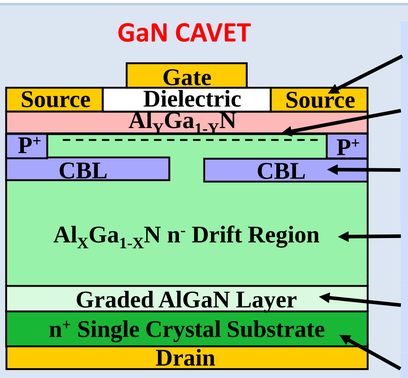
Wide Bandgap Power Electronics and Thermal Science

S&T Campaign: Materials Research
Electronics
Energy Efficient

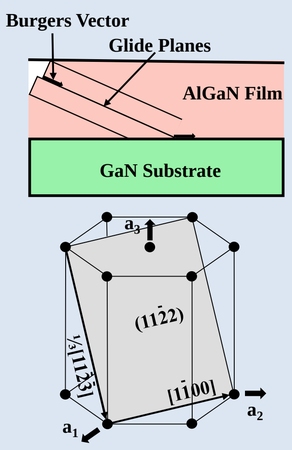
Ken Jones: (301) 394-2005, Kenneth.A.Jones162.civ@mail.mil
Aivars Lelis: (301) 394-5426, Aivars.J.Lelis.civ@mail.mil
Nick Jankowski: (301) 394-2337, Nicholas.R.Jankowski.civ@mail.mil
Sasha Batyrev: (410) 306-4582, Iskander.G.Batyrev.civ@mail.mil

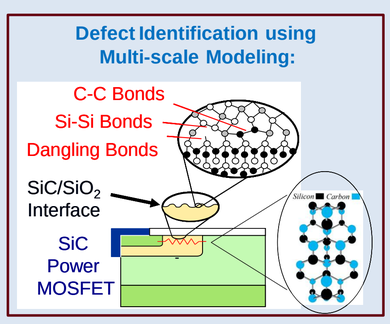
Research Objective

Determine how material and fabrication defects, as well as the temperature, affect the operation and reliability of WBG semiconductor devices

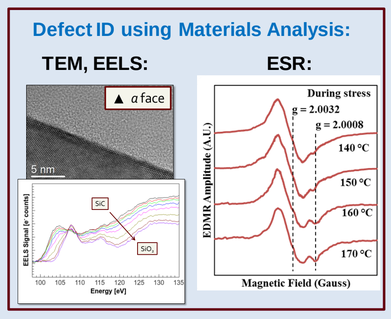


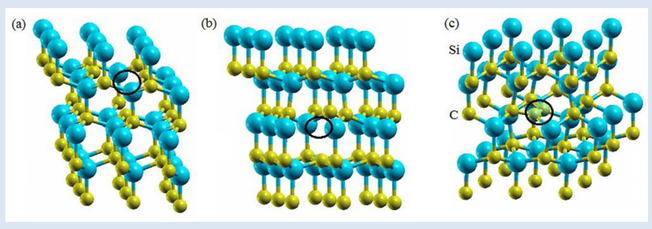
- Form Ohmic contact to high Al% AlGaN layer
- Deposit thin AlN layer to reduce alloy scattering
- Create a p-type current blocking layer (CBL)
- Grow a low doped, high Al% AlGaN drift region
- Use graded AlGaN to reduce TDs created by mismatch
- Use high structural quality single crystal substrates





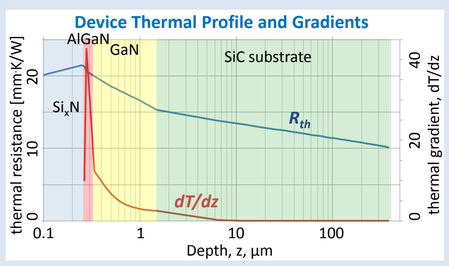
SiC MOSFETs

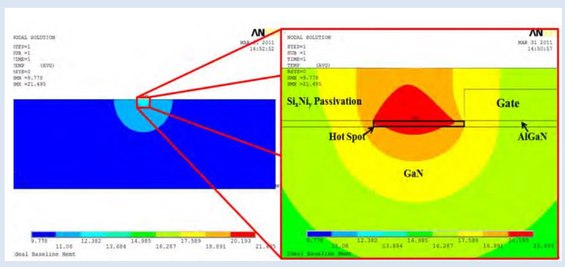




Multi-scale modeling:
DFT coupled w/ device simulator results—C di-interstitial is dominant Interface trap

Temperature Measurement





Modeled hot spot in GaN-AlGaN HEMT

Challenges

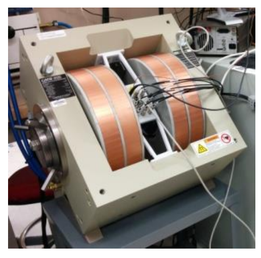
- **Understanding of cause and effect of various crystalline and point defects in WBG materials and their associated insulating layers and interfaces on device performance and reliability**
- **More precisely identifying the interrelationships between electrical, mechanical and thermal domains within the device and how the interactions initiate failure modes.**
- **Developing physics based relationships between failure modes and initial device measurements, as well as how they are accelerated by increasing the temperature**
- **Delineating between macroscopic diffusion and quantum mechanical ballistic transport as represented by phonons in heat conduction processes as devices become smaller**

ARL Facilities and Capabilities to Support Collaborative Research

Materials Characterization

Double Crystal X-Ray System

DLTS System



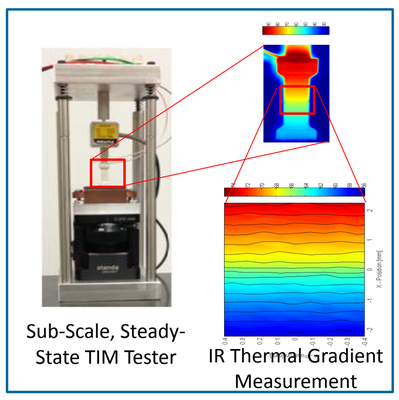
Hall System

Device and Device Reliability Measurements

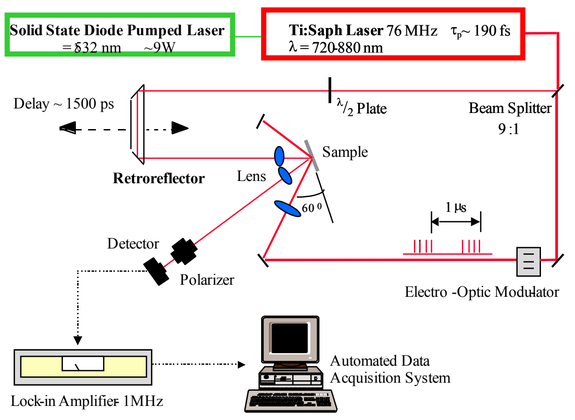
Semiconductor Parameter Analyzer with Automated BTI Testing

Dynamic High Temp Reverse Bias System (DHTRB)

Thermal Measurements



1D steady state TIM tester



Time Domain Thermoreflectance system

Complementary Expertise/Facilities/ Capabilities Sought in Collaboration

- **Knowledge of the physics of the operation of WBG devices and how their operation and reliability are affected by defects, and unique device measurement capabilities**
- **Knowledge of the physics of how defects are formed and ways to reduce their concentration and/or mitigate their negative effects, and unique equipment to measure their concentrations and properties**
- **Knowledge of the physics of thermal conduction and how it is affected by material defects and interfaces, and unique equipment to measure it**
- **Unique devices you want to be processed, and devices for which you want to be thoroughly characterized and their reliability measured**
- **Modelers of WBG devices, material defects and how the defects affect the properties of the components of the devices, and the thermal conduction and how the phonons are affected by defects and interfaces**