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Fully Automated Wide Temperature Range Semiconductor Characterization

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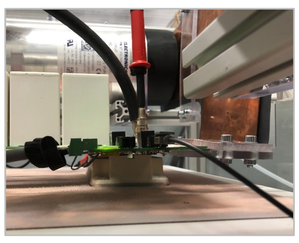
Motivation

Low Temperature Power Electronics

Properties

- Lower $R_{DS,on}$
- Lower forward voltage
- Faster switching
- Lower switching losses
- Reduced cooling effort due to thermal isolation

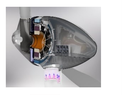
Higher system efficiency

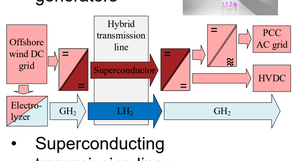


Module at -70 °C

Applications

- Superconducting motors and generators





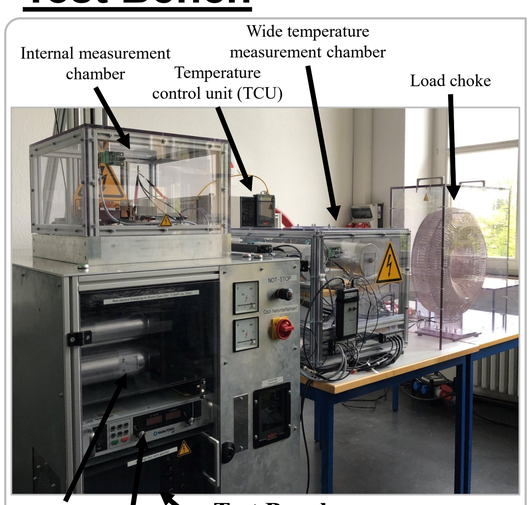
- Superconducting transmission lines

Wide Temperature Range Semiconductor Characterization

Precise temperature control	Temperature control unit
Ensure save temperature operating area of periphery	
Whole module measurement	Tempering plate instead of climatic chamber
Prevent icing	Hermetic, nitrogen filled measurement chamber
Easy and flexible configuration, measurement, data evaluation	In-house developed control and evaluation software
Affordable measurement technology	Minimized setup (no helium chillers, curve tracers..)

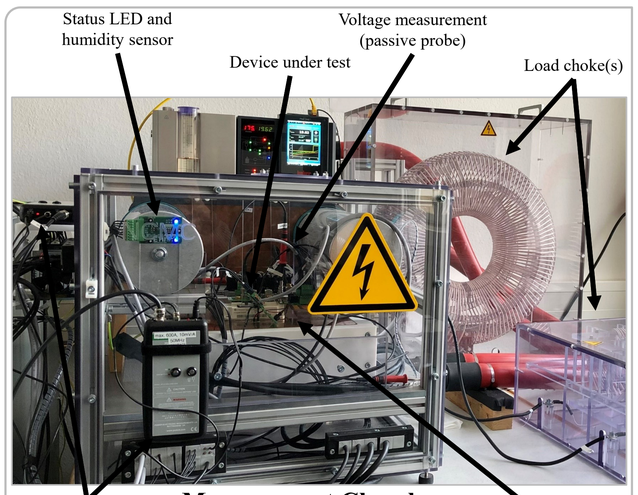
Semiconductor Test Bench

Hardware Setup



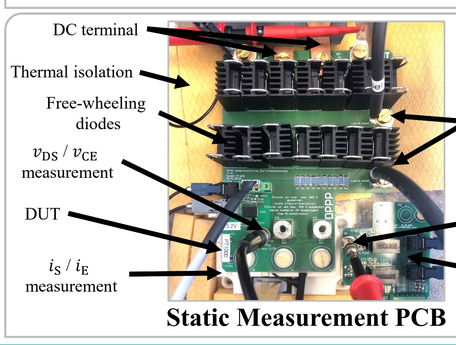
Test Bench

- Up to 1.8 kV DC link voltage
- Up to 4 kA current pulses
- T = −75°C to 150°C
- 2 measurement chambers

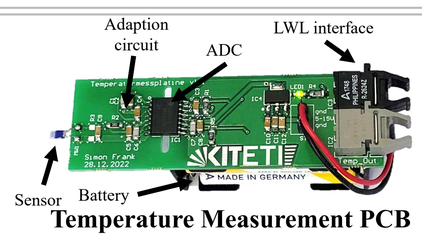


Measurement Chamber

- Chamber: l x w x h = 58 x 58 x 52 cm
- Tempering plate: l x w = 32 x 32 cm
- 2.1 mF DC link capacitance
- *HUBER Unistat 815w* TCU



Static Measurement PCB

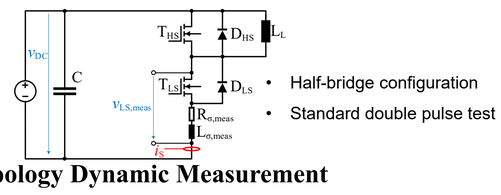


Temperature Measurement PCB

- PT100: 0.218 °C resolution
- PT1000: 0.041 °C resolution
- Internal module NTC

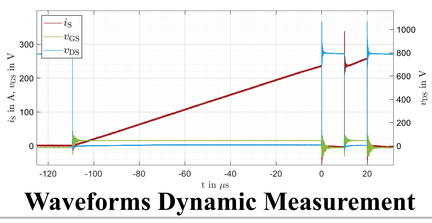
Measurement Setup

Dynamic Behavior



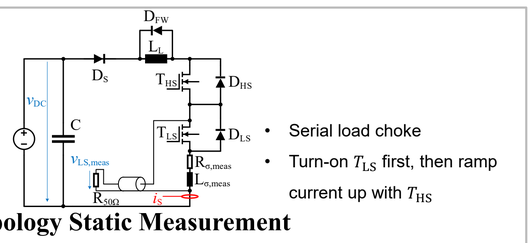
- Half-bridge configuration
- Standard double pulse test

Topology Dynamic Measurement



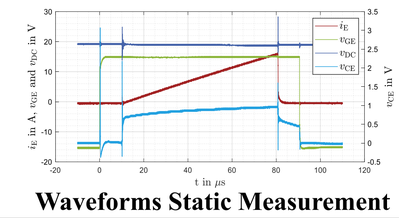
Waveforms Dynamic Measurement

Static Behavior



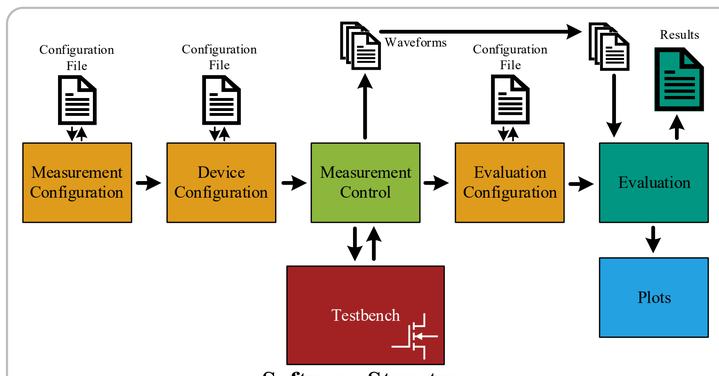
- Serial load choke
- Turn-on T_{LS} first, then ramp current up with T_{HS}

Topology Static Measurement



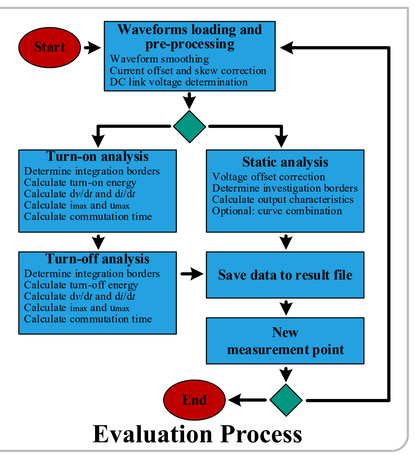
Waveforms Static Measurement

Control and Data Evaluation



Software Structure

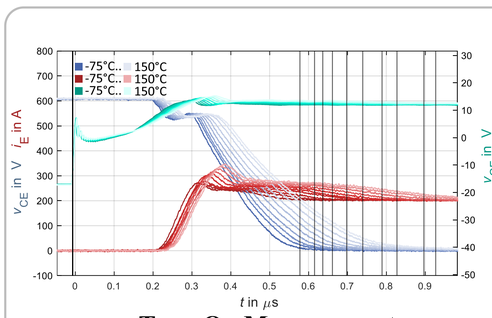
- Fully automated
- *MATLAB / Python*-based app with GUI



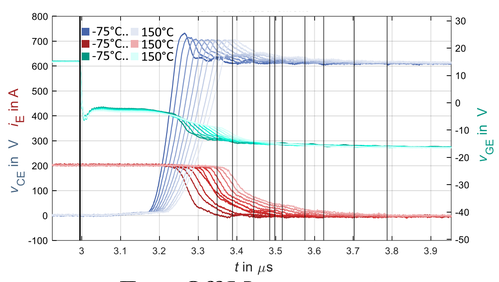
Evaluation Process

Results

Dynamic Behavior



Turn-On Measurement



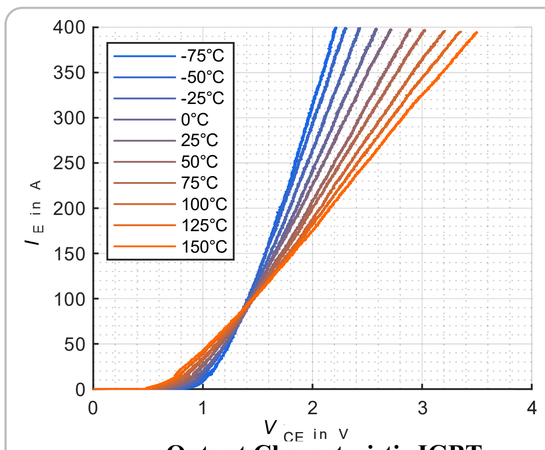
Turn-Off Measurement

- $I_{E,sw} = 200$ A
- $V_{CE,sw} = 600$ V
- $V_{GE} = -15/15$ V
- $R_{G,on} = 2.7\ \Omega$, $R_{G,off} = 2.7\ \Omega$
- $C_{DC} = 2.1$ mF + 125 µF
- $L_L = 349$ µF
- *Lecroy HDO 4104* 1 GHz, 12 bit oscilloscope
- *CWT UltraMini CWTUM/3/R* Rogowski coil
- *PPE4 kV* voltage probe
- Temperature range: T = −75 to 150 °C

Dynamic Behavior

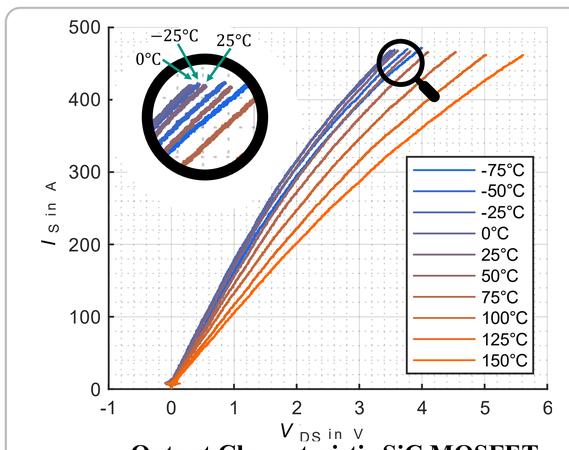
Output Characteristics

Si-IGBT ← → **SiC-MOSFET**

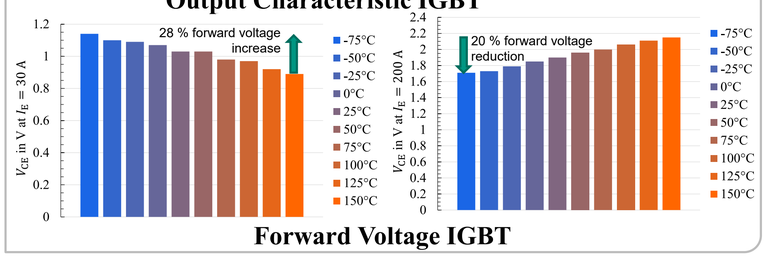


- $I_{E,max} = 400$ A
- $V_{DC} = 20 - 250$ V
- $V_{GE} = -15/15$ V
- $R_{G,on} = 2.7\ \Omega$
- $R_{G,off} = 2.7\ \Omega$

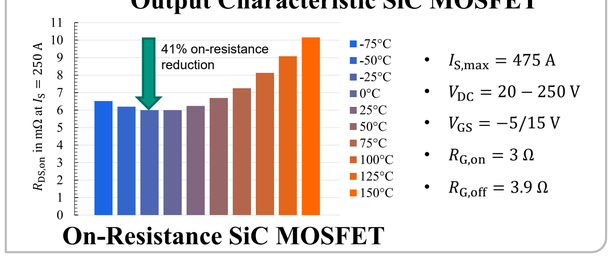
Output Characteristic IGBT



Output Characteristic SiC MOSFET



Forward Voltage IGBT



- $I_{S,max} = 475$ A
- $V_{DC} = 20 - 250$ V
- $V_{GS} = -5/15$ V
- $R_{G,on} = 3\ \Omega$
- $R_{G,off} = 3.9\ \Omega$

On-Resistance SiC MOSFET

- *Lecroy HDO 4104* 1 GHz, 12 bit oscilloscope
- *CWT UltraMini CWTUM/3/R* Rogowski coil
- *PPE 4kV* voltage probe
- DC link capacitance: $C_{DC} = 2.1$ mF
- Load inductance: $L_L = 71.4$ µF
- Temperature range: T = −75 to 150 °C

Summary

- **Easy-to-use, flexible, wide temperature range test bench for static and dynamic characterization of power semiconductors**
- Operation proofed over the temperature range from −75 to 150 °C
- Static characterization without additional curve tracer
- Results promise more efficient converters when operated at lower temperatures

Future work

- Test bench adaption to GaN semiconductors
- Breakdown voltage measurements
- Further semiconductor measurements over a wide temperature range

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