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InRel-NPower - Innovative Reliable Nitride based Power Devices and Applications

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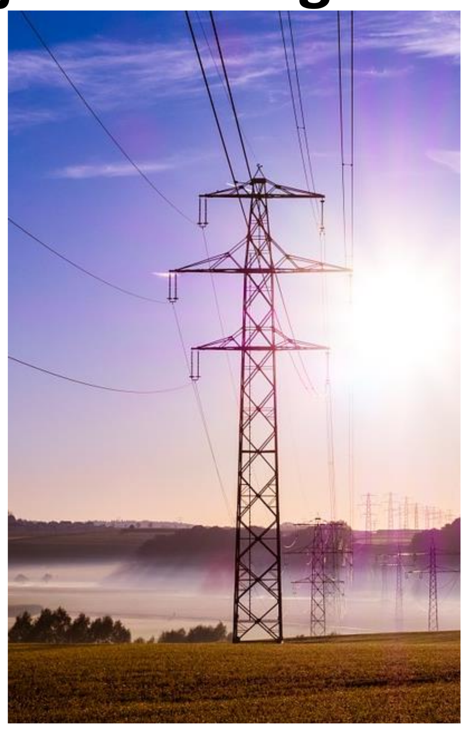
Overview and Introduction

Electric Energy: a major challenge

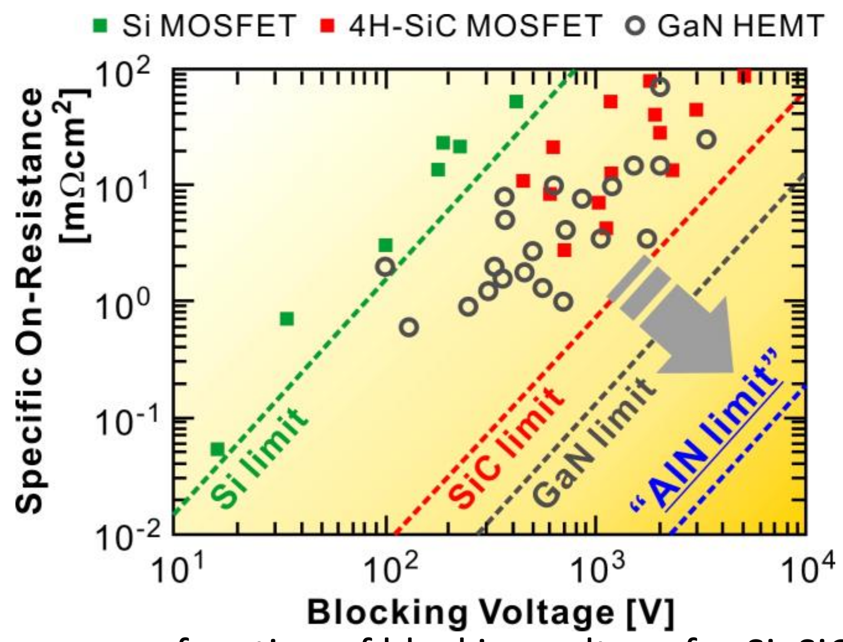
The way in wich energy is used has great impact on the economy, the environment and society. Currently, 40% of the energy used in the world is electricity, and it is expected to reach 60% by 2014.

However, a major part of the produced electricity is lost in electric power conversion.

To reduce such losses we must create electronic devices that use new materials with higher efficiency.



Nitride-based semiconductors



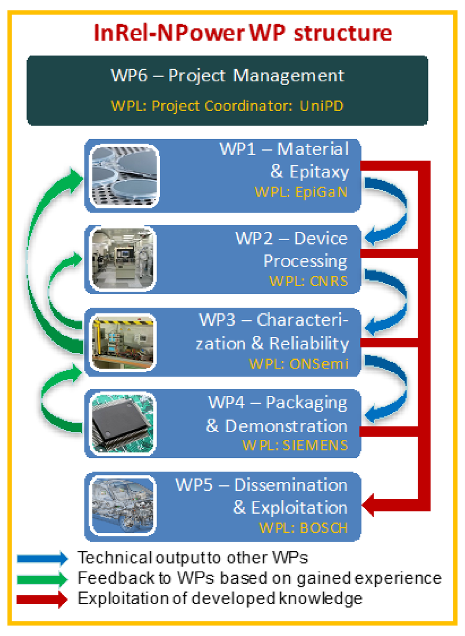
On-resistance as a function of blocking voltage for Si, SiC, GaN and AlN semiconductor materials. Nitrides outperform all others.

Ambition of the *InRel-NPower* project

The *InRel-NPower* project researches GaN and AlN-based transistor devices for application in power electronics.

These material have performances 10 to 100 times higher than silicon – currently being used - which could result in conversion systems achieving a 99% conversion efficiency!

We aim to mature the technology: by focusing on the raw material, on the packaging and by demonstrating its potential in a final device.



Material/Epitaxy and Device Processing

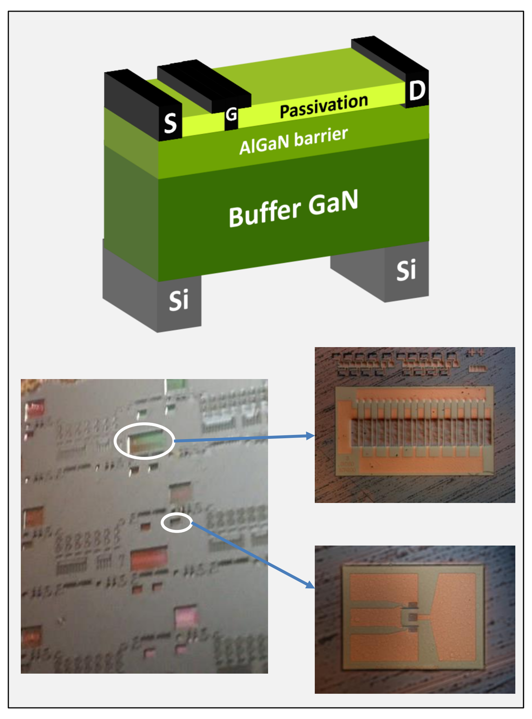
Material and Epitaxy

III-nitride material is the core enabler of superior switching devices:

- GaN-on-Si
  - The project's baseline technology, with an emphasis on improving reliability by using different epitaxial buffer structures
- AlN-based electronics
  - Explorative investigation of the epitaxy of Ultra-Wide Bandgap layer structures grown on AlN templates (obtained by HVPE or 3SG)or bulk substrates (grown by PVT).
- Advanced Material Characterisation
  - A major objective is to determine the correlation between material properties and device performance through XRD, AFM, SEM, TEM, CL, PL, EBSD, …

Device Processing

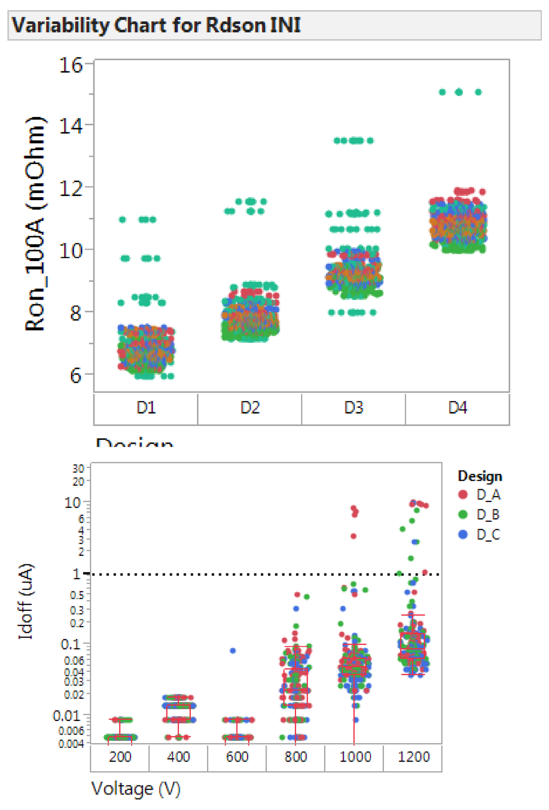
- Optimization of power device processing on 6-inch GaN-on-Si wafers in ON-Semi's pilot line
  - Improvement of specific process modules for highly reliable and stable devices targeting on-resistance < 20mΩ, 650V
- Development of higher voltage GaN-on-Si power devices beyond 2 kVolts
  - Optimization of substrate removal and subsequent replacement of the substrate by AlN material
- Development of new types of power devices based on AlN bulk substrate to enhance the breakdown voltage while delivering higher thermal dissipation.



Characterization and Reliability

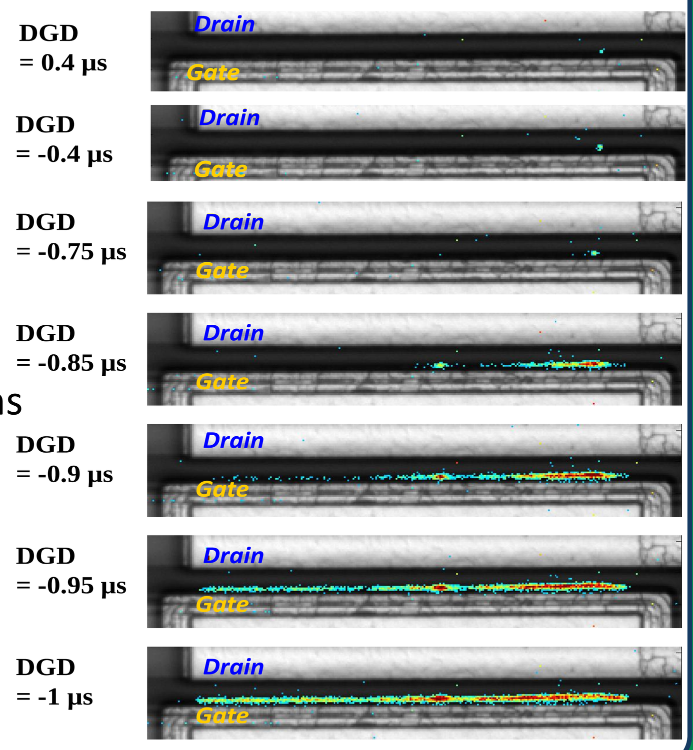
Characterization

- Statistical data collection of prime transistor parameters. Up to 100A, up to 1.2kV.
- Wafer level Pulsed I-V for dyn Ron characterization on >100 devices per wafer
- Substrate ramp measurements to investigate the effect of buffer traps
- Wafer level reliability e.g. HTRB, HTGB, at various voltage levels, including short circuit testing
- Device screening, binning strategy
- Measurement on devices with Si substrate removed, and on GaN-on-AlN devices. Up to 3kV.
- Catholuminescence and electroluminescence



Reliability

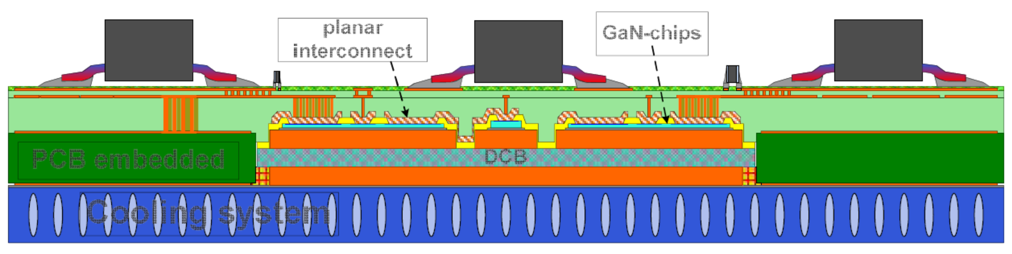
- GaN power devices with proven reliability, beyond JEDEC
  - standardization of the requirements and protocols for the analysis of the stability of HEMTs for high-voltage operation
- Understanding of GaN HEMT transistor failure mechanisms to enable life time prediction for use conditions
  - Analyze and modeling of the failure mechanisms of high voltage/power HEMTs operated under realistic use conditions
  - correlate the parametric degradation processes during accelerated stress to GaN material parameters
  - define stress and failure analysis protocols
- Extraction of acceleration models (field, temperature, current,…) to build mission profiles



Packaging and Demonstration

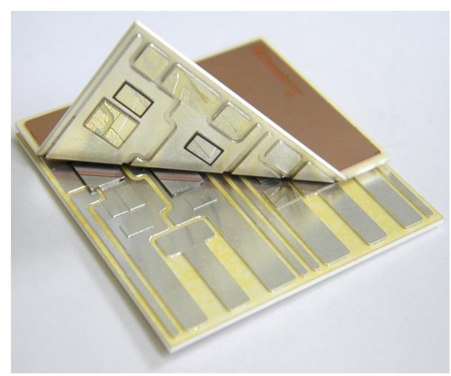
Advanced low inductance packaging for power devices

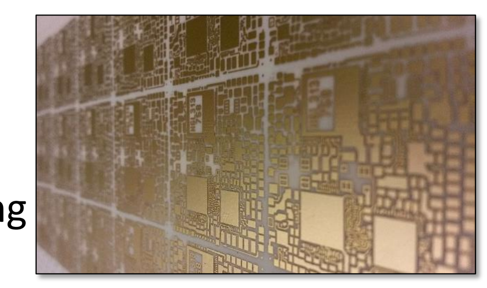
- Low inductance packaging
  - Flexible planar interconnection
  - Reduced electrical noise from smaller system
  - Higher frequency drive operation
- Compact packaging
  - Higher reliability, robustness and reduction of system size
  - Includes embedded active and passive components/ sensors and cooling
- Demonstrator (objectives):
  - Motor drives inverter with 60 % less power losses, more than 30 % reduction in volume and 50% higher power density
  - DC2AC converter: 2KW@30V at 50°C, peak efficiency up to 99% and expected life of 10^6 hours at 30°C



Advanced double-sided ceramics module design

- Low inductance packaging
  - Double-sided ceramics design
  - Usage of AMB-base power substrate and LTCC-base logic counter-substrate
- Compact packaging
  - Higher power densities by integration of further active and passive components / sensors on LTCC-substrate
  - High effective and efficient AMB-backside cooling
- Robustness characteristics
  - Built-up using robust double-sided Ag-sintering joining technology with potential up to 200°C junction temp.
  - Validation of design's robustness characteristics including new GaN-devices especially by power cycle tests





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