Twenty Years of Power Electronics at OE/SNL

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Office of Electricity, U.S. Dept. of Energy / SNL

DOE OE POWER ELECTRONICS DEVELOPMENT

2003 — **World's first Fiber Optic Electrical Transducer to Pass Military Vibration and Shock Certification**
Exceeds 30Mhz
Capable of Operating up to 34.5kV without additional Insulation, Isolation, or Cooling

2004 — **World's First Voltage Controlled 4500V/400A Turn-Off Thyristor**
4500V and 400A rated
Integrated Si MOSFET and GTO
Embedded Current Sensing Capability

2005 — **World's First High Temperature SiC Single-Phase Inverter**
3 kW (1200 V/150 A peak)
250 °C Junction Temperature
Integrated Gate Driver

2006 — **World's First Highly Accelerated Lifetime Testing (HALT) of High Voltage SiC Modules**
Dramatically Accelerates Design Cycle
-100 °C to 250 °C (1.7 °C/s Ramp)
48 in × 48 in Table Size
6 axis 75 gRMS Vibration

2007 — **World's First High Temperature SiC Power Module**
50 kW (1200 V/150 A peak)
250 °C Junction Temperature
Integrated HTSOI Gate Driver

2008 — **World's First Monolithically Integrated Single Chip Transistor**
Integrated SJT/Diode Chip at 1200V

2009 — **World's First Commercially Available Ultra-High-Voltage SiC Thyristor**
Rating exceed 6.5kV, 200kHz, 80A
> 200°C
junction temperature

2010 — **World's First High Voltage, High Temperature, Reworkable SiC Half-Bridge Power Module**
> 15 kV / 100 A, > 200 °C
Reworkable
Wire Bond Free, Low Parasitic Design
Device Neutral
HV Isolated Gate Driver

2011 — **World's First High frequency, high temperature, SiC half-bridge power module**
15 kV/100 A, 20 kHz, 200C
Reworkable
Low Parasitic Design
Device Neutral
HV Isolated Gate Driver

2012 — **World's First Avalanche Rugged Multi-kV Power Mosfet**
1 Joule at 5000V

2013 — **World's Highest Voltage Normally Off SiC JFET**
6.5 kV, 20kHz, 60A
200°C Junction Temperature

2014 — **World's First Commercial Monolithic Switch**
1.2 kV SiC Device

2015 — **Green Tech Gold**

2016

2017

2018 — **World's First high power modular GaN-based inverter**
20 kW per Module
Integrated GaN Gate Driver
Stackable to 100 kW

2019 — **World's First 3D printed iron nitride and nylon composite transformer core**
Operating temp up to 150C, 10X lower loss than bulk iron nitride, up to 1Mhz

2020 — **World's First commercially available iron nitride soft magnetic component**
1.89 T high magnetization
~ 200 µΩ·m high resistivity
> 200 C operating temperature

2021

2022

2023

UNIVERSITY PARTNERSHIPS:

INDUSTRY PARTNERSHIPS:

MAM

Foli Research, LLC

TRS Technologies

Airak Corp.

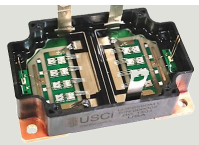
INDUSTRY ACQUISITIONS:

GeneSiC SEMICONDUCTOR

Navitas

Aug. 2022

UnitedSiC



qorvo

Oct 2021

ARKANSAS POWER ELECTRONICS INTERNATIONAL

Wolfspeed

July 2015

Areas of Interest:

Power Conversion System for Scalable ES Deployments

- Modular topologies for direct MV grid connection
- Integration of storage in existing and emerging power electronic energy infrastructure

Uninterruptible Converter Topologies for Critical Storage Assets

- Fault-tolerant and reconfigurable hardware architectures
- Hot-swap capable converters and storage systems

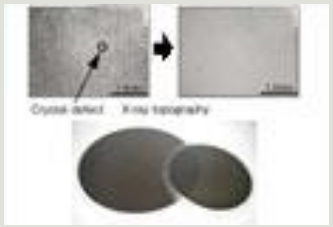
Applications of Power Electronics in Storage System Safety

- Stranded energy extraction
- Active response to thermal runaway

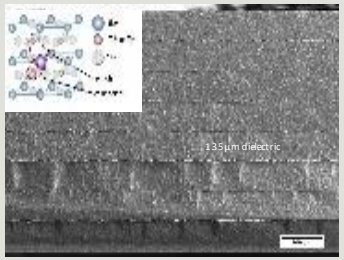
Integration of Advanced Components

- Wide bandgap devices
- Advanced magnetics
- Advanced capacitors

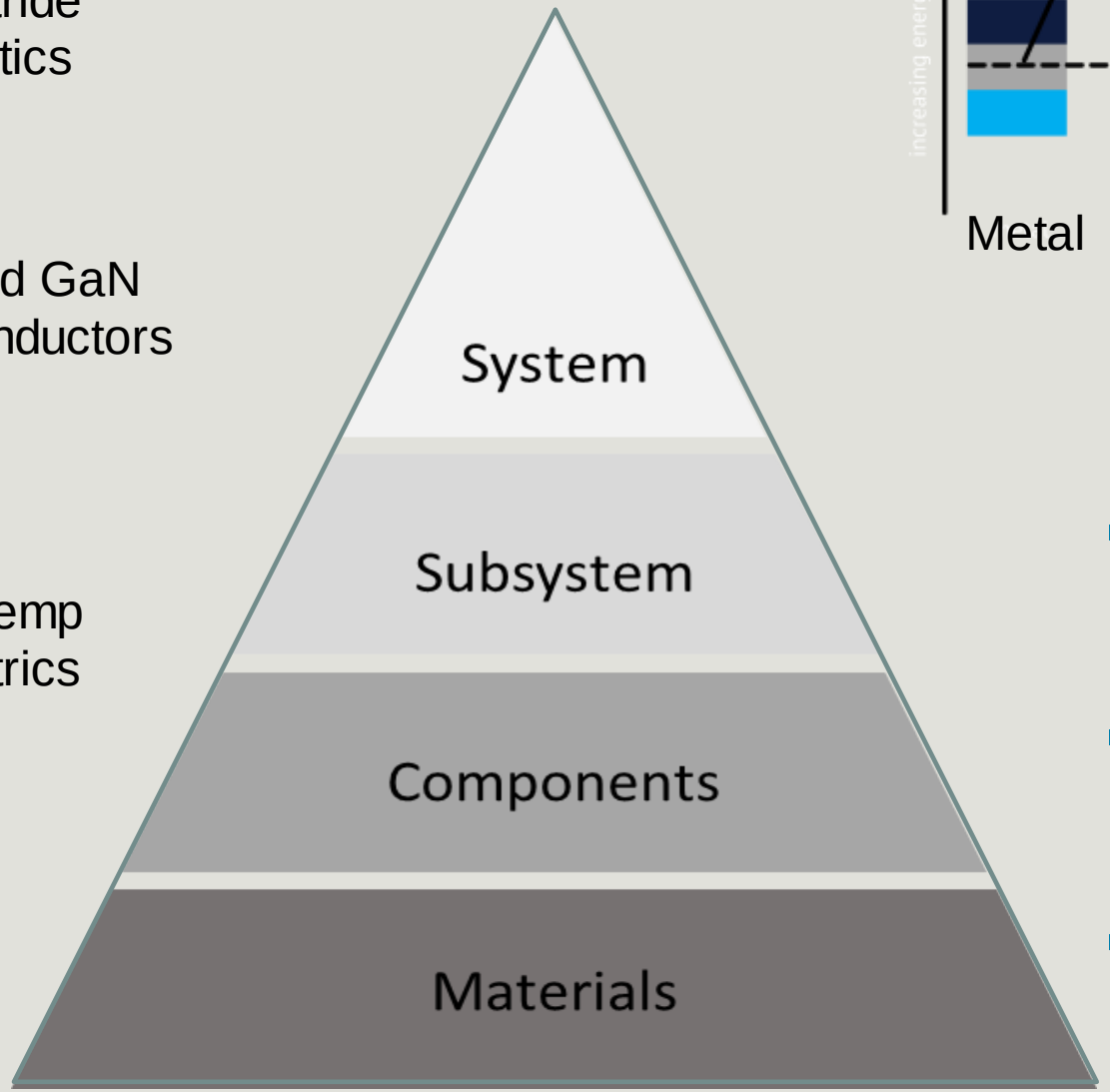
Iron Nitride Magnetics

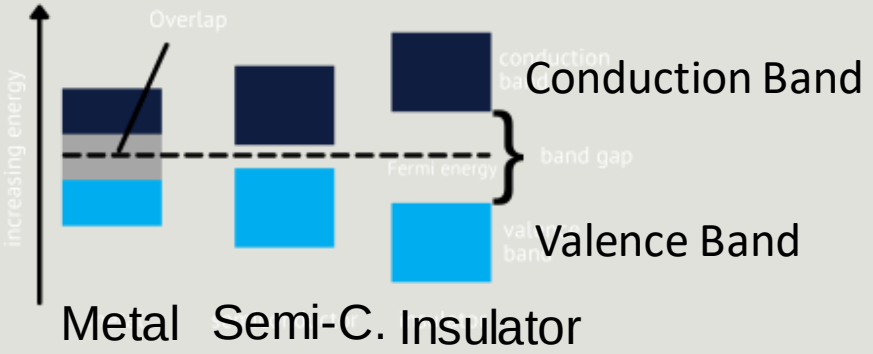


SiC and GaN Semiconductors



High Temp Dielectrics

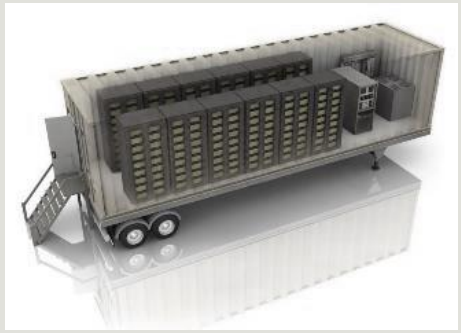




Materials

- Bottom layer in the PE R&D spectrum (non-application specific)
- Foundation for other technological improvements
- Advanced wide band-gap, magnetic materials, new capacitor dielectrics, etc.

MATERIALS TO MEGAWATTS:



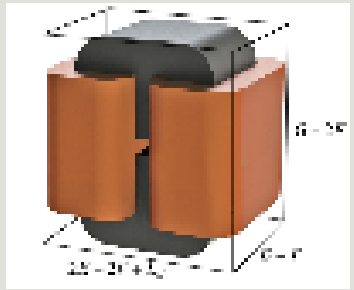
Grid-tied ES PCS

Remote ES PCS

Systems

- Subsystems form the system or Power Conversion System (PCS)
- Self-contained, fully functional unit to performs end-use applications
- Includes DC/AC disconnects, system controls, final packaging, etc.

Switches

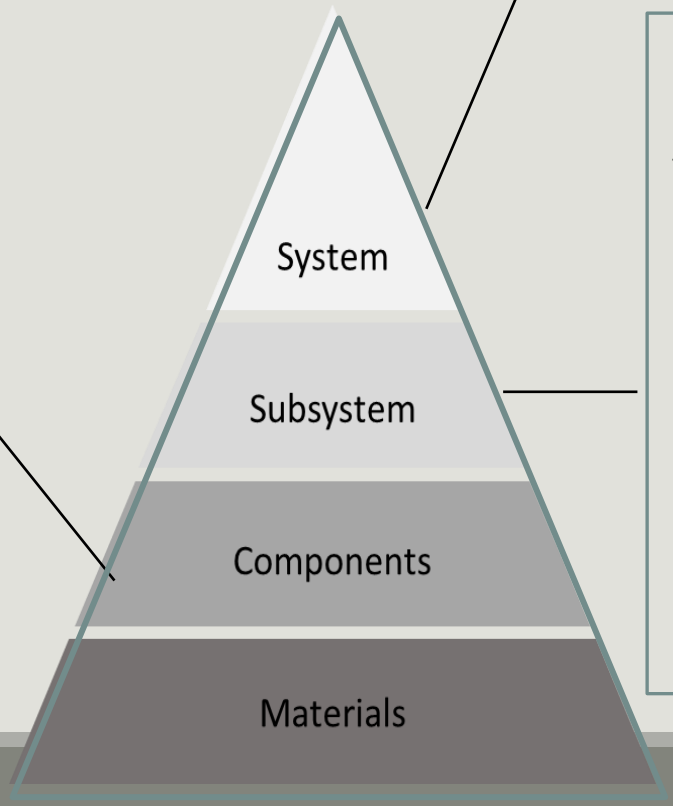


Inductors and transformers

Components

- Materials combined form components
- Basic building blocks of circuits
- Includes switches, capacitors, inductors, etc.

Capacitors



Power Converter Modules

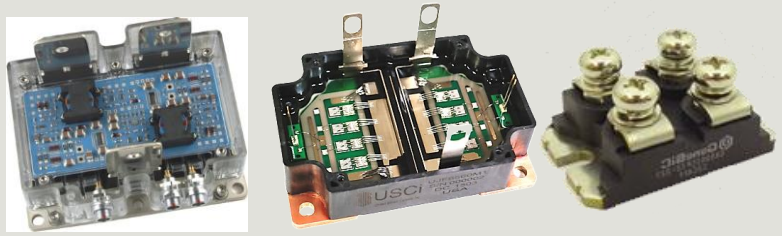
Subsystems

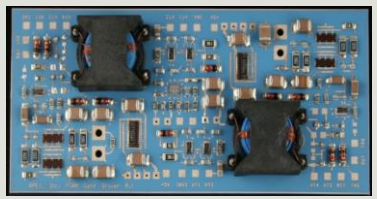
- Multiple components form subsystems
- Perform a specific task within the PES
- Includes subsystem controls, sensors, thermal management, protection, power stage, etc.

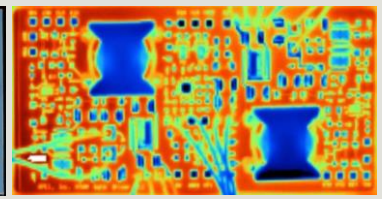
WBG-BASED SYSTEMS:

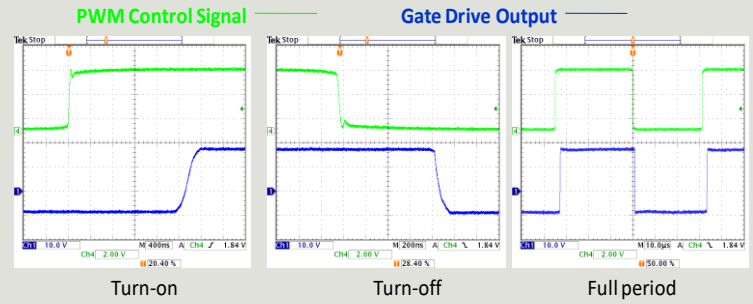
WBG devices

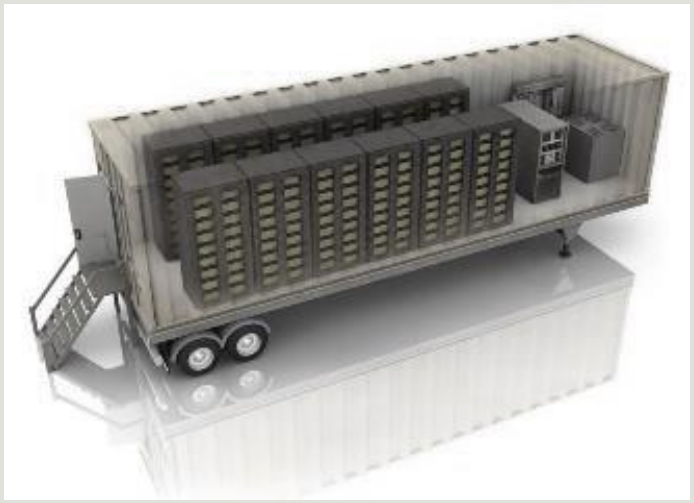
- Higher switching frequencies
- Higher breakdown voltage
- Higher junction temperatures



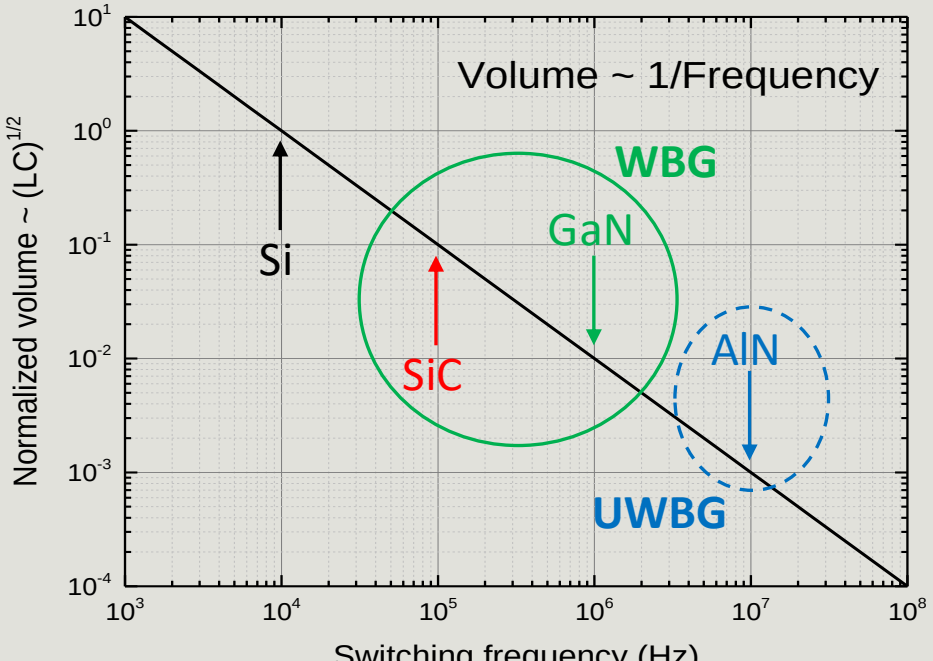








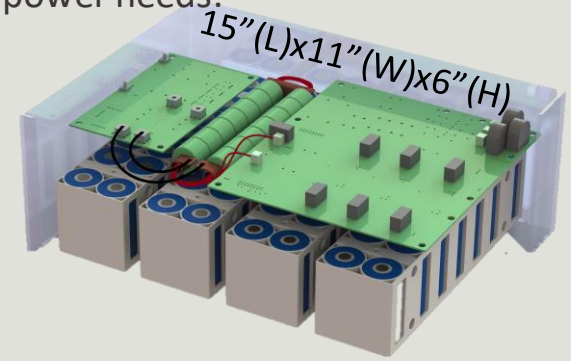
Transportable Energy Storage System



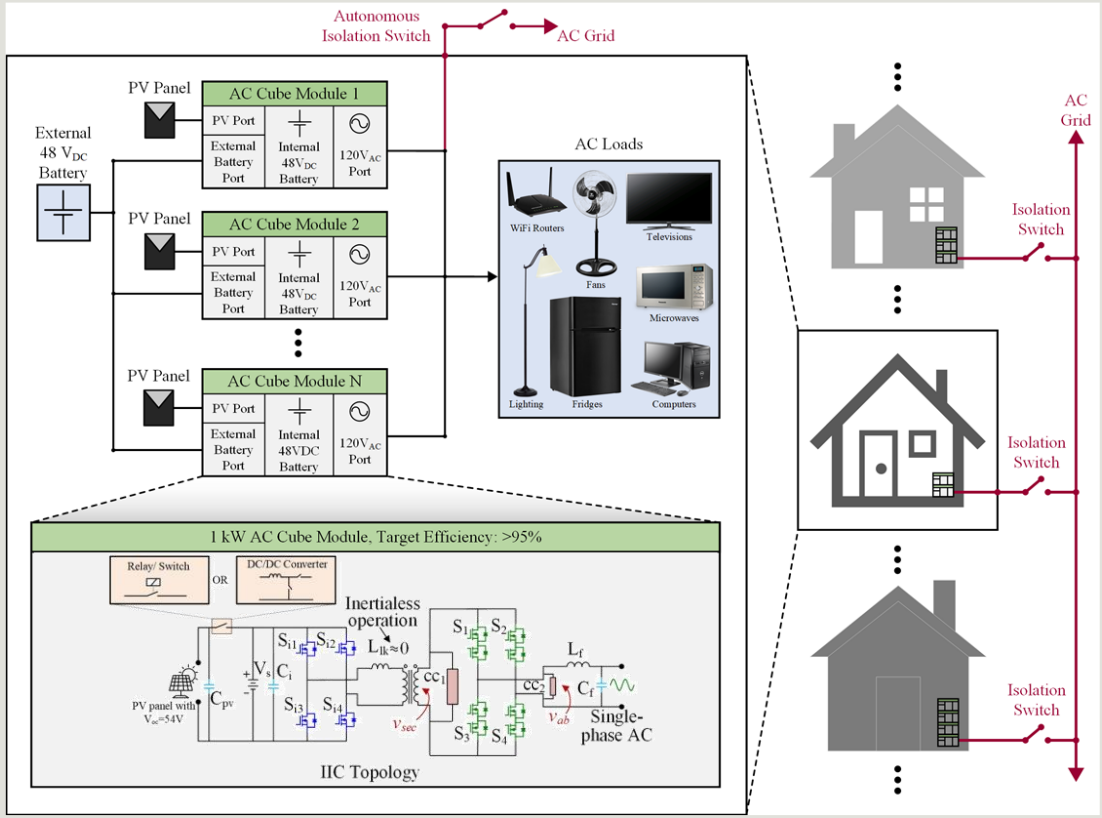
WBG-based systems along with advanced magnetics, capacitors and packaging can ultimately reduce energy storage power conversion system size and weight up to *an order of magnitude* over present state of the art silicon-based systems and significantly reduce energy losses.

RESILIENT STORAGE INTEGRATED ELECTRICITY FOR THE NAVAJO NATION

- **Project Description:**
  - Develop a safe, flexible, reliable, and resilient plug-n-play building block (AC-Cube), that can be used individually or scaled as needed, to address a range of applications and fulfill the electric power needs.
- **Project Team:**
  - Georgia Tech, Center for Distributed Energy
  - Navajo Tribal Utility Authority
  - Sandia National Laboratories



- **Project Impact**
  - For disadvantaged communities that are deprived of electric power and affected by high-impact low-frequency events (such as hurricanes or wildfires) — there are few sustainable power solutions available that are compact, flexible, capable of rapid deployment, and installed/operated/maintained without skilled technicians.
  - This impacts thousands of people in the US, many living Native American nations and communities, or impacted by unforeseen catastrophic events that compromise the bulk power system.
- **Accomplishments**
  - Successfully designed, developed, and validated the first AC-Cube prototype.



- >1 kW “AC Cube” >250 W PV panel and 1 kWh, 48 VDC battery
- Stack AC Cubes for higher power, add extra batteries & PV panels for longer run times
- Connect to grid at main AC panel to supply sub-circuits or to return power (needs electrician)
- Plug-n-play connect of multiple stacks of AC Cubes to form an adhoc microgrid
- Target <$1000 for 1.25 kW/1 kWHr AC Cube w/ internal battery, 250 W PV panel, grid connect

Ultimately the Work Force is the Client!