

Technical Discussion 5.0

Power Electronics Integration

Session Chair
Note Taker

Johann W. Kolar
Jelena Popovic-Gerber

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Session Outline

► Introduction

- Integr. GaN Technology for HF Conv.
- Integr. High V_{in} Ind./Cap. DC/DC Conv.
- Integr. Techn. for Modular MV Conv.

D. Kinzer / Navitas Semicond. Inc.
B. Wicht / Reutl. Univ. - BOSCH
W. van der Merwe / ABB

► Discussion

Introduction

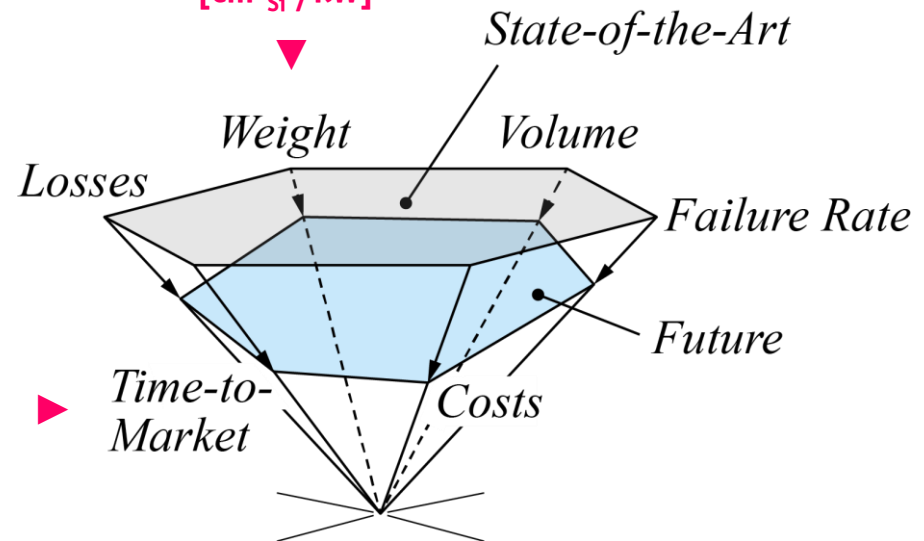
► Power Electronics Performance Trends

Environmental Impact...

$[\text{kg}_{\text{Fe}} / \text{kW}]$
 $[\text{kg}_{\text{Cu}} / \text{kW}]$
 $[\text{kg}_{\text{Al}} / \text{kW}]$
 $[\text{cm}^2_{\text{Si}} / \text{kW}]$

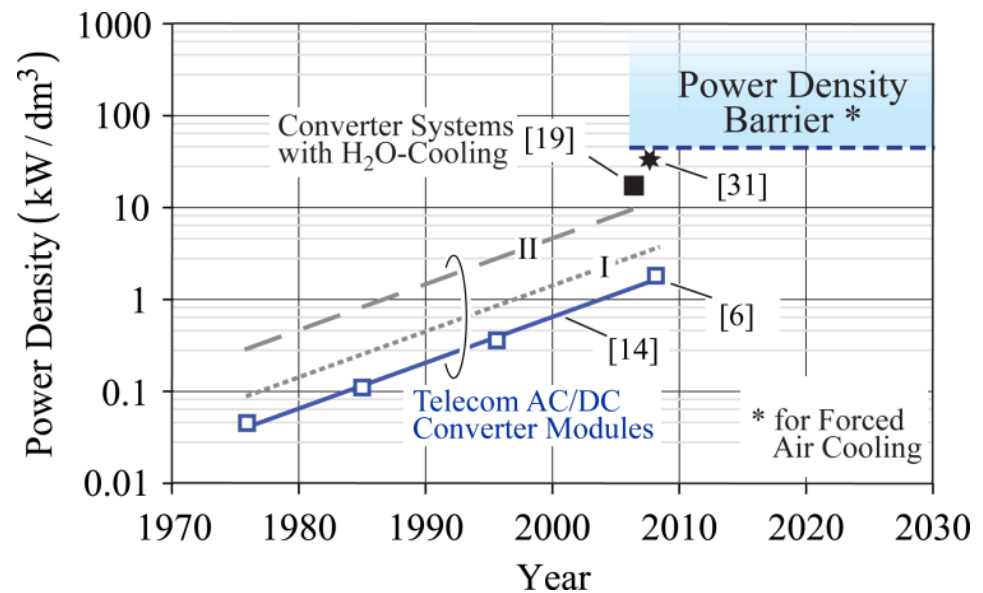
■ Performance Indices

- Power Density $[\text{kW}/\text{dm}^3]$
- Power per Unit Weight $[\text{kW}/\text{kg}]$
- Relative Costs $[\text{kW}/\$]$
- Relative Losses $[\%]$
- Failure Rate $[\text{h}^{-1}]$



► Performance Trends – Power Density

- Telecom Power Supplies:
Factor 2 over 10 Years



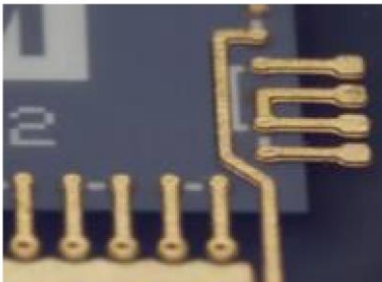
→ Integration as Enabler of Further Performance Improvement

Some Examples of Integration

- Power / Electronics / Cooling into PCBs
- Switches & Gate Drives
- Passives & Sensors
- Full Converters

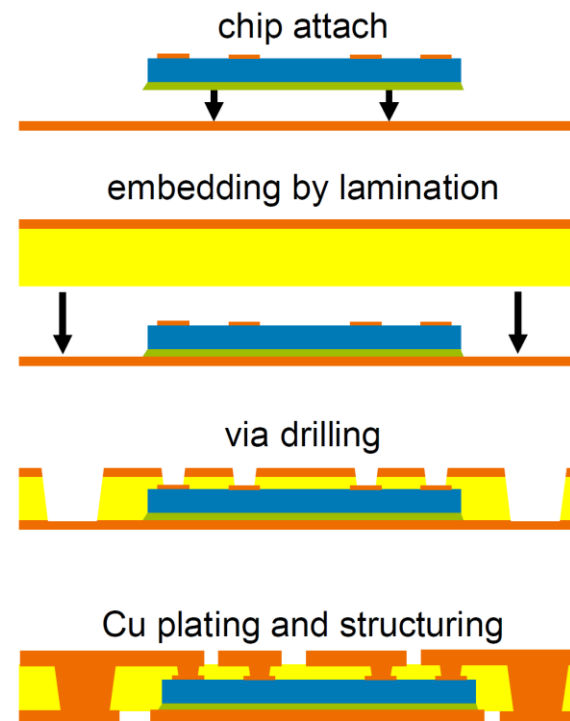
► Novel PCB Technologies for High Power Density Systems

■ Chip in Polymer Process / Multi-Functional PCB



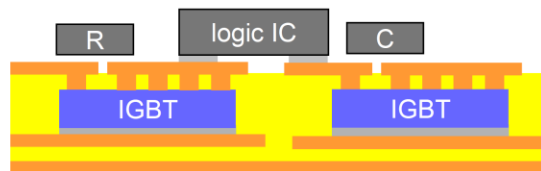
embedded chip in PCB structure.

- **Chip Embedding by PCB Technology**
- **Direct Cu Contact to Chip / No Wires or Solder Joints**
- **Thin Planar Packaging enables 3D Stacking**
- **Improved Electrical Performance and Reliability**

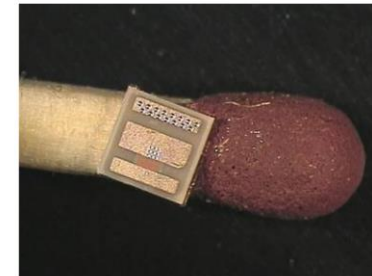


► Planar Power Chip Package

■ Novel Concepts for Power Packages and Modules



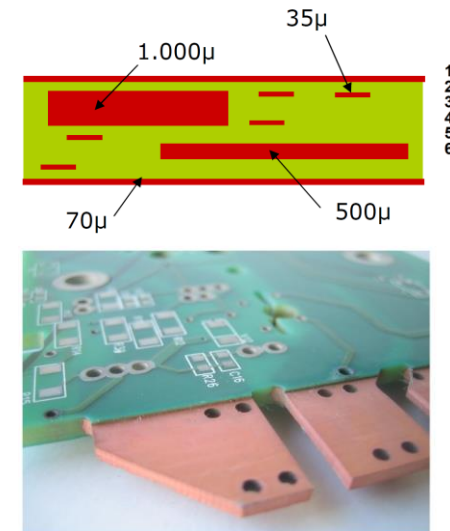
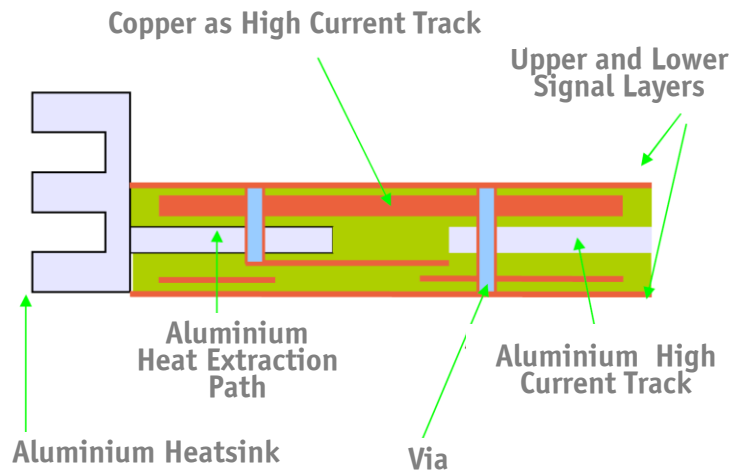
Module with Power and Logic Devices



Single Chip Package for MOSFETs and IGBTs

► Multi-Functional PCB

- Multiple Signal and High Current Layers
- Integrated Thermal Management



- Substantial Change of Manufact. Process → “Fab-Less” Power Electronics
- Advanced Simul. Tools of Main Importance (Coupling with Measurment.)
- Testing is Challenging (Only Voltage Measurement)
- Once Fully Utilized – Disruptive Change (!)

► GE Planar Power Polymer Packaging (P4™)



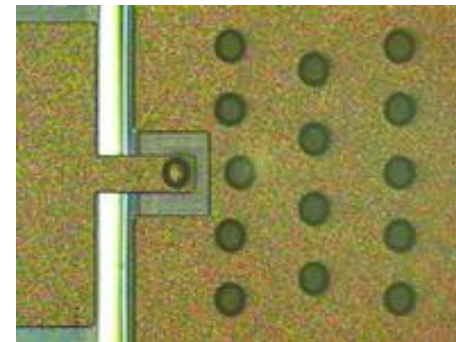
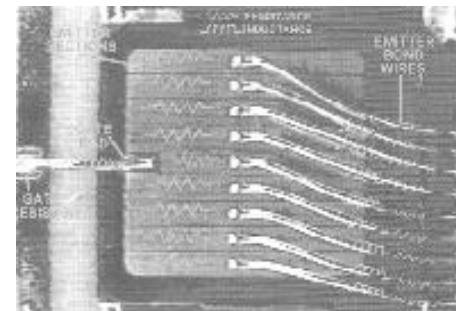
GE Global Research

United States - India - China - Germany

Oriented Toward High Power Devices
<2400V / 100A...500A
<200W Device Dissipation

Wire-Bonded Die on Ceramic Substrate
Replaced with Planar Polymer-Based
Interconnect Structure

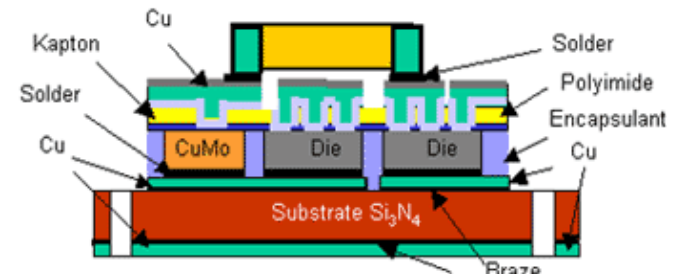
Direct High-Conductivity Cooling Path



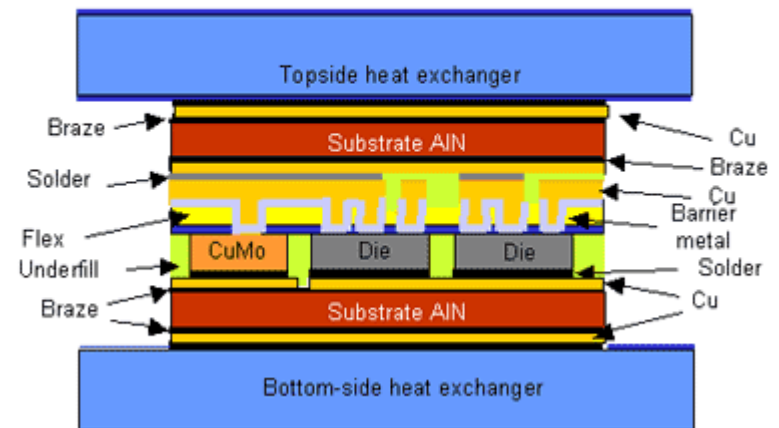
► GE Planar Power Polymer Packaging (P4™)

- Reduces Wire Bond Resistance by Factor 100
- Significantly Lower Switching Overvoltages
- Reduced Switching Losses
- No Ringing
- Reduces EMI Radiation
- Enables Topside Cooling
- No Mechanical Stress of Wire Bond Process
- Reduces CTE Wire Bond Stress on Chip Pads

CROSS SECTION OF A POWER OVERLAY MODULE



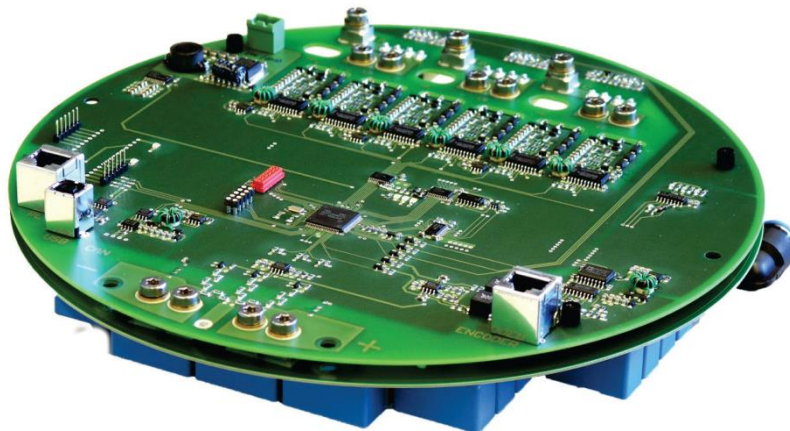
DOUBLE-SIDED COOLING OF A POWER OVERLAY MODULE



► 3ph. Inverter in p²pack-Technology

- **Rated Power** 32kVA
- **Input Voltage** 700V_{DC}
- **Output Frequency** 0 ... 800Hz
- **Switching Frequency** 20kHz

Source: 

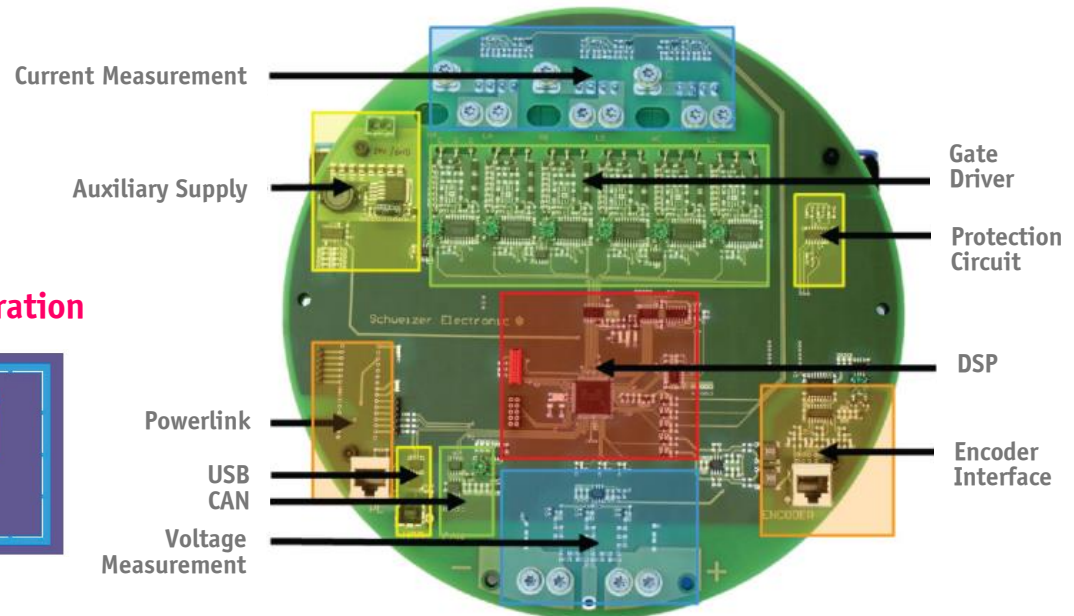
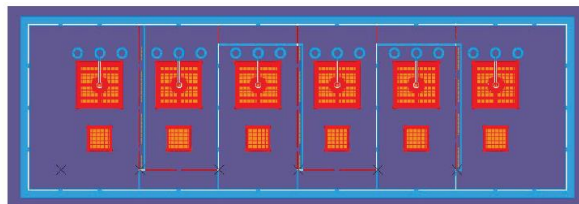



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Source: **SCHWEIZER**
ELECTRONIC
 ener
tronics

– Power Semiconductor PCB Integration



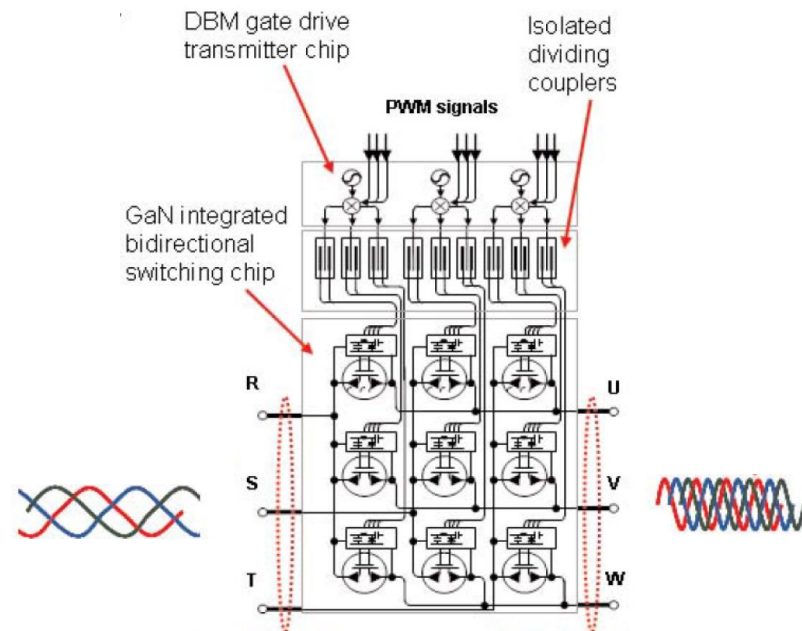
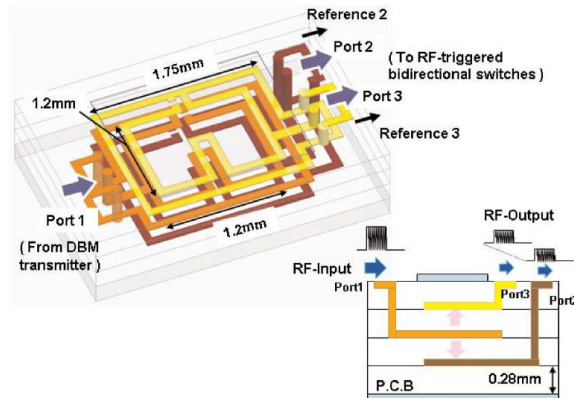
► Latest Systems Using WBG Devices → GaN

Source: **Panasonic** ISSCC 2014

■ GaN 3x3 Matrix Converter Chipset with Drive-By-Microwave (DBM) Technology

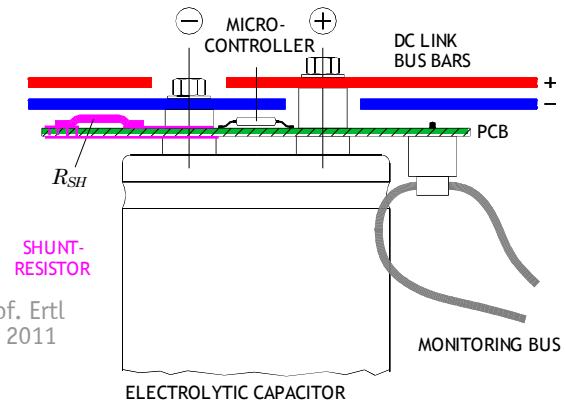
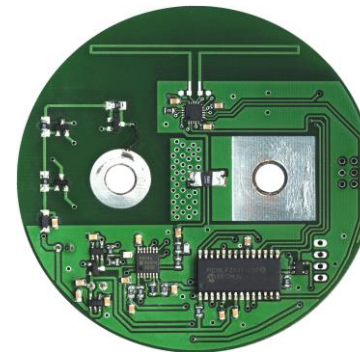
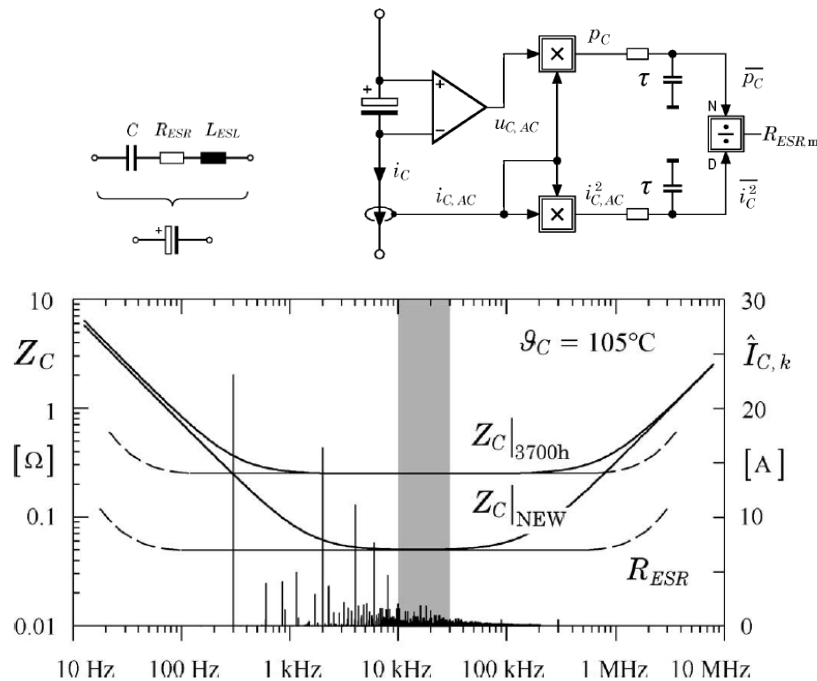
- 9 Dual-Gate Normally-Off Gate-Injection Bidirectional Switches
- DBM Gate Drive Transmitter Chip & Isolating Dividing Couplers
- Extremely Small Overall Footprint - $25 \times 18 \text{ mm}^2$ (600V, 10A – 5kW Motor)

5.0GHz Isolated (5kVDC) Dividing Coupler



► Condition Monitoring of DC Link Capacitors

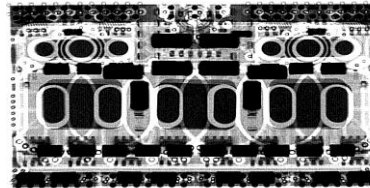
- On-Line Measurement of the ESR in "Frequency Window" (Temp. Compensated)
- Data Transfer by Optical Fibre or Near-Field RF Link
- Additionally features Series Connect. Voltage Balancing
- Possible Integration into Capacitor Housing or PCB



Source: Prof. Ertl
TU Vienna, 2011

► Hybrid Integration of Converters

■ Industry Is Leading the Field !



- Industry Low-Power Power Electronics (below 1kW) Heavily Integrated – PCB Based Demonstrators Do Not Provide Too Much Information (!)
- Future: “Fab-Less” Research @ Universities?

Selected Topics for Discussion

Definition

- Integration vs. Adv. Packaging (Compact “Hybrid” Combination)
- Functional Integration (e.g. Topologies)

Level & Type

- Low Power Electronics (Micro-Power-Electronics, e.g. SiP)
- Medium Power Converters (kW)
- High Power Converters (MW) - PEBB

- Switches & Gate Drives only

Drivers / Needs (?)

- Higher Performance
 - * Higher Power Density (High Sw.Frequ. → Min. Parasitics)
 - * Reduced Costs
 - * etc.
- On-Line Monitoring etc.

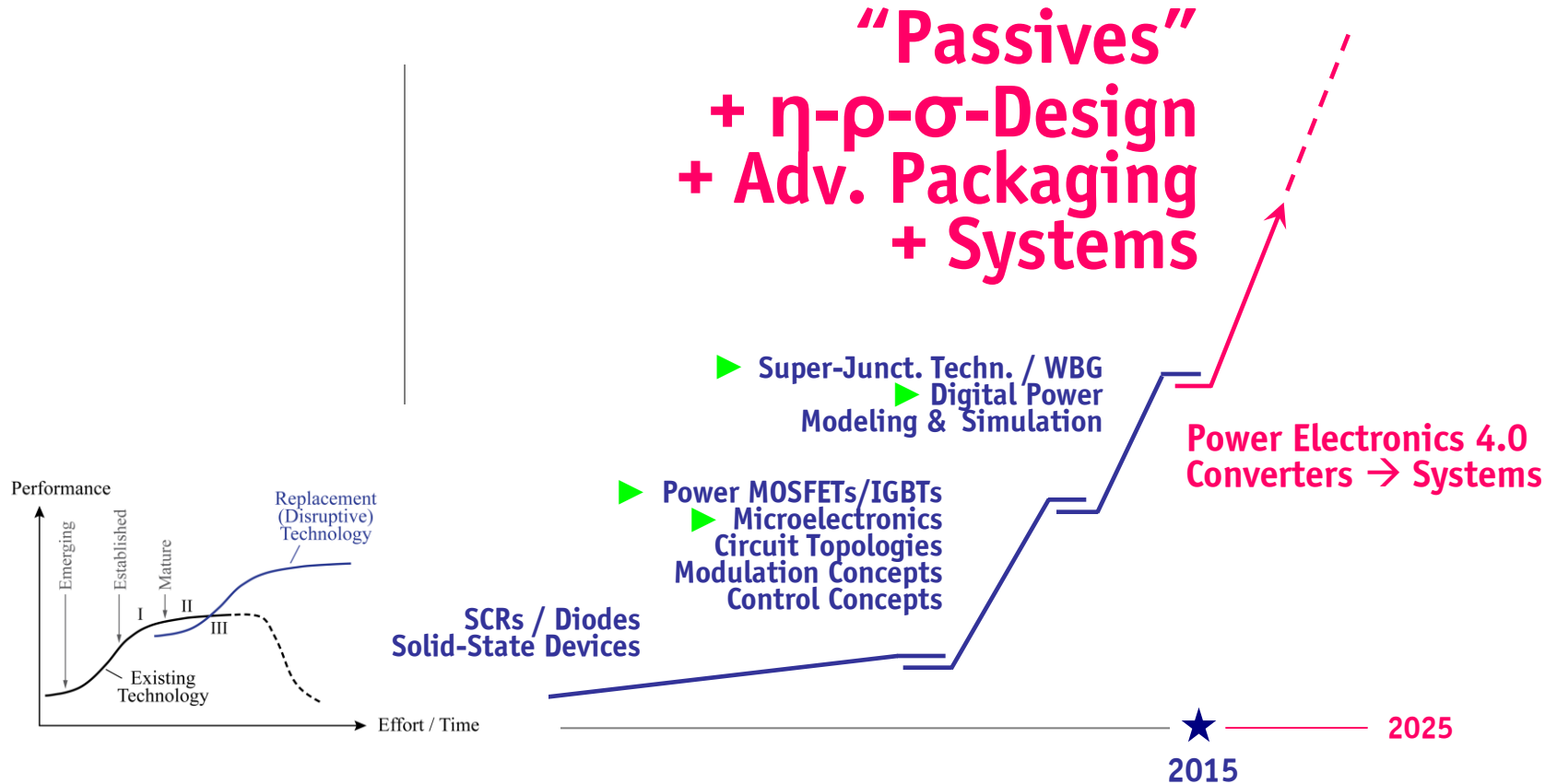
Challenges / Gaps

- Flexibility vs. Economy of Scale - Discussion Since 30 Years (!)
- New “Devices” (incl. Sensors / Communic. etc.)
- Testing
 - U-I-Temp.-Probes Integrated w. Converter
 - Next Gen. Oscilloscope with Integrated Simulator & On-Line Parameter Adjustment?
- Design
 - New Design Tools
- Manufacturing
 - Power Electronics “Fabs”

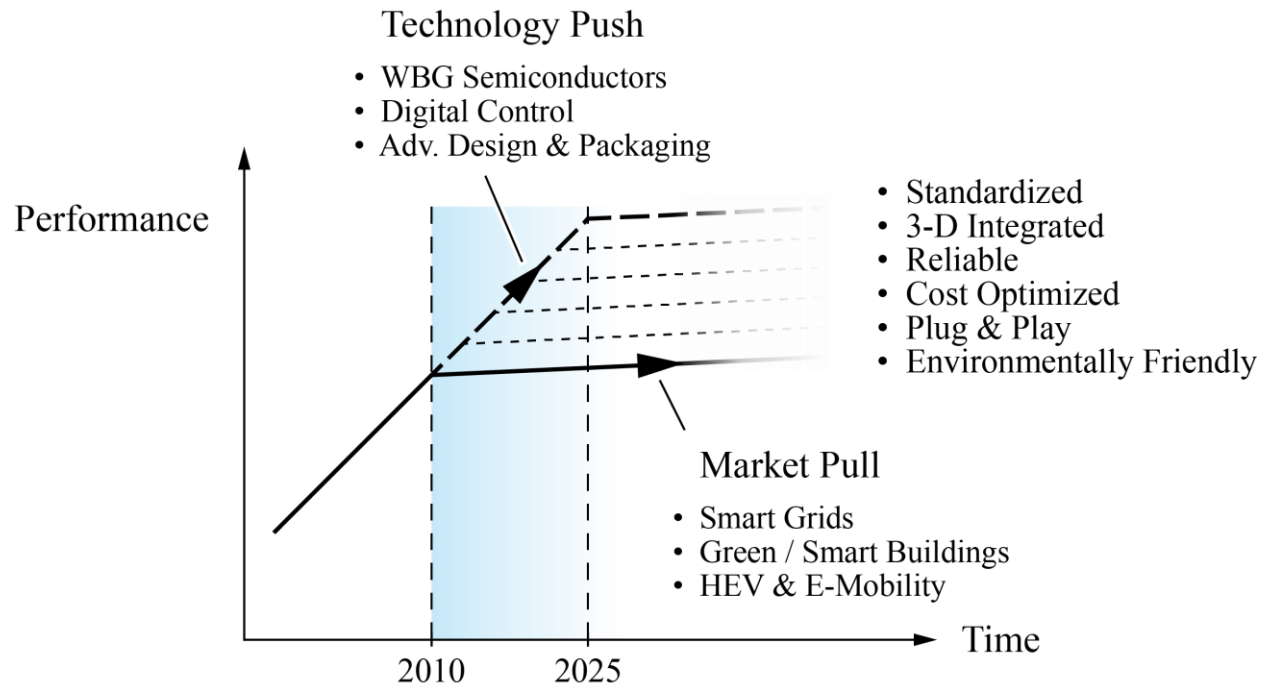
Future

- Last Step to Maturity ? (Acc. to “Laws” of Innovation)
- Power Electronics Takes Same Path as Analog Electr. in 1980?
- What is Next in Academic Research ?
- “Only” Applications?

► Technology S-Curve



► Future Developments



- **WBG Semiconductors + Next Level of Integration**
- **New Applications Could Establish Mass Markets solving the WBG Chicken-and-Egg Problem**