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

ITRW

NEREID meeting

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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 grows fast; more good quality devices are entering into the market.
- There are clear needs from industry, academia, education and public authorities to have reliable and comprehensive view on the Strategic Research Agenda and Technology Roadmap.
- Now it is the right time to launch ITRW, to provide reference, guidance and services to future research and technology development.

ITRW, ITRS, HITRS and ITRDS

- Power WBG is in a similar position as Silicon 30 years ago.
- ITRS was terminated in 2015.
- Heterogeneous technology continues as HITRS and is supported by IEEE CMTP
- Roadmap for Devices and Systems, ITRDS, is part of Rebooting Computing of IEEE ComSoc.

ITRW versus ITRS

- Could ITRW emulate the success and impact of ITRS?
- System value of technology development is the key to success.
- As devices get better, the technology challenges seem to migrate to rest of system.
- How to deal with broad scope 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).

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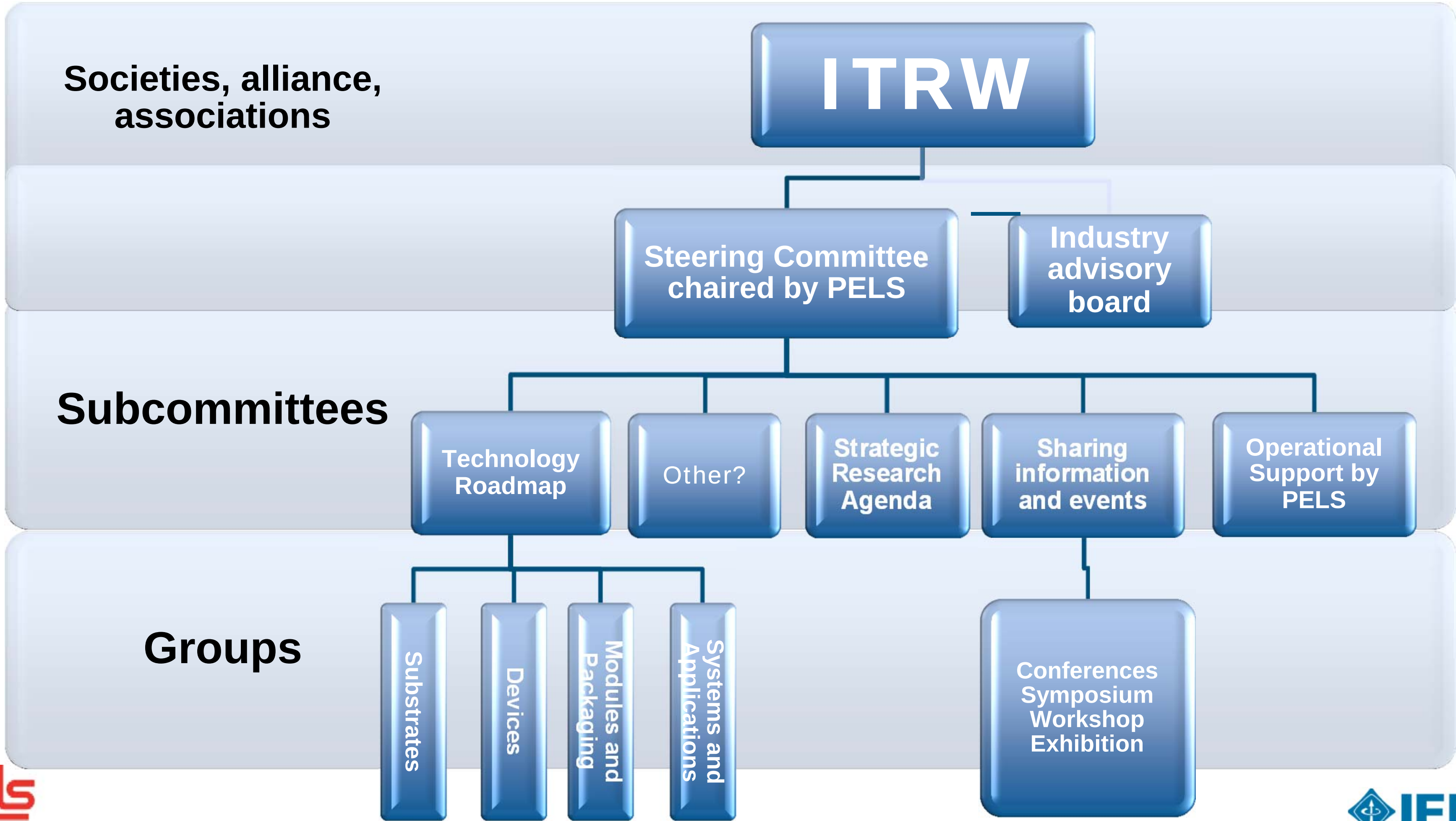
Activities

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

ITRW Structure and Governance



Governance

- **Steering committee**
  - consists of representatives from relevant society, association and alliance,
  - 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

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- Sub-groups
- Metrics and Benchmarking

Sub-groups

The decided subgroups in the technical committees are:

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

Working Scope

- Acknowledging to the Moore's law, ITRW will be the engine of the virtuous cycle, i.e.:
  - the power density scaling,
  - the better performance, the 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

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- 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

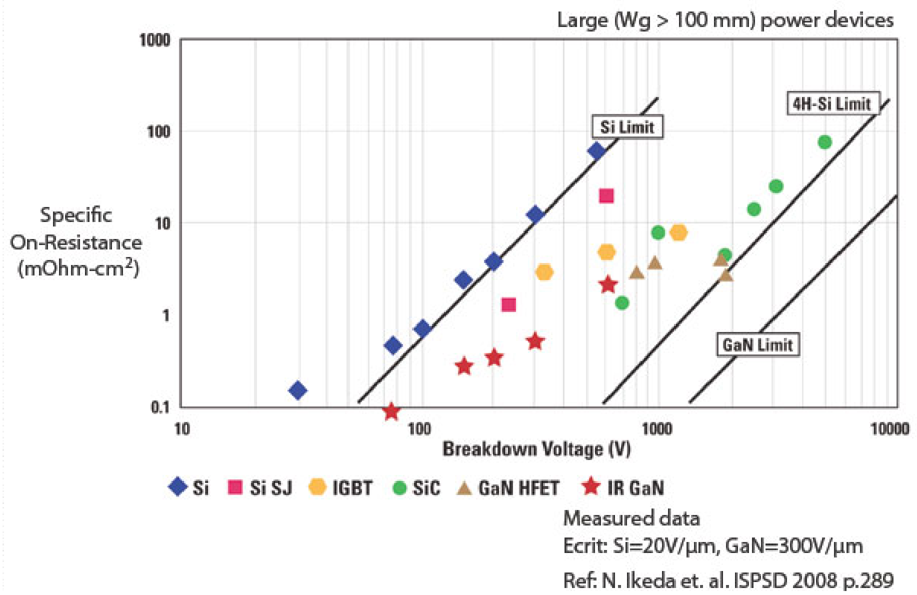
- Maximum voltage.
- Continuous current
- Pulsed current
- Maximum ower Dissipation
- Peak Recovery Rate
- Forward Transconductance
- Turn on/off delay times
- Turn On/Off rise/fall times

Secondary Metrics

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

Rationale

- A useful comparison?



- Can one 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

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

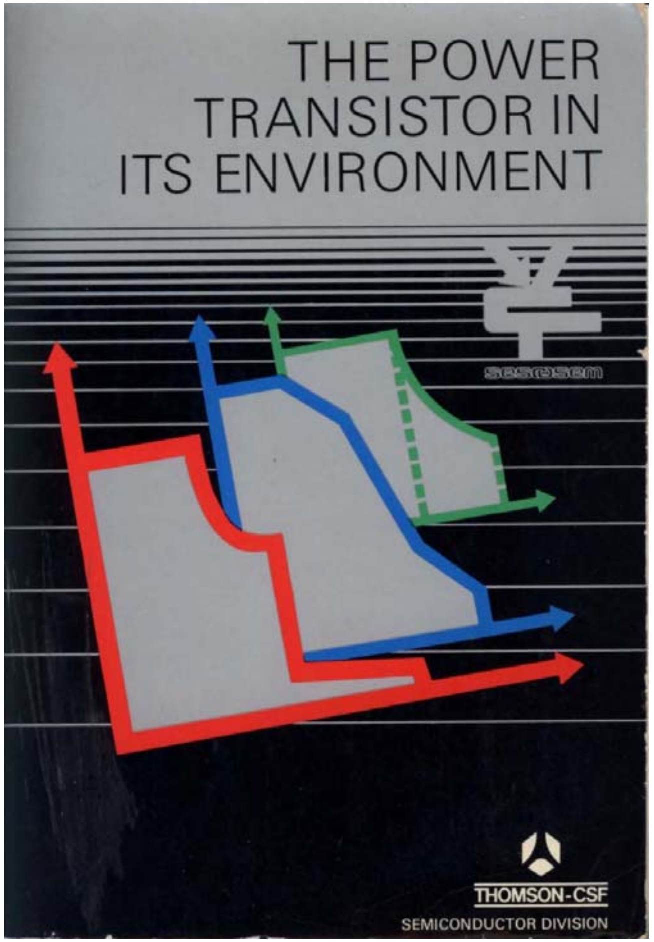
Possible Module / System Metrics

- 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 benfits.
- Cost
  - Important, but benchmarking may be difficult.

The WBG power transistor in its environment

- Who remember 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

- 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!**

Next Steps

- Technical Briefings to the ITRW steering committee and workshop
- Steering Committee Meetings
- Meeting Dates:
  - WiPDA (November 2016 – Fayetteville, USA)
  - APEC 2016 (March 2017 – Tampa, USA)
  - IWIPP 2016 (April 2017 – Delft, Netherlands)
  - ISPSD 2016 (May 2017 – Sapporo, Japan)

QUESTIONS?

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FEPPCON Future of Electronic Power Processing & Conversion