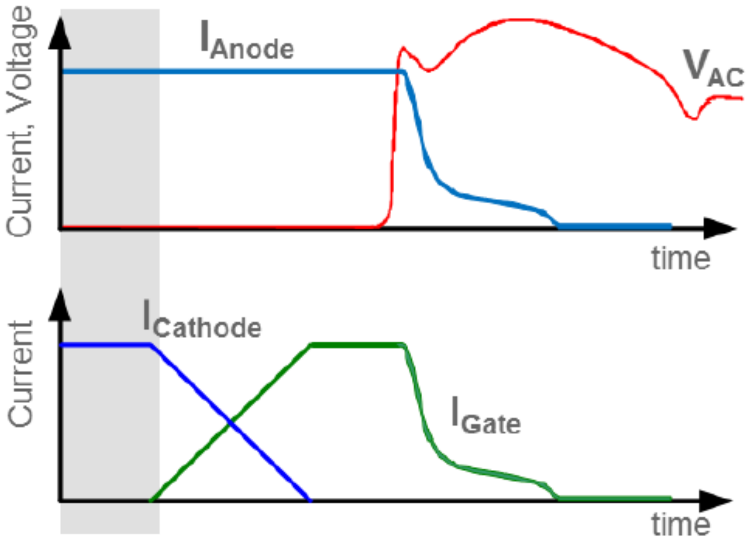
IGCT Principles

March 2018

ABB

The IGCT principal
Thyristor On-state

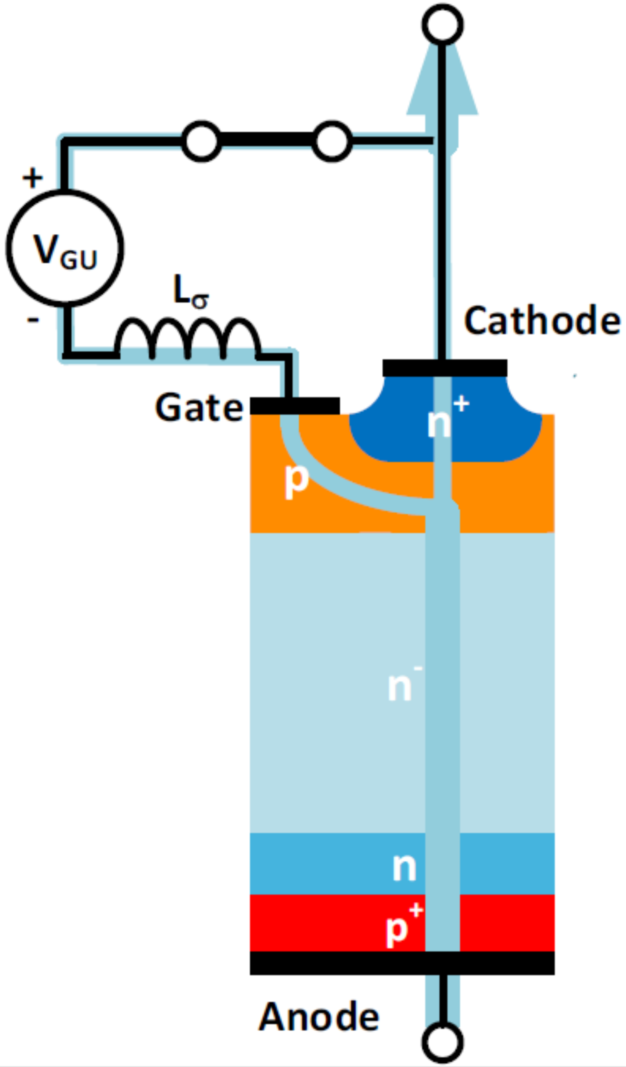


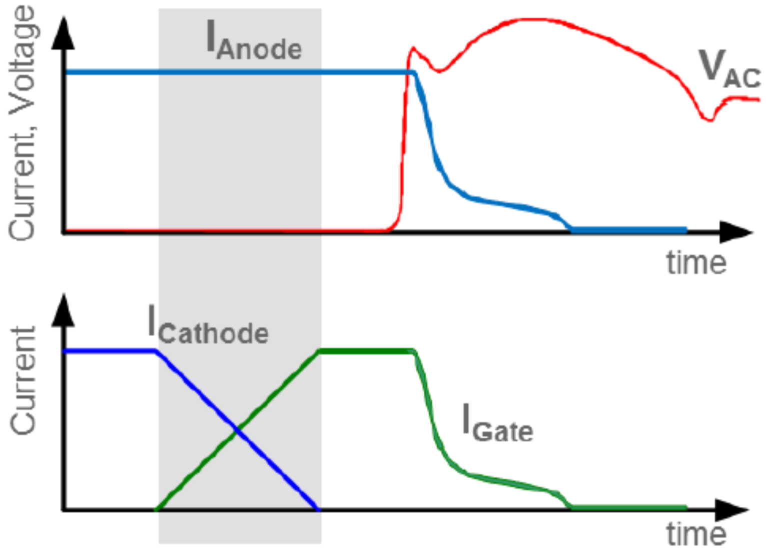


Conducting state of IGCT

- Thyristor mode active
- Electron emission from cathode
- Hole emission from Anode

The IGCT principal
Thyristor - current commutation

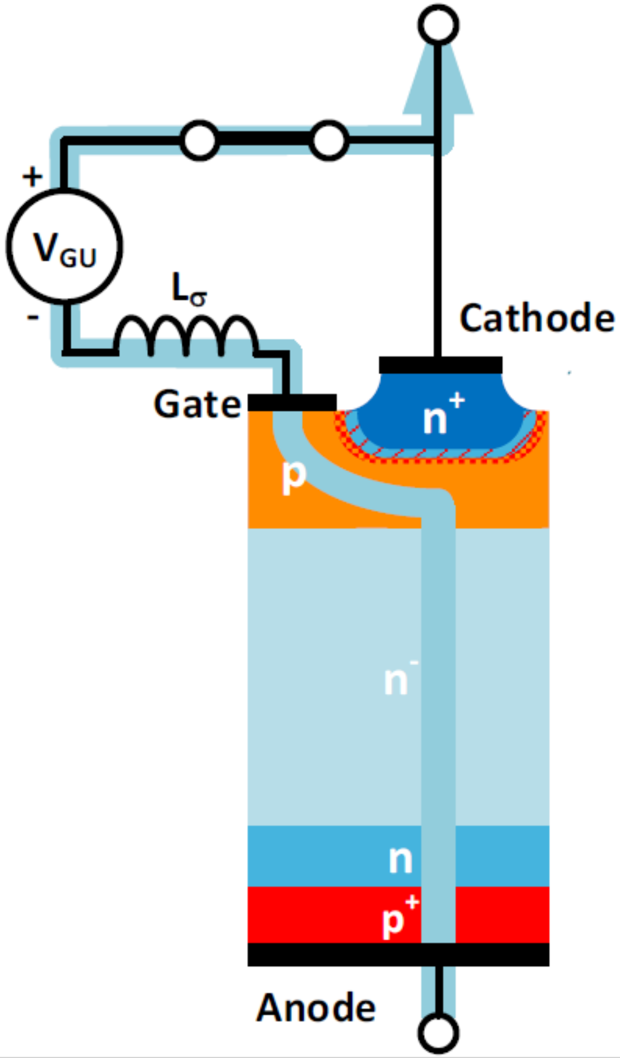


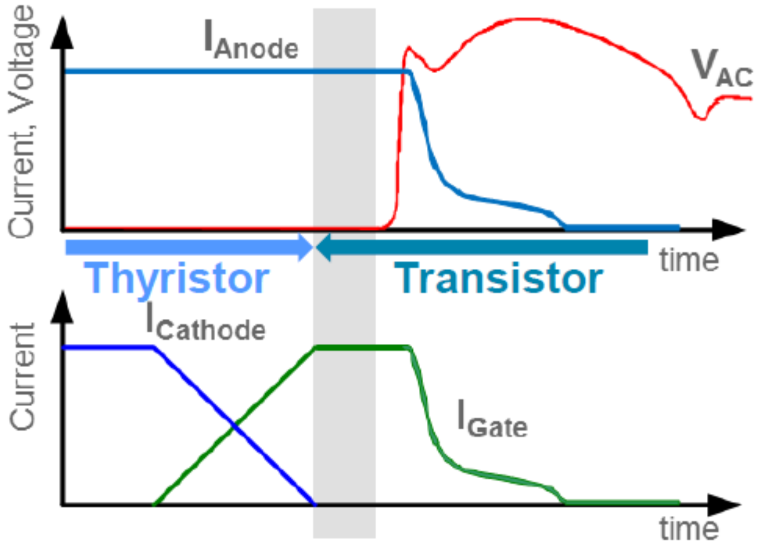


Anode current commutates from Cathode to Gate

- Commutation $dI_{Gate}/dt = V_{GU}/L_\sigma$
- Low inductive Gate circuit necessary

The IGCT principal
Transistor - Anode current commutated to Gate

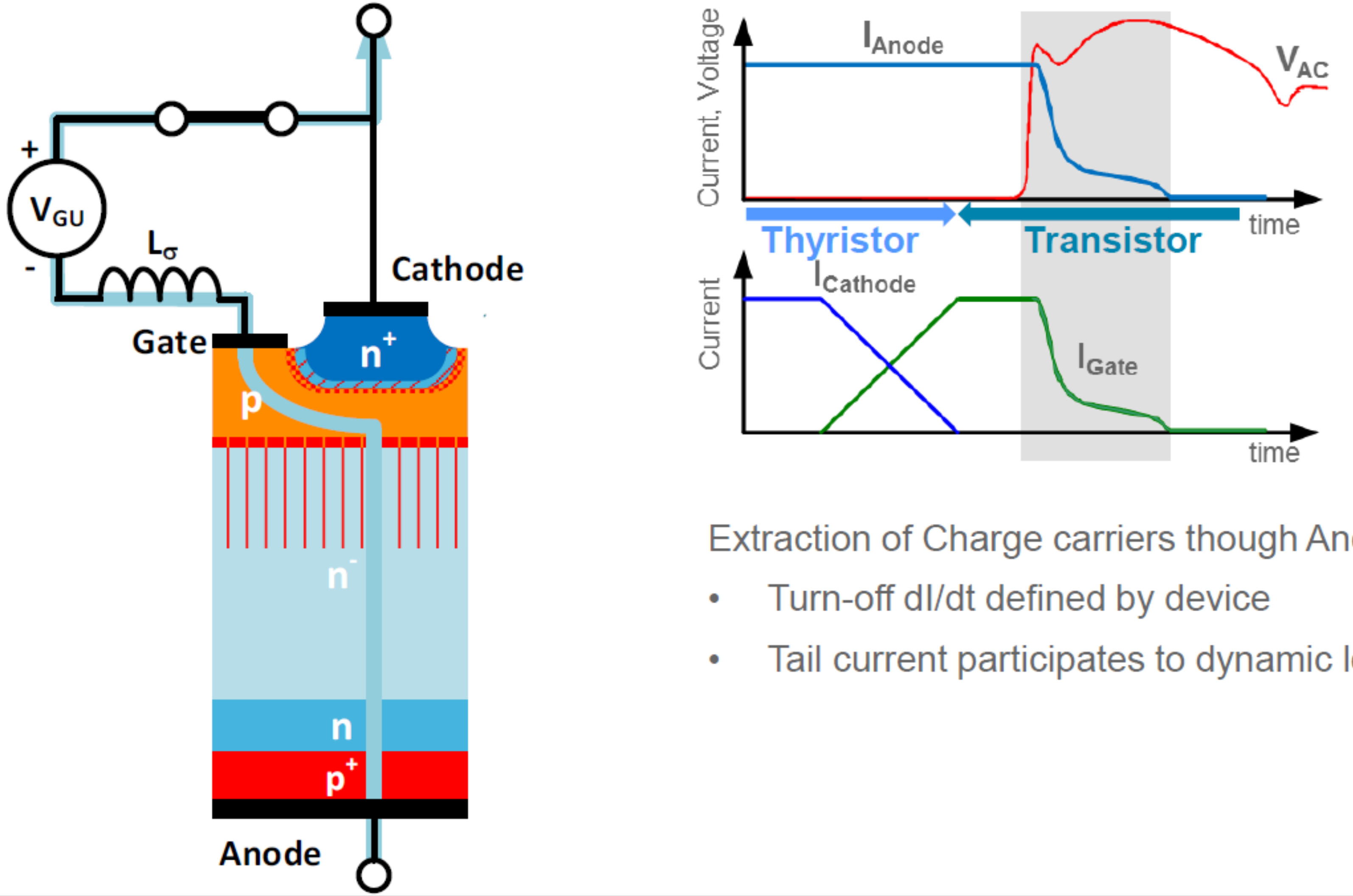




Transistor mode activated

- Cathode fully bypassed though Gate Unit
- Thyristor converted to open base pnp Transistor
- Hard drive condition: commutation before V_{AK} rises
- Commutation time ~ $I_T \cdot L_\sigma / V_{GU}$

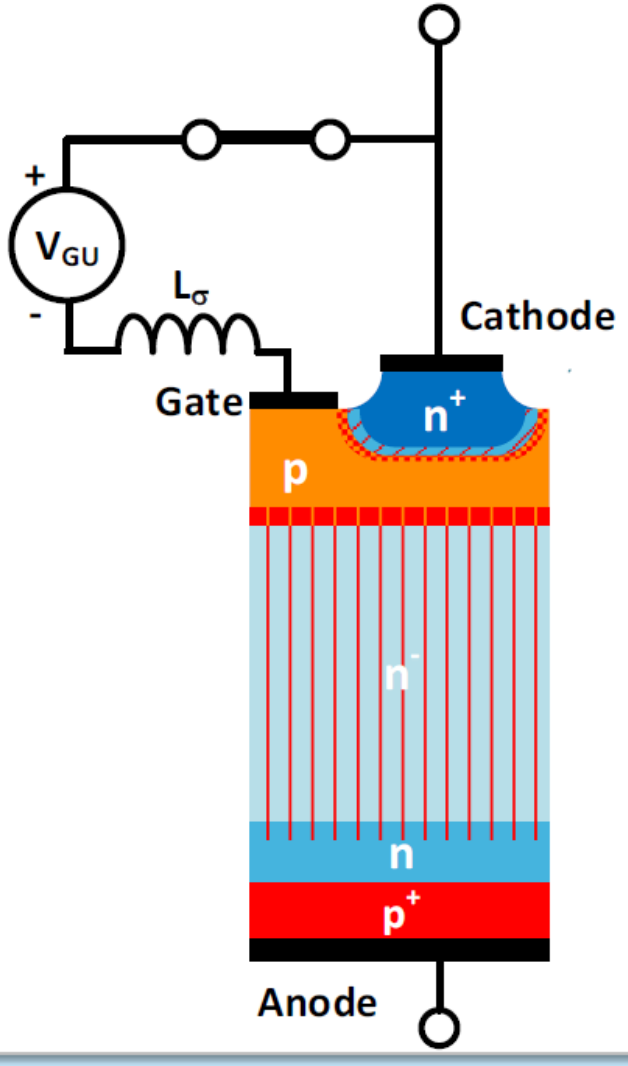
The IGCT principal
Turn off as Transistor

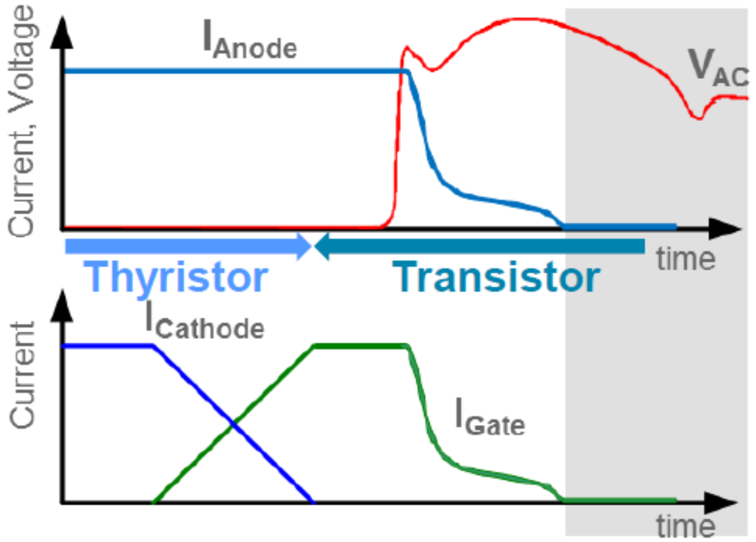


Extraction of Charge carriers though Anode and Gate

- Turn-off dI/dt defined by device
- Tail current participates to dynamic losses

The IGCT principal
Blocking device



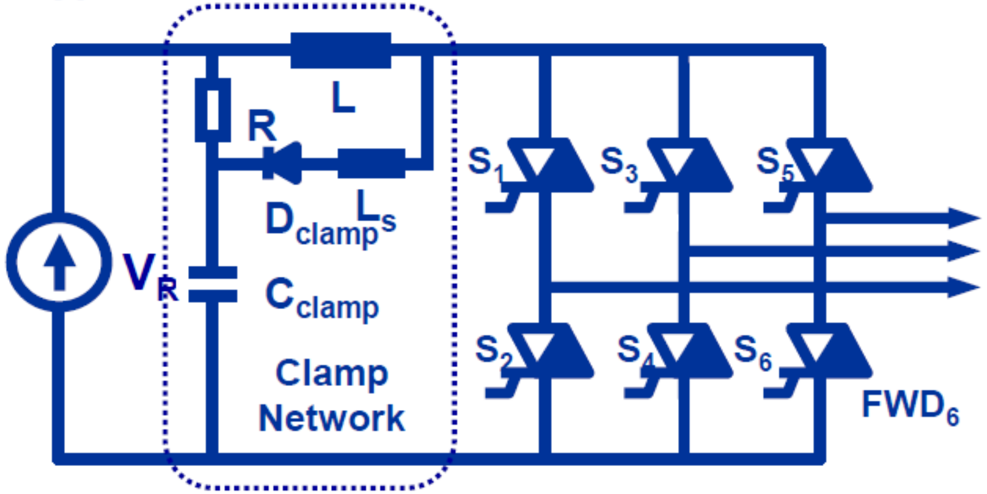


Blocking state of IGCT

- Transistor mode active
- High dV/dt immunity through low inductive Gate – Cathode coupling (for powered Gate unit)

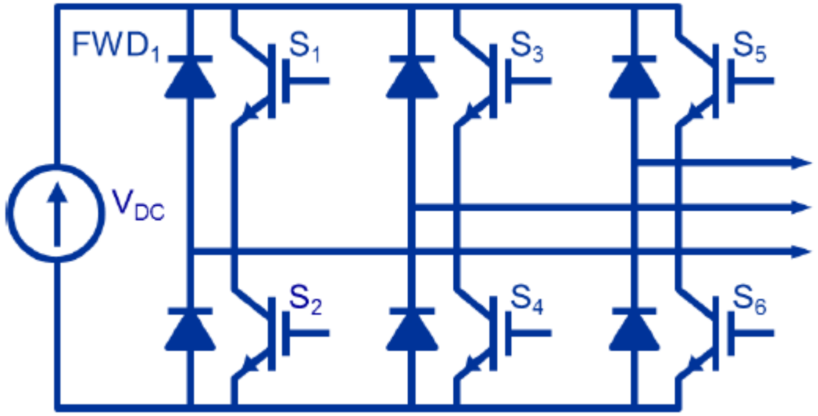
IGCT - IGBT
Circuit design

Typical IGCT circuit



- No dI/dt control by switch possible
- extra components
- limited fault current
- no turn-on losses in devices
- circuit is **mandatory for thyristors** (optional for transistors)

Typical IGBT circuit



- Turn-on dI/dt limited by switch
- no passive components
- no fault current limitation
- turn-on losses in S1-6
- circuit is suitable for ***transistors only***

+ Due to Thyristor structure Low On-state of IGCT

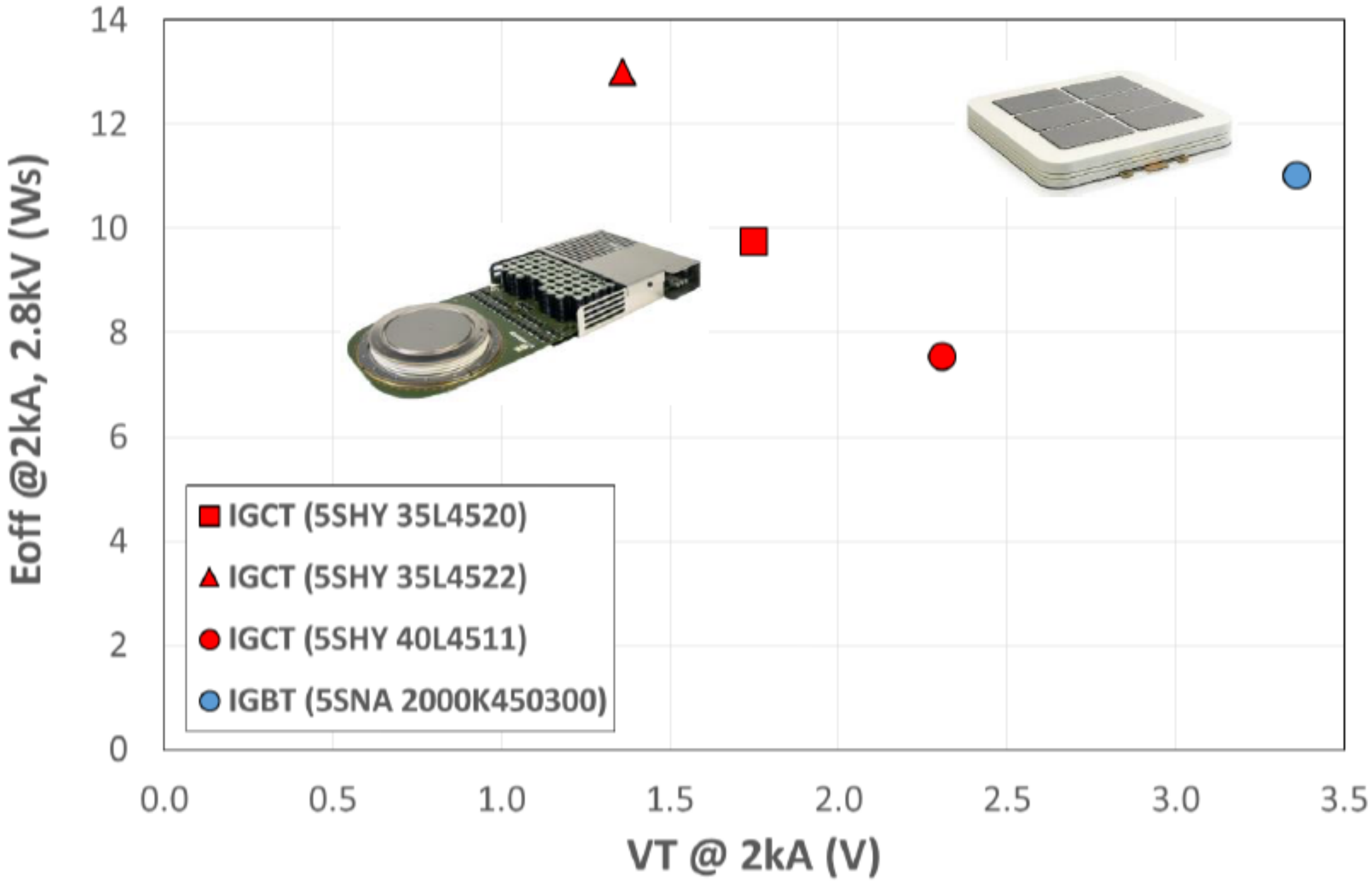
+ Hermetic housing - robustness

+ High reliability

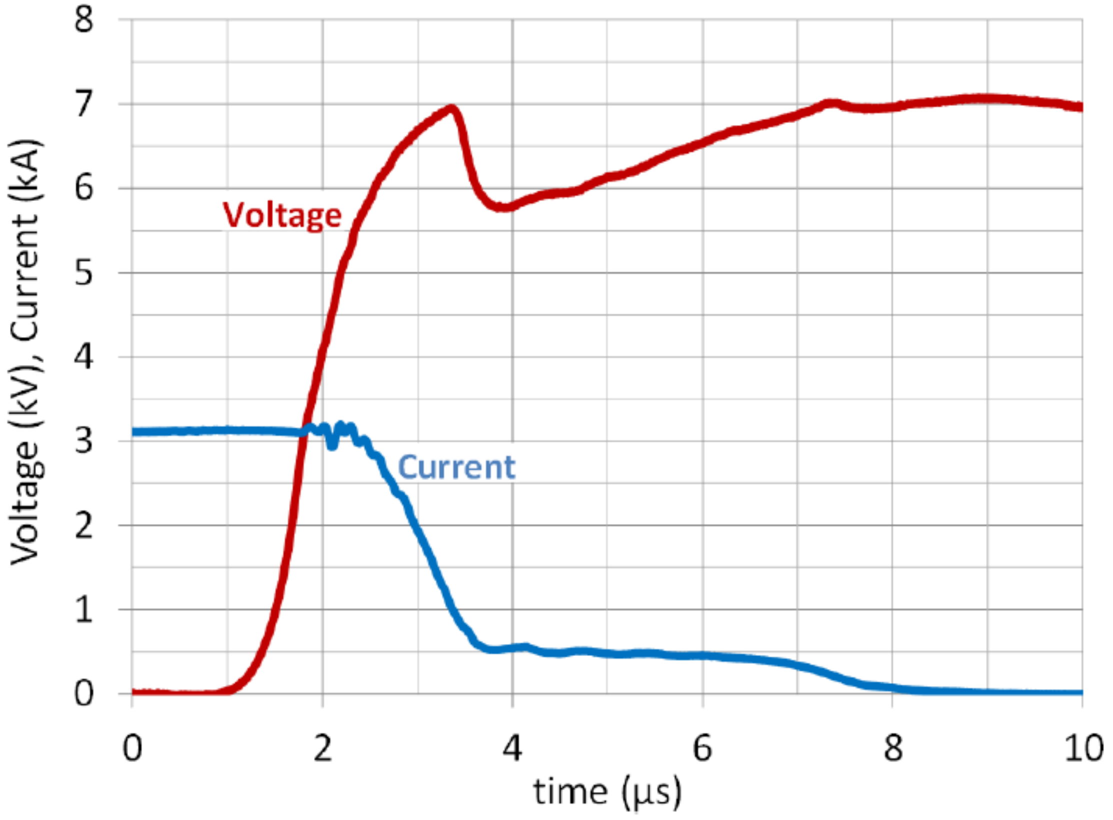
+ No explosion in fault cases

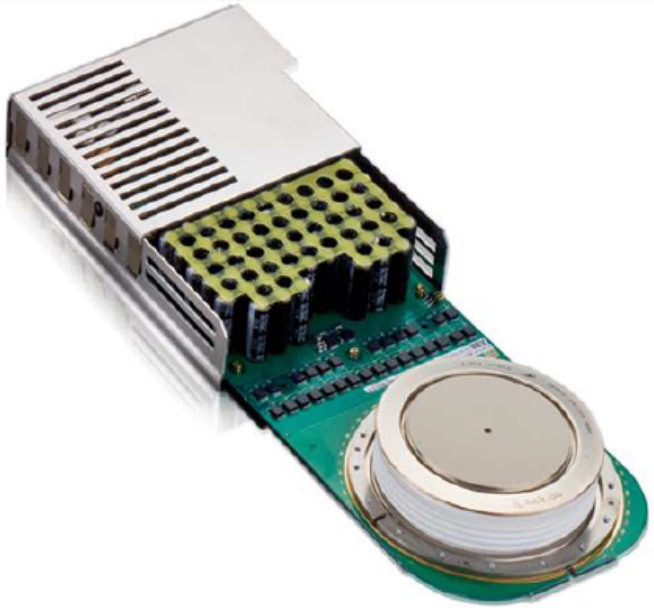
- Higher power consumption of Gate unit

- Clamp circuit needed



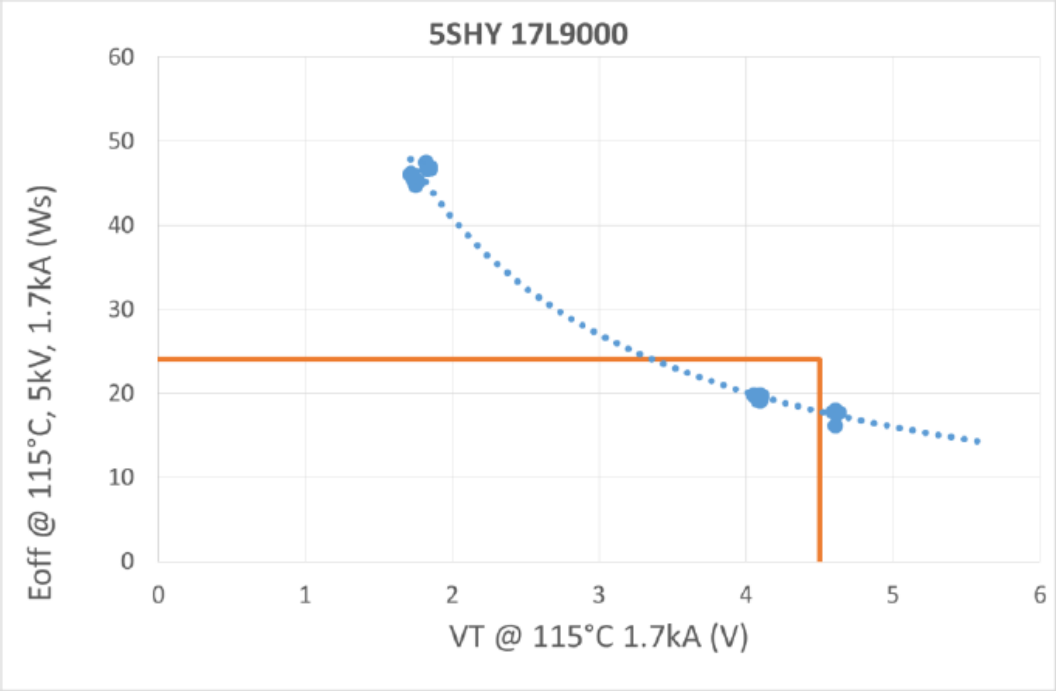
10kV IGCT

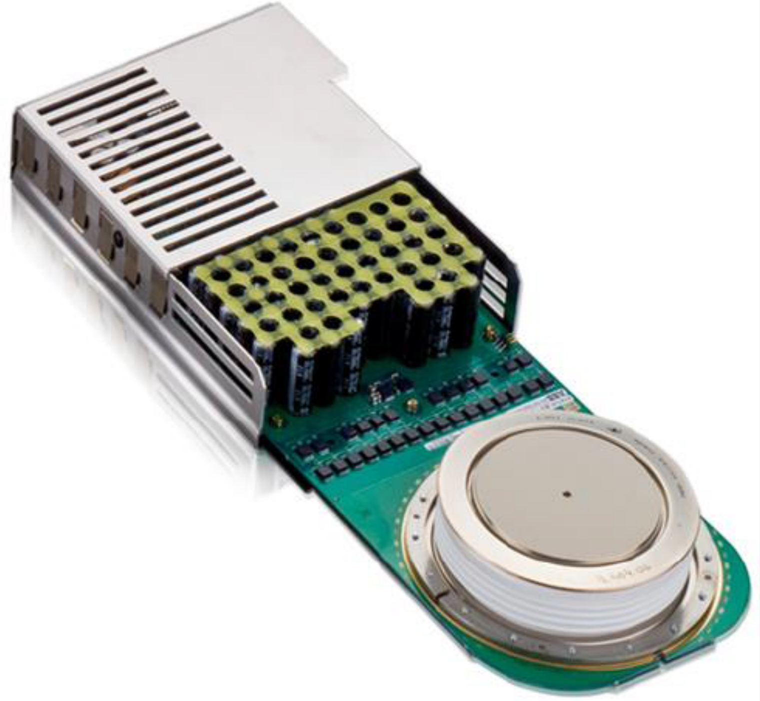




91mm 10kV IGCT Turn-off 6kV DC-Link at 125°C
3300A Max. Current

10kV IGCT

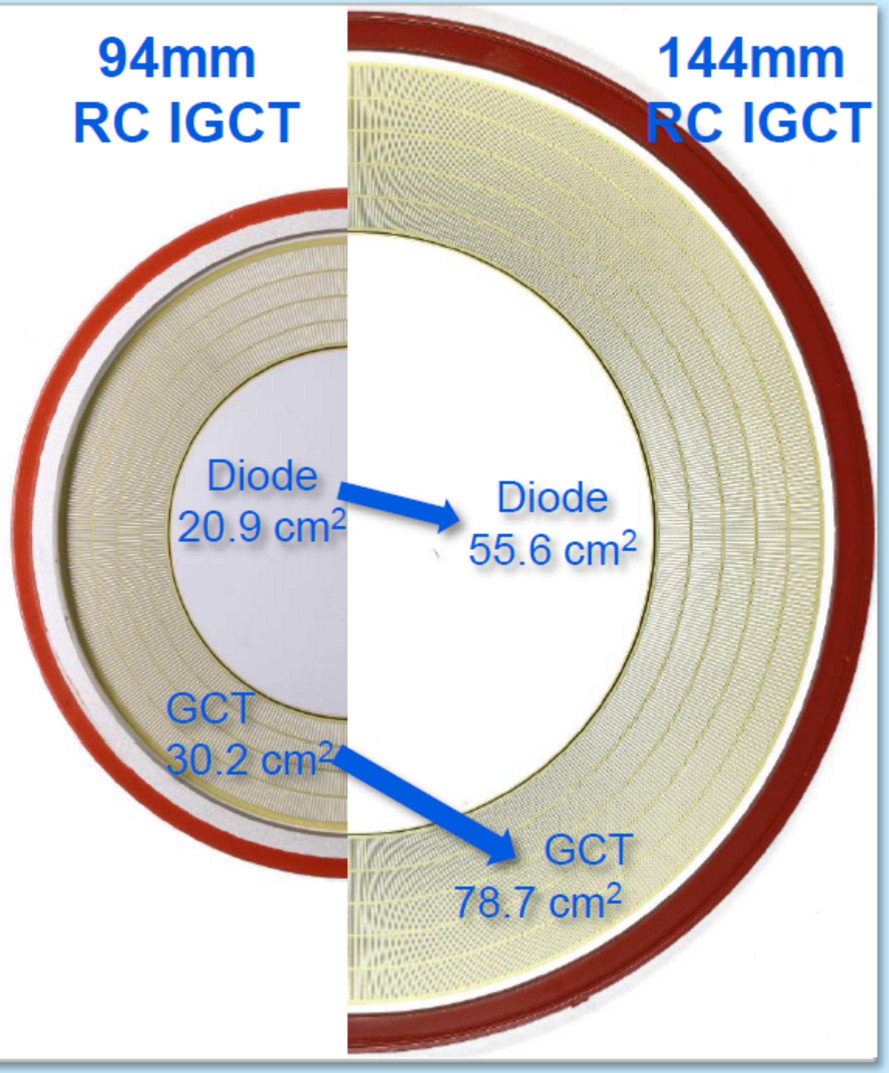




91mm 10kV IGCT Technology curve @ 115°C 6kV DC-Link 1700A

IGCT power handling improvement
144mm RC-IGCT – Area scaling

Parameter	Required scaling	remark
SOA	~ A	Area scaling challenging
Current capability	~ A	Frequency test to be done end 2016 (lighthouse test SE)
Losses	~ A	Possible for same Si thickness
Rth	~ 1/A	ok
$L_{\sigma GK}$	~ 1/A	Defined by circumference $\sim 1/\sqrt{A}$ ► constructive improvements of GK circuit necessary
L_{σ}	~ 1/A	Difficult in mechanical setup ► constructive improvements mechanical setup



Proceedings of the 27th International Symposium on Power Semiconductor Devices & IC's
May 10-14, 2015, Kowloon Shangri-La, Hong Kong

An Experimental Demonstration of a 4.5 kV "Bi-mode Gate Commutated Thyristor" (BGCT)

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I. Introduction

The IGCT has been established as the device of choice for high power applications such as medium voltage drives, wind power conversion, pumped hydro, STATCOMS and railway interties, to name a few [1-5]. In most of the voltage source inverter applications, the freewheeling diode has to be connected anti-parallel to the IGCT to conduct current in the reverse direction during freewheeling mode. The monolithic integration of the freewheeling diode leads to better component integration in terms of processing and reduced parts count at the system level, therefore improved reliability [6-7].

Fig. 1. The top view of 38 mm, 4.5 kV conventional RC-IGCT.

II. BGCT Concept and Design

A. BGCT Concept

The BGCT is a reverse conducting IGCT, however, its design concept differs from that of the conventional RC-IGCT. In a conventional RC-IGCT, the GCT-area is separated from the diode-area whereas in BGCT the diode- and GCT-areas (segments) are integrated interdigitatedly as shown in Fig. 2. In BGCT, each individual segment is designed to act either as GCT cathode or diode anode. The GCT-segments have parallel edges while diode-segments have a slightly triangular shape. On the back (bottom) side, the doping contrast represents the diode cathode regions in a slightly triangular shape surrounded from the GCT anode region. In the BGCT design, the placement and ratio of the diode-segments and GCT-segments can be freely adjusted to meet the requirements of a specific application. We have fabricated the first devices with 3:1 GCT to diode ratio as this gives the good lateral plasma distribution in the device in both GCT- and diode-modes of operation.

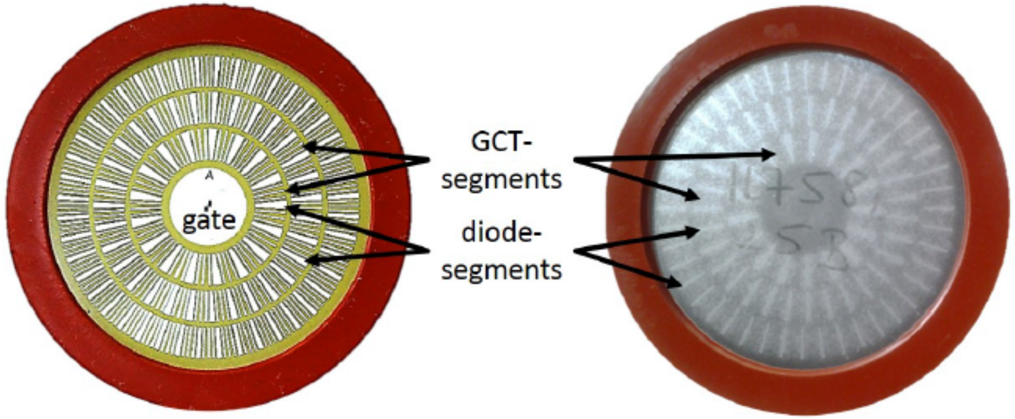
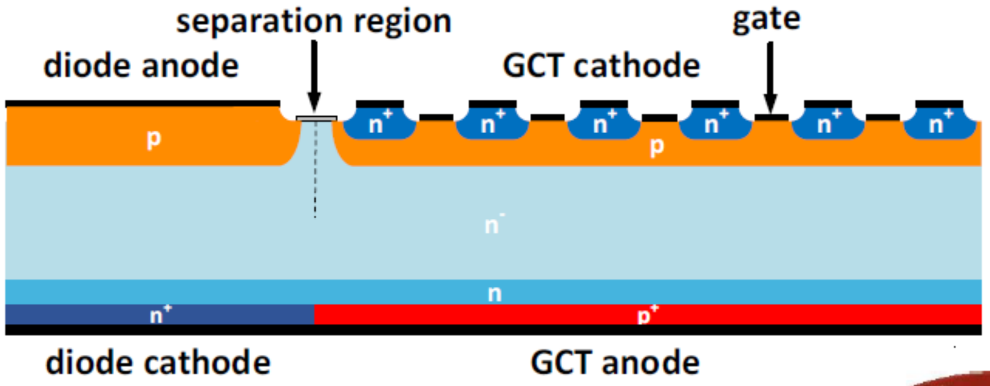


Fig. 2. The first fabricated 38 mm, 4.5 kV BGCT.
Left: top view. Right: bottom view.

Bi mode Gate Commutated Thyristor (BGCT)

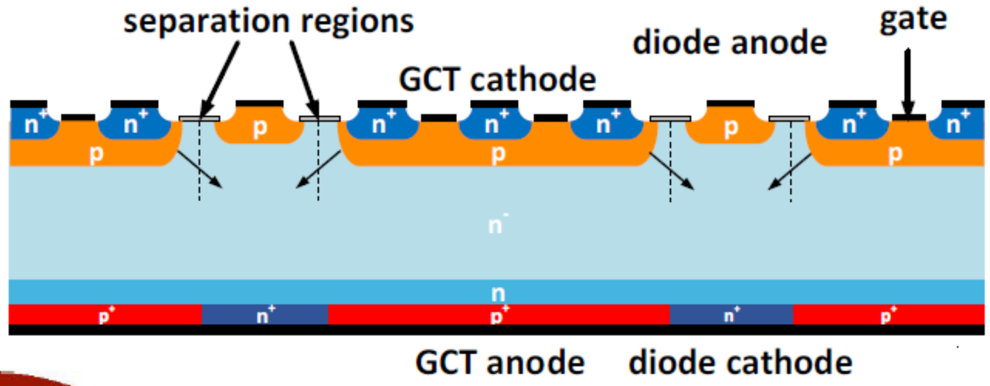
Device Structure

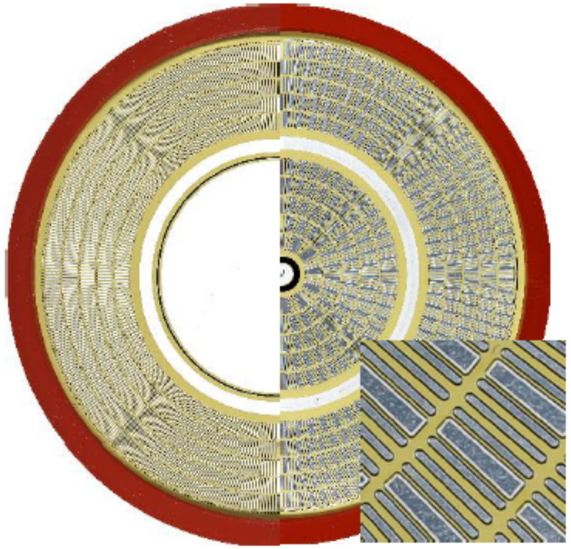
RC-GCT



- One separation region

BGCT

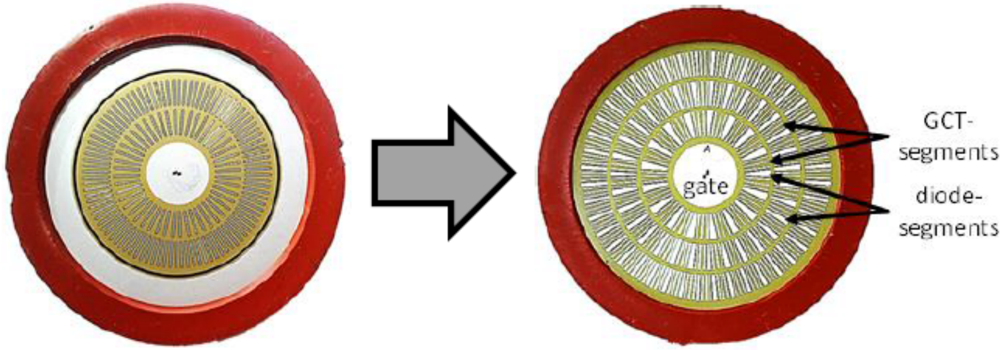


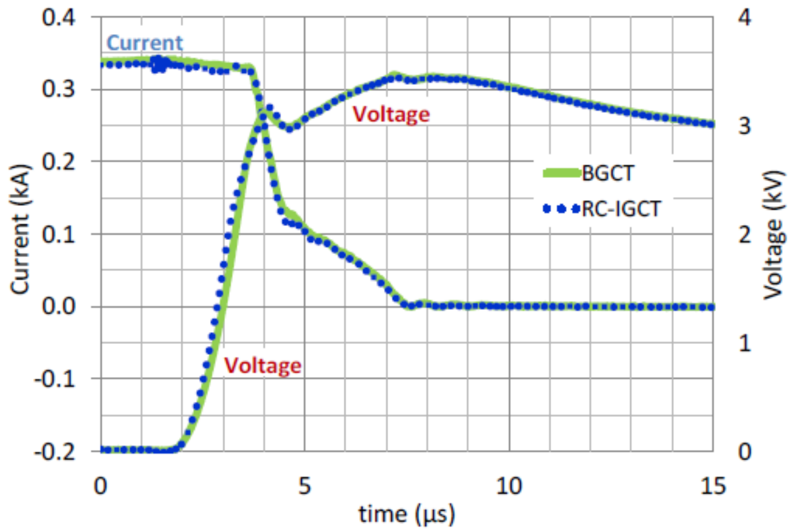


- Plasma spread from diode to GCT region (and visa versa)
  - ▶ better Si area usage
- Interdigitated Diode and GCT areas
  - ▶ better thermal performance
  - ▶ better Load cycling performance
- Softer diode (FCE effect),
  - ▶ thickness reduction possible (lower losses)
- High shorting density
  - ▶ Higher dV/dt ruggedness

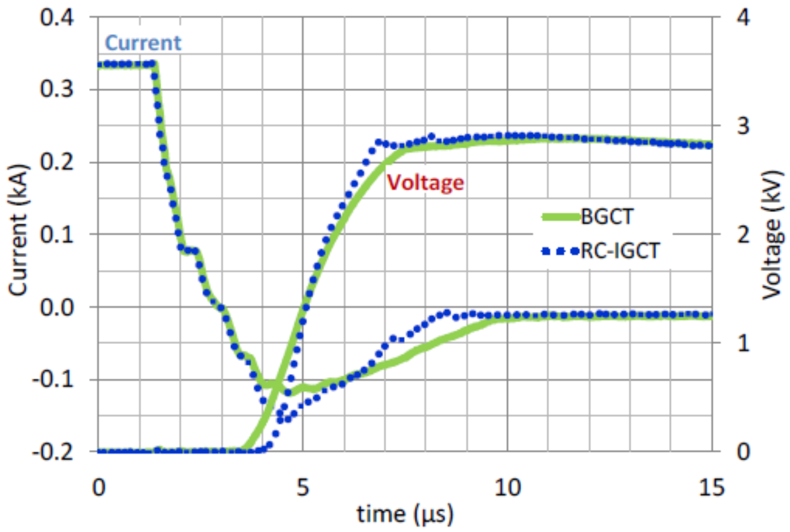
Bi mode Gate Commutated Thyristor (BGCT)

Results on 38mm prototypes





GCT Turn-off



Diode Reverse Recovery