NASA-Supported Research on Electric Materials

Randy Bowman

NASA Glenn Research Center
LMA / High Temperature and Smart Alloys Branch

August 9th, 2017

NASA Supported Research on Electrical Materials

- **<u>In-House</u>**: The following topics areas have been identified to be active areas on work at the various field centers.
- **<u>External</u>**: Summary of SBIR, STTR, and NRA (Aerospace architecture, mission, or system concepts) awards in the last three years that are related to electrical materials.

Wide Bandgap Semiconductors and Solid State Materials

NASA In-House

- GRC Smart Sensors and Evaluation Branch (https://sic.grc.nasa.gov/). Focused on improved crystal growth and sensor/electronic device processing technologies. This includes world-record operation of high temperature electronics.

Externally Funded

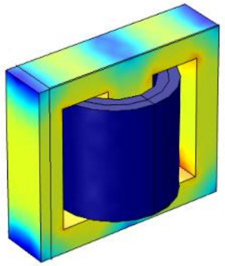
- “Radiation and High-Temperature Tolerant GaN Power Electronics” (solar electric propulsion systems).
- “High Power Ga2O3-based Schottky Diode” (develop a new generation of radiation hard high-power high-voltage Ga2O3-based Schottky diode).
- “Ultra-Radiation-Hardened Power Conversion”
- “A Novel Approach to Improving the Radiation Hardness of SiC Power Devices” (improve hardening by depositing the gate oxide with Atomic Layer Deposition (ALD) techniques).
- “Characterization and Mitigation of Radiation and High Temperature Effects in SiC Power Electronics” (modeling of physical mechanisms behind measured radiation response).
- “Improving the Response of Silicon Carbide Devices to Cosmic Radiation” (rad-hard designs).
- “Monolithically Integrated Rad-Hard SiC Gate Driver for 1200 V DMOSFETs” (developing analog and digital circuits that can be fully integrated with 4H-SiC power switching devices).
- “Development of Diamond Vacuum Differential Amplifier for Harsh Environment Power Electronics” (using low electron affinity nanodiamond (ND) material as electron emitters).
- “A Silicon Carbide Foundry for NASA's UV and High Temperature CMOS Electronics Needs” (developed a patent-pending technology to design and fabricate Silicon Carbide (SiC) MOSFET opto-electronic integrated circuits (ICs)).

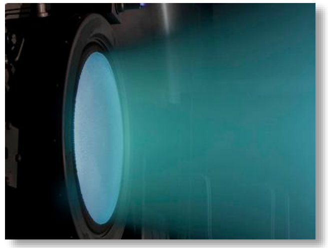
Wide Bandgap Semiconductors and Solid State Materials – con't

Externally Funded

- "Radiation Tolerant 35% Efficient Phosphide-Based 4-Junction Solar Cell with Epitaxial Lift-Off" (enhance the performance and capabilities of solar photovoltaic arrays).
- "A Ferroelectric Semiconductor Absorber for Surpassing the Shockley-Queisser Limit" (develop new solar cells based on a ferroelectric semiconductor absorber material)
- "3D Nano-Epitaxial Lateral Overgrowth…. Solar Cells for Space Applications" (advanced surface nano-engineering technologies to control the formation, propagation and annihilation mechanism of extended defects)

Magnetic Materials





NASA In-House

- Apparently only NASA GRC is active in this area.
- Funded by the NASA Hybrid Electric Aircraft project
- Applications involve motor controller filter circuit inductors, motor stators, magnetic gears.
- Developing soft magnetic nanocomposite ribbons.
- Capable of producing large quantities and size of these unique materials.
- Capable of producing relevant-size components.
- Wide range of characterization capabilities.
- Developing modeling capabilities to aid in component design.

- Also performing processing studies on Hiperco for Hall-Thruster program.

External Programs

- Advanced magnetic core and high frequency transformer fabrication for combined photovoltaic / energy storage grid integration and enabling technology. In partnership with DOE's NETL facility in Pittsburgh.

Externally Funded

- None

Dielectric Materials

NASA In-House

- None identified.

Externally Funded

- “Ultra-High Energy Density, High Power and High Efficiency Nanocomposite Capacitor for Aerospace Power System” (advanced nanocomposite capacitor).
- “Lightweight High Energy Density Capacitors for NASA AMPS and PPUs” (development of lightweight, high energy density DC-link capacitors)
- “High Efficiency Hybrid Energy Storage Utilizing High Power Density Ultracapacitors For Long Duration Balloon Flights” (based on lithium chemistries).
- “Nanostructured Dielectrics for High-Temperature Capacitors” (novel ceramic dielectrics with the unique nanostructured architecture comprised of closely packed parallel one-dimensional chains of dipoles).

Rare Earth Materials

NASA In-House

- None identified.

Externally Funded

- None identified.

Superconducting and Advanced Conducting Materials

NASA In-House

- High conductivity copper via CNT additions. In-house research in collaboration with external wire producers.
- Includes sorting techniques ("metallic CNTs), wire coating, wire processing development for incorporating CNTs, evaluations of ampacity, chemistry, conductivity, etc.).
- Also evaluating Covetic Cu-C composites which are metal-carbon nanomaterials fabricated using an induction furnace. An electric current is applied into an activated carbon-infused molten metal medium.

Externally Funded

- "Lightweight Electrical Power Cable Production" (develop graphene wire).
- "Low AC-Loss Superconducting Cable Technology for Electric Aircraft Propulsion" (MgB2 multifilament superconducting cables)
- "Lightweight CNT Shielded Cables for Space Applications" (CNT cables to minimize electromagnetic interactions).
- "Low Loss Superconducting Magnets Operating at 15 - 40 K" (development and testing of high current density low loss Nb3Sn wires and MgB2 magnets.).

Electronic Insulator Materials

NASA In-House

- High-voltage protection for power distribution cables.

Externally Funded

- “Thermal Insulator for a Venus Lander” (developing a flexible material for 460°C surface temperature to protect electronics)

Thermal Management Materials

NASA In-House

- “Advanced Thermal Management Materials and Technologies” (Ceramics Branch). https://www.grc.nasa.gov/WWW/StructuresMaterials/Ceramics/highlights/thermal.html
- High conductivity carbon based composites reinforced with carbon nanotubes, nanofibers, or high conductivity carbon fibers. Also, high conductivity graphite and silicon carbide foams incorporated with phase change materials are being investigated.

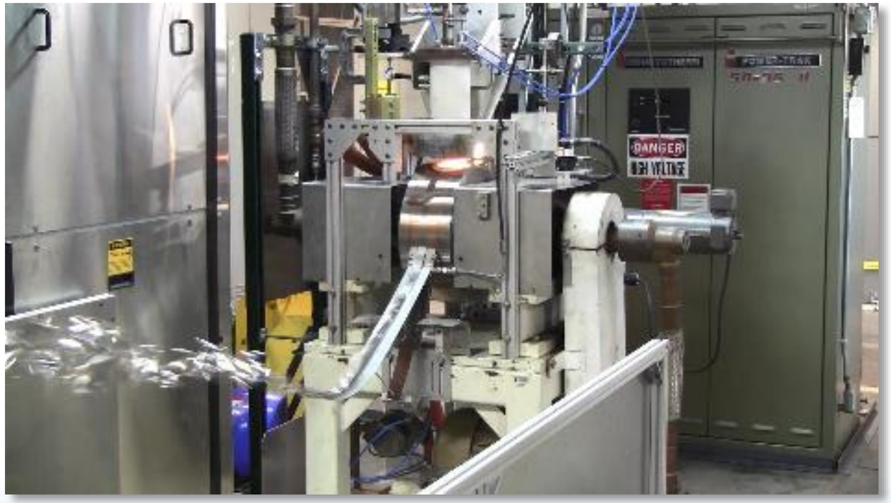
Externally Funded

- “3D Manufacturing of Integrated Heat Exchangers” (3D manufacturing of high thermal conductivity materials).

Materials Performance at Component Scale

<u>NASA In-House</u>

- Scaling up of the nanocomposite soft magnetic materials is a major focus of our magnetics work.
- Large caster gives us the capability to produce large size and quantities.
- Currently working on large scale fabrication details.
- Have delivered inductor components for use in hybrid electric filter circuit.



Materials Performance at Component Scale – con't

<u>NASA NRA's</u> (Aerospace architecture, mission, or system concepts)

- Silicon-carbide Lightweight Inverter for Megawatt-power (SLIM)
- Modular and Scalable High Efficiency Power Inverters for Extreme Power Density Applications
- Ultra-Light Highly Efficient MW-Class Cryogenically-Cooled Inverter for Future All Electric Aircraft Applications

Electrodes

NASA In-House

- Li-ion battery anode and cathode material development.
- Photovoltaic and Electrochemical Systems Branch. Maintains primary technical expertise in all areas of advanced photovoltaic (PV) devices, solar array
- technology, electrochemical energy sources, and energy storage systems in support of NASA
- missions.

Externally Funded

- “A Novel Electrode Material for Thermionic Power Generation” (nanomaterial C12A7 electride as an electrode material for temperatures in excess of 1600°C).
- “High Energy Density Li-Ion Batteries Enabled By a New Class of Cathode Materials” (non-oxide cathode materials).
- “Advanced Lithium Sulfur Battery” (novel super ion conducting ceramic electrolyte, entrapped sulfur cathode, and a lithium metal anode).

Other

NASA In-House

- “3D printed electronics” (MSFC). Develop in-space manufacturing capabilities to produce functional electronic and photonic component on demand.
- Aerosol jet printing of various circuit building blocks: crossovers, resistors, capacitors, chip attachments, EMI shielding.