International Technology Roadmap for Wide Band-gap **Power** Semiconductor

ITRW

3D-PEIM

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June 14, 2016

IEEE POWER ELECTRONICS SOCIETY
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Wide Band-gap devices: the driving force to the next electronic industry.

- Wide band-gap devices are highly suitable to harsh working conditions such as high voltage, high temperature, high frequency, and high radiation exposure.
- The working voltage can reach as high as 10,000 volt, while the heat flux can exceed $1*10^7$ W/m^2, which is far beyond the realm of Si devices.
- Applications include spaceship, airplane, high speed train, ocean oil drilling platform, EV/HEV and intelligent manufacturing.
- Application areas of internet of things (IoT) require new technologies such as power electronics, RF devices and solid state lighting.

Content

- Information on ITRW
- Sub-groups
- Bench marking

Motivation

- R&D activities in wide bandgap devices are growing rapidly; more good quality devices are entering into the market.
- There are clear needs from industry, academia, education and public authorities to have a reliable and comprehensive view on the Strategic Research Agenda and Technology Roadmap.
- Now is the right time to launch ITRW, to provide reference, guidance and services to future research and technology development.

ITRW versus ITRS

- Could ITRW emulate the success and impact of ITRS?
- System value of technology development is the key to success.
- ITRS is running against 7nm limit, WBG converters are already 99%+
- As devices get better, the technology challenges migrate to the rest of the system.
- How to manage the broad range of applications?

Mission

The International Technology Roadmap for Wide Band-gap Power Semiconductor (ITRW) ***fosters and promotes the research, education, innovations and applications of WBS technologies globally***, and is

co-initiated by IEEE PELS and organizations representing USA, Japan, China, Europe, UK.*

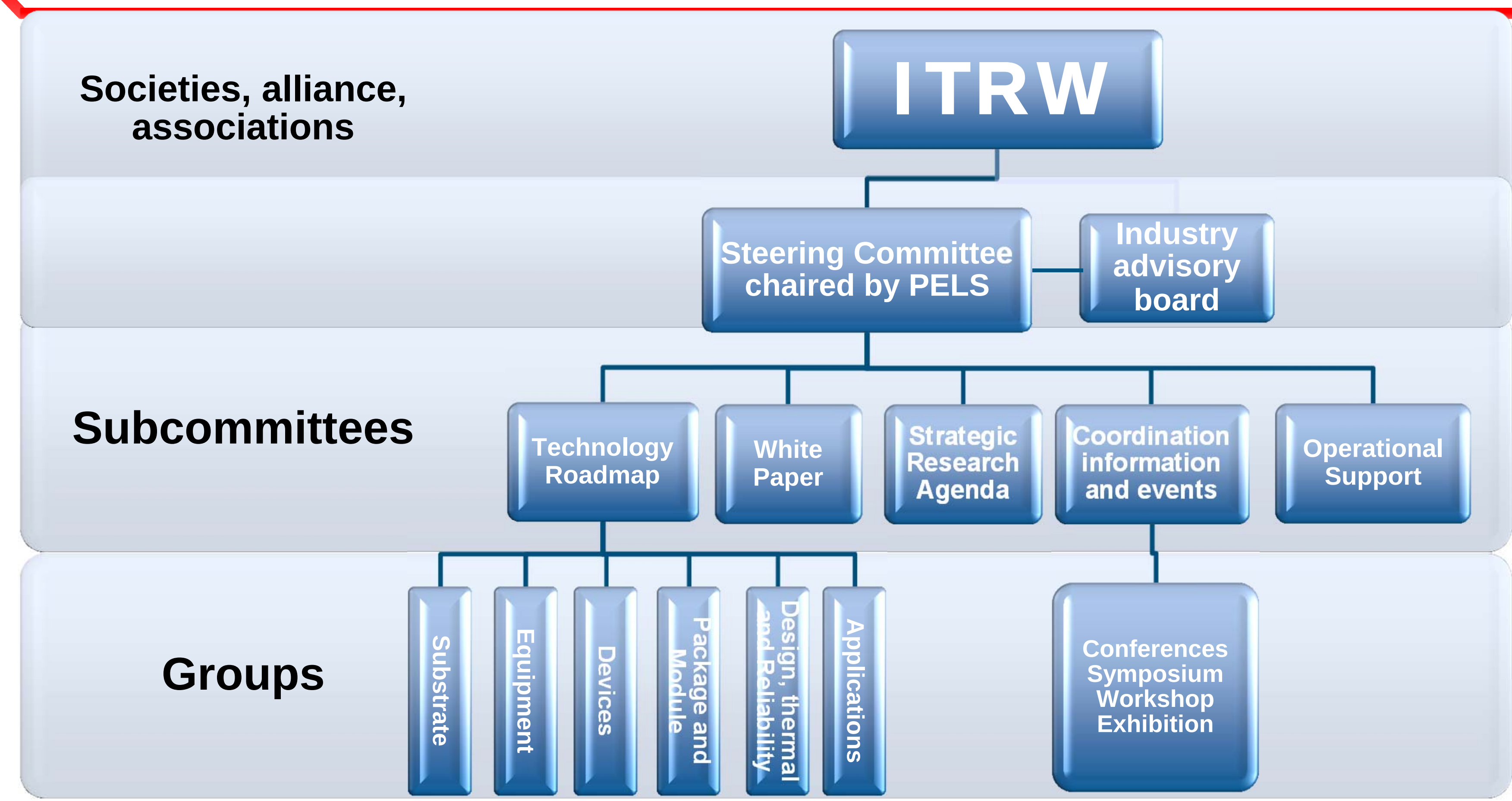
and coordinated by IEEE PELS.

*Founding partners: US Department of Energy, Power America, NEDO (Japan), SIP (Japan), CWA (China), NMI (UK).

Activities

1. Technology Roadmap
2. White Paper
3. Strategic Research Agenda
4. Information and Events

Governance


Societies, alliance, associations
ITRW
Steering Committee chaired by PELS
Industry advisory board
Subcommittees
Technology Roadmap
White Paper
Strategic Research Agenda
Coordination information and events
Operational Support
Groups
Substrate
Equipment
Devices
Package and Module
Design, thermal and Reliability
Applications
Conferences Symposium Workshop Exhibition

Governance

- **Steering committee**
  - consists of representatives from relevant society, association and alliance, i.e., PELS, ECPE, CWA, etc
  - membership per term for 3 years
  - Chair (PELS) and co-chairs will be elected
  - The decision making body, 2/3 votes
- **Subcommittees and working groups**
  - Consist of volunteers of international leading experts from both academia and industries
  - The working body of ITRW
  - Chair and co-chairs will be appointed by steering committee
- **Industrial advisory board**
  - Consists of peoples from relevant companies representing the complete value chain of this industry and the global geographic distribution
  - Provides inputs and advise to the steering committee
  - Chair and co-chairs elected by the board

Operation Model

- Open platform based on the contribution of global leading experts as volunteers
- Members' meetings: twice per year, in combination with major conference/event
- Technology roadmap, update once per 2 years
- White paper and Strategic Research Agenda will be defined according to need
- Events will be organized according to need
- Web for information sharing and advertisement
- TU Delft is willing to take care of operational supporting
- Budget: Euro 50,000/year

Content

- Information on ITRW
- Sub-groups
- Metrics and Benchmarking

Sub-groups

The initial technical committees have been defined as:

1. Substrates and EPI materials
2. Devices and process integration
3. Modules and Packaging
4. Power Electronic system integration and application

Working Scope

- Acknowledging Moore's law, ITRW will be the engine of a virtuous cycle, meaning the key drivers in in this context are:
  - power density scaling,
  - better performance and cost ratio,
  - and finally the market and economy.
- The growth of the market will in turn benefit new technology investment and development.
- The ITRW will support the technical feasibility and the economic validity of the ecosystem.

Working Scope

- ITRW will be a solid supporting white paper for the technical feasibility and the economic validity of this ecosystem.
- The ITRW also has a strong prescriptive effect, it will provide research guidance, landscape and applications forecast for the actors in the semiconductor ecosystem.
- Therefore, it will significantly contribute to technology exploration and increase resource efficiency in the very fast technological development of the industry.

Content

- Information on ITRW
- Sub-groups
- Metrics and Benchmarking

Rationale

- We need metrics to establish some method of comparison.
- Need to define metrics that are:
  - – Agreed by the technical community
  - – Able to be tolerant of technology change
  - – Have unimpeachable value

Typical Power Device Metrics

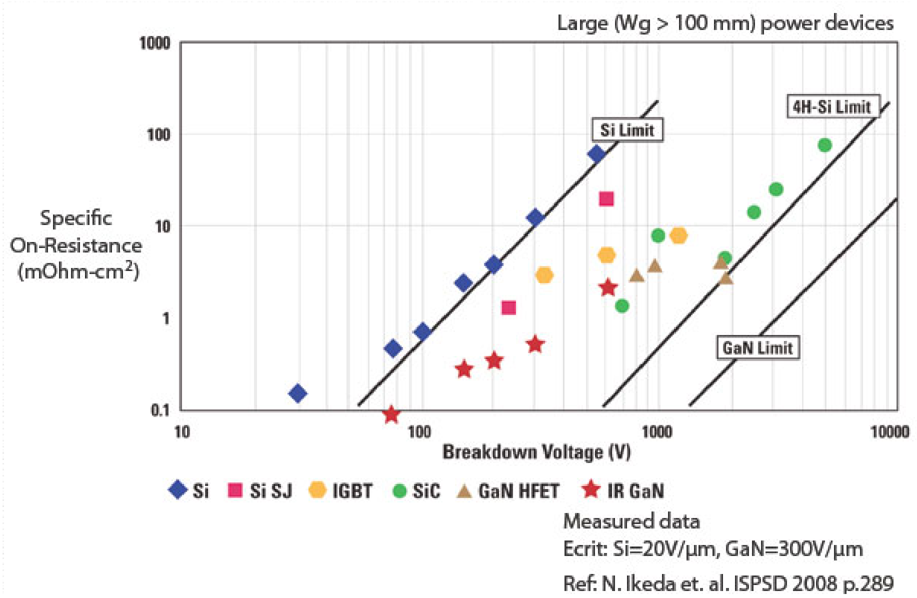
- Maximum voltage.
- Continuous current
- Pulsed current
- Maximum ower Dissipation
- Peak Recovery Rate
- Forward Transconductance
- Turn on/off delay times
- Turn On/Off rise/fall times

Secondary Metrics

- Parasitics
  - Inductance
  - Capacitances
- Thermal resistance
  - Package dependent
- What others ??

Rationale

- A useful comparison?



- How to quantify the system integration?

Metrics

Technical levels:

1. Substrates and EPI materials
2. Devices and process integration
3. Modules and Packaging
4. Power Electronic system integration and application

What are suitable benchmarks/metrics for modules, packaging and system integration?

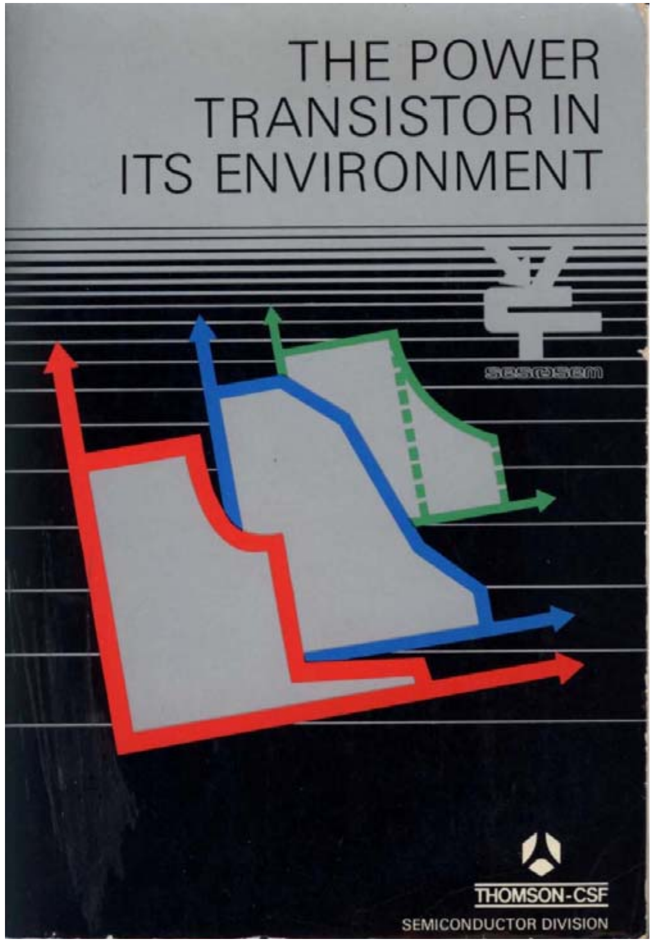
Possible Module / System Metrics

- Efficiency
  - SiC and GaN inverters already at 99%+ efficiency = not much room for progress?
- Reliability
  - IEEE PELS SiC FET Reliability Testing Case Study
  - Initially it can boost the acceptance of WBG devices, until on par with Si.
- Power volume/weight density
  - Always a good metric because less material is cheaper and obvious system benefits.
- Cost
  - Important, but benchmarking may be difficult.

The WBG power transistor in its environment

- Who remembers the 1978 book by Thomson CSF?

- What is the environment for WBG system integration?

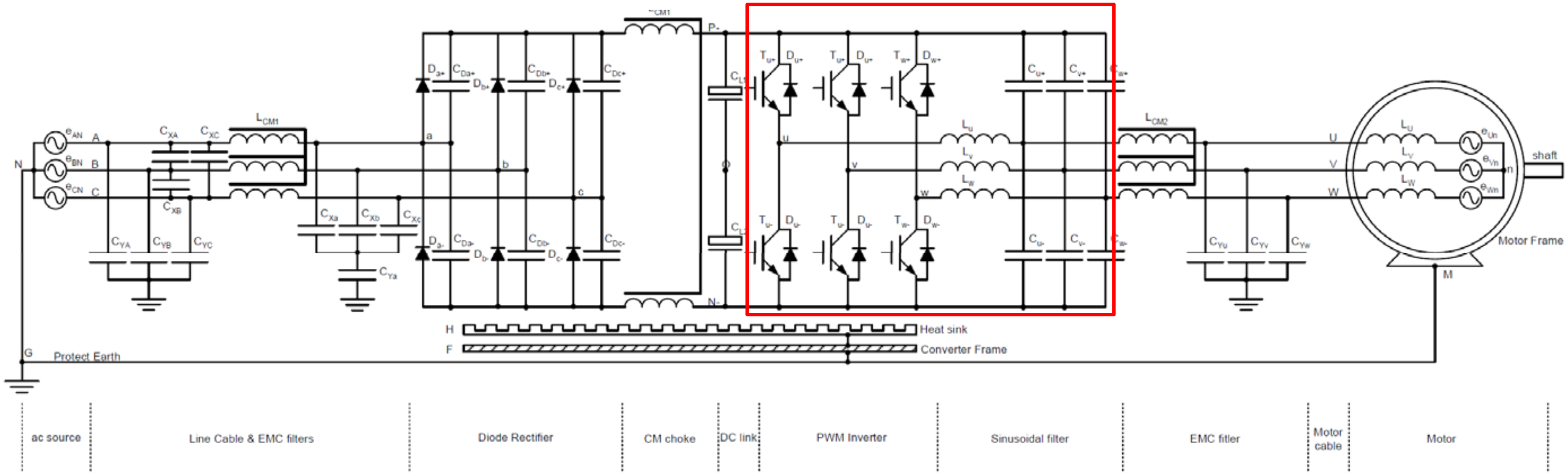


The WBG power transistor in its environment

- The immediate electrical environment are the parasitic inductances and capacitances.
- Since they interfere with the very fast switching of WGB devices, it is better to deal with them on a higher level than devices = power modules and switching cells (e.g. on PCB)
- Convenient of a power module is that thermal and mechanical properties can be dealt with at the same time. (Not the case with a PCB switching cell)

The WBG power transistor in its environment

- Fast transients create more EMI in the system.



- Example of resonant switching cells used in drive for EMC sensitive environments.

The WBG power transistor in its environment

- Device metrics are meaningless on system integration level.
- A limited set of benchmarks that can easily be validated are needed.
- EMI and EMC are important system integration criteria: benchmarking on converter/sub-converter/switching-cell level.
- Standardised test platforms are needed to measure electrical, mechanical, thermal and EMC performance.
- **Better insights are welcome!**

QUESTIONS?

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IEEE Power Electronics Society
FEPPCON Future of Electronic Power Processing & Conversion