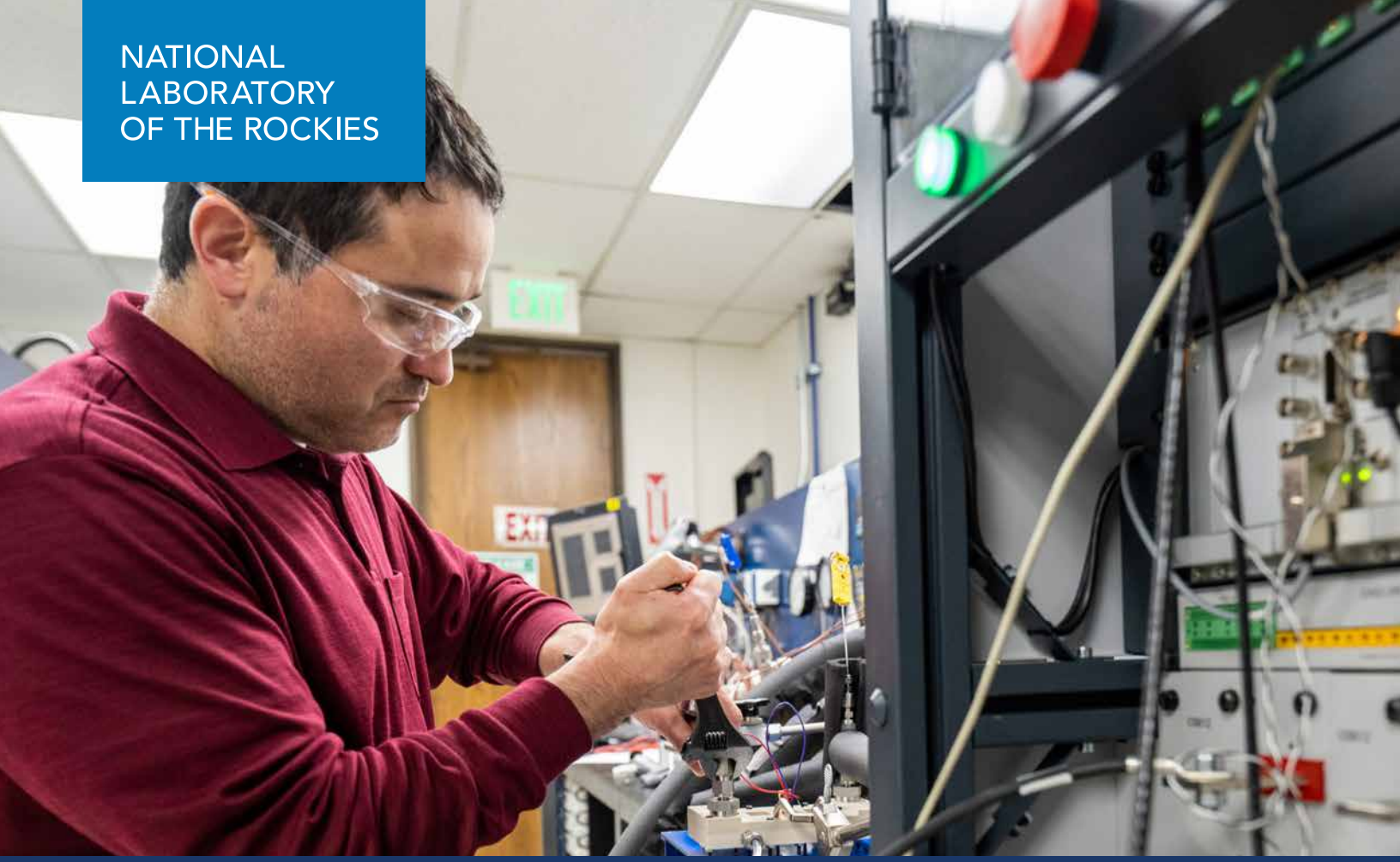
NATIONAL LABORATORY OF THE ROCKIES



Advanced Power Electronics and Electric Machines

The National Laboratory of the Rockies' (NLR's) advanced power electronics and electric machines (APEEM) research group develops world-class experimental and modeling capabilities to design and evaluate efficient and reliable power electronics and electric machines, as well as innovative thermal management systems to maximize their performance. They also design, fabricate, and characterize advanced power electronics packaging and are developing state-of-health monitoring techniques.

Our researchers deliver safe, reliable, high performing, power-dense components that allow seamless integration between energy sources, transportation modes, and the power grid. Their work increases the reliability, affordability, and efficiency of our transportation and energy systems.

Sreekant Narumanchi | Group Manager

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Research Capabilities

Power Electronics

Wide-scale modernization—of our transportation systems, electrical utilities, data centers, and other critical sectors—will rely on better power electronics, electric machines, and electric-drive systems, all of which help control and convert electricity into usable forms. NLR's research works to improve electronics, power electronics and electric machine component and system performance, reliability, and efficiency. These advancements can help minimize weight and volume of components and can enable greater performance at a lower cost.

Our scientists and engineers work closely with manufacturers, suppliers, universities, and other research organizations to develop solutions that overcome the most challenging technical barriers to higher-efficiency technologies, including medium- and heavy-duty vehicles, data centers, electrical grid components, and other applications. They are devoted to designing, building, and characterizing power converters, control systems, traction drives, advanced gate drivers, state of health estimation of converters, electric machines, and batteries, all in addition to performing degradation analysis for individual components and modules.

Most importantly, NLR's world-class research and characterization facilities form an end-to-end pipeline. Our researchers can design, build, characterize, and validate prototypes spanning from proof-of-concept to high-performance systems all in one laboratory setting.

Module development and characterization

NLR researchers push the boundaries of power electronics by improving the performance, reliability, durability, and power density of power electronics modules and packaging.

The laboratory has established a one-stop solution for fabricating and characterizing ultra-wide-bandgap (UWBG) power semiconductor devices, building modules to accommodate those devices, and creating systems to characterize these high-performance power modules and meet energy goals of the future. The wide-bandgap (WBG) and UWBG semiconductor devices evaluated at NLR offer improved performance, reliability, and cost.

Module development research at NLR also aims to design, fabricate, and characterize a universal architecture for medium-voltage power modules that could be used with both silicon carbide (SiC) and gallium nitride (GaN) devices for current and future high-voltage applications. This research includes wide-band-communication-enabled smart modules which exploit wireless power transfer to eliminate gate driver ancillary power supply issues at extremely high voltage levels, isolating the power module to provide onboard state-of-health information.

Finally, because high-temperature bonded interface materials are essential to enable compact, lightweight, low-cost, reliable power electronics packaging that fully utilizes the capabilities of both WBG and UWBG devices, NLR researchers apply the laboratory's world-class thermal-fluids modeling and management capabilities to each package.

Thermal-fluids modeling and management

Advanced thermal management systems are critical to the performance and safety of all electrified traction drive components, including semiconductor power devices, power modules, inverters, and electric motors, as well as electronics packaging for multiple other applications. NLR researchers are experts in system-level thermal management designs that incorporate advanced heat transfer to regulate temperatures throughout the complete power electronics and electric machine system.

NLR researchers rely on cutting-edge modeling capabilities to develop predictive and remaining lifetime models to evaluate and improve the reliability of new high-temperature technologies. NLR's electric machine

thermal management research generates experimental data and simulation processes for the modeling, analysis, design, and construction of new electric machines for vehicles and other applications.

NLR research helps to better understand and evaluate the material and interface properties of electric machines as a function of temperature. Researchers also develop and evaluate advanced fluid-based electric machine cooling strategies for improved performance and reliability of electric vehicles.

Thermomechanical reliability analysis of devices, modules, inverter/converter, and electric machines

Modeling stress, strain, and strain energy density within the packaging stack-up helps researchers to understand the impact of these factors on package and module reliability. NLR helps to design, develop, fabricate, and validate wide-bandgap power electronics systems for electric-drive vehicles and other applications.

NLR's role encompasses the thermal design optimization and thermo-mechanical modeling and analysis of critical components. The thermo-mechanical analysis includes:

- Cooling design and thermal performance impacts of alternative manufacturing processes
- Die, package, and interface material analysis for power module reliability
- Manufacturing process impacts versus thermal cycling impacts on power module reliability
- Power module stress and deflection for safety and coolant system sealing
- Inverter enclosure stress and deflection based on operating and safety requirements.

Physics-of-failure-based reliability analysis

NLR researchers rely on leading-edge modeling and characterization to perform reliability evaluation and failure analysis of new power electronics designs. Advanced modeling capabilities allow researchers to identify thermal bottlenecks and optimize the performance of power electronics packaging. In addition, researchers leverage extensive characterization through thermal, humidity, and vibration testing to better understand how stressors affect emerging technologies. As a result, NLR-designed systems prioritize safety, reliability, and efficiency for peak operating performance.

Microelectronics

MEMS-based systems

NLR can provide microelectromechanical systems (MEMS)-based designs such as resonator-based circuits. MEMS devices such as piezoelectric resonators are widely used in low-power circuits for frequency generation. However, MEMS devices could be used in power conversion and voltage regulator circuits.

Microcontroller-based systems

The team can design and fabricate microcontroller (MC)-based systems that can utilize sensors to implement a feedback control system. These types of systems have applications in both low- and high-power electronics. An MC-based system involving sensors and communication stack acts as the key component to realize internet of things (IOT). This combination can be used to design smart power converters for both transportation and utility applications.

Laboratory Experimental Capabilities

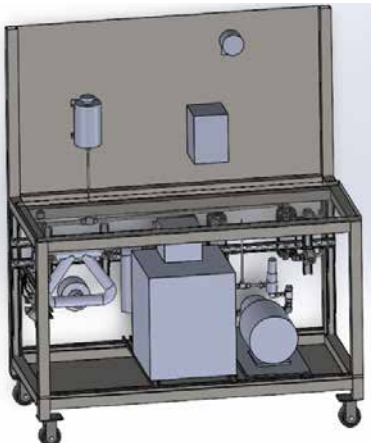
Fluid-based Thermal Management

Single-Phase Liquid Cooling Test Bench

A water-ethylene glycol (50/50% mixture by volume) flow loop is used to develop and evaluate heat exchangers, liquid jets, and spray technologies for cooling electrical system components such as electric motors and inverters. The loop can deliver flow rates up to 36 liters per minute at temperatures up to 100°C. Experimental studies include heat-transfer performance of multiple flow configurations such as jet impingement cooling, and surface enhancement techniques. The flow loop can be used with the ABC-1000 power supply or the transient thermal tester.

High-Temperature Single-Phase Liquid Cooling Test Bench (under development)

A high-temperature (105°C-120°C) water-ethylene glycol (WEG) pressurized flow loop is under development. The flow loop is instrumented to accurately measure flow rates, temperatures, and pressures and can provide flow rates of up to 35 liters per minute and fluid temperatures of up to 120°C. This system is targeted at providing cooling to power electronic components operating in extreme conditions and high-demand applications (i.e. military and heavy-duty vehicles).

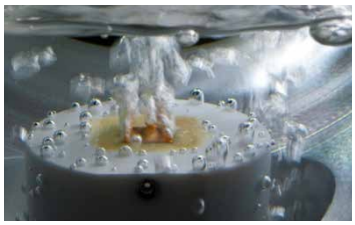


Dielectric Fluid Thermal Performance and Reliability Evaluation Loop

A small dielectric fluid coolant loop is used to conduct experiments using dielectric fluid coolants (e.g., oils). The flow loop can be used to circulate dielectric coolants through cold plates for thermal resistance and pressure drop measurements. The dielectric fluid loop can also be used with the Siemens Power Tester to power and measure the thermal resistance for power modules. The flow loop is compatible with a wide range of fluids due to its stainless steel construction, can achieve flow rates of up to approximately 3 liters per minute, and can maintain fluid temperature up to 70°C. A separate reliability fluid loop is also available and used to evaluate the long-term reliability of dielectric fluid coolants. The reliability loop is designed to maintain elevated fluid bulk temperatures and impose electric potential and uses vehicle components (i.e., tubing and pump).

Two-Phase Liquid Cooling Test Benches

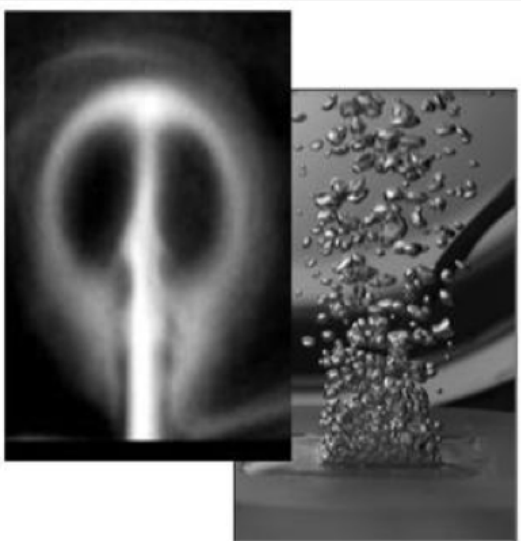
An immersion boiling vessel and a high-pressure vessel are used for two-phase cooling research. All are compatible with a wide range of refrigerants/dielectric coolants and are instrumented to precisely measure and control temperature and pressure. The loops are used for fundamental and system-level experiments to evaluate two-phase heat transfer for a variety of applications.



Thermal Measurement and Characterization

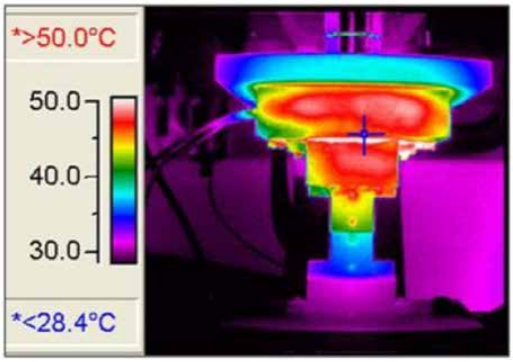
High-Speed Digital Video

A Photron Fastcam high-speed video camera is used for flow visualization. It provides full resolution (1,024 × 1,024) up to 2,000 frames per second (fps). Higher frame rates (up to 120,000 fps) are possible at lower resolutions. The equipment can be used in conjunction with a Schlieren Shadowgraph system and/or stroboscope for additional visualization capability. The camera is used for flow visualization of self-oscillating jets, flow within heat exchangers, synthetic jets, other flow configurations, and two-phase heat transfer experiments.



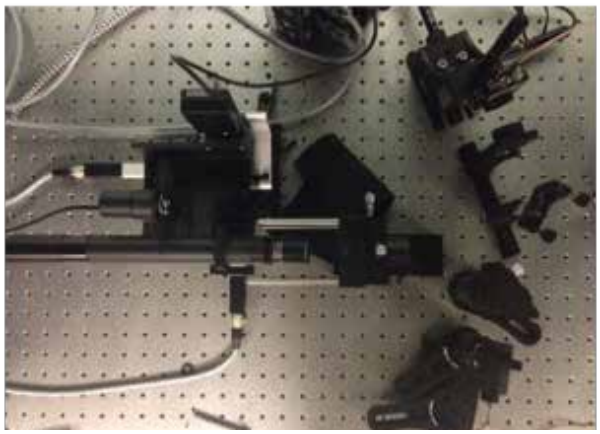
Infrared (IR) Imaging

The infrared camera is used to understand the temperature distribution in devices and equipment for a variety of applications. Examples include imaging of the thermal interface material (TIM) test apparatus, inverters, and energy storage devices. IR imaging of hot spots and temperature gradients in power electronic devices is an essential tool, owing to the importance of temperature uniformity to power electronics performance and reliability.



Frequency-Domain Transient Thermoreflectance Technique

The frequency-domain transient thermoreflectance technique employs two localized fast lasers to help determine critical thermal properties of materials and interfaces, such as thermal conductivity and thermal resistance. A modulated pump laser is irradiated on the sample surface to induce temperature rise and consequent thermal wave travels through the sample, while the modulated temperature change on the other surface is detected by a probe laser. By extracting inherent phase information, thermal properties are derived, and it is efficient for evaluating thermal performance of thermal interface materials and multilayer packaging structures.



Differential Scanning Calorimeter

The differential scanning calorimeter (DSC) measures the heat flow of a test sample relative to a reference standard. Several properties can be measured with the DSC, including heat capacity, glass transition point, phase transitions, polymer degradation, and oxidative stability.

Transient Thermal Tester

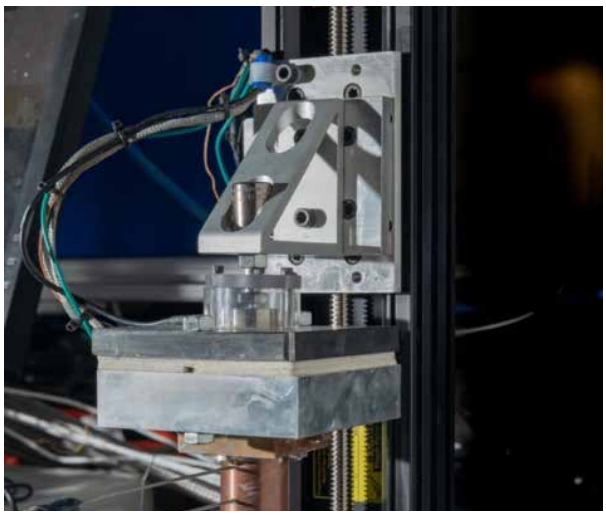
The Mentor Simcenter POWERTESTER 2400A 16C 12V has four heating channels each with a maximum output of 600 A, 12 V for a total maximum current of 2,400 A and 16 (4 × 4) measurement channels. A POWERTESTER allows in-situ measurement of the thermal resistance of a power electronics package (based on insulated gate bipolar transistor (IGBT), or metal oxide semiconductor field effect transistor (MOSFET)). Transient conduction analysis can be used to compute the resistance-capacitance network for the package and identify the resistance of select package materials and layers. The system can power cycle devices per the AQG 324 standard and evaluate for thermal degradation via thermal resistance measurements.

Large Calorimeter

This calorimeter can measure the heat generation and efficiency of electronic components within a test cavity measuring 60 × 40 × 40 cm at heating rates up to 1 kW under thermal isolation conditions, from -40 to 100 °C. There are dual power ports for power electronics testing. It can be powered by any of the laboratory battery cyclers with a capability of 0 to 440 VDC and current of 0 to 530 A.

ASTM D-5470 Thermal Interface Material (TIM) Tester

The ASTM D-5470 "TIM Stand" is an ASTM standard that is designed to measure the thermal resistance of thermal interface materials such as thermal greases, gels, phase-change materials, other polymeric materials, carbon nanotube interface material, bonded interface materials, and others. It is capable of measuring both solids and grease but has limitations in measuring powders and liquids. The TIM stand in the APEEM group is custom-built equipment so it is clear how the measurements are being performed and the key output parameters calculated. There are a variety of fixtures to accommodate different sample geometries but the most common are 1.25-inch-diameter round samples and 1x1 inch square samples.



Thermomechanical Reliability Analysis

Vertical Thermal Shock Chamber

The vertical thermal shock chamber is used to study thermally induced stresses in novel bonded interfaces and advanced electrical interconnects. The equipment includes an upper hot chamber and a lower cold chamber, and a conveyor system moves samples between the two chambers, inducing thermal stresses under controlled conditions. The chamber contains a workspace volume of 38 × 27 × 28 cm and can operate from -75°C to 210°C.

Thermal Cycle Testing Array

The thermal cycle testing array is used to study thermally induced stresses in novel bonded interfaces and advanced electrical interconnects at slower ramp rates (3 to 5 °C/min) than the vertical thermal shock chamber. Multiple chambers allow for simultaneous testing of samples at various ramp rates, dwell times, or mean cyclic temperatures. The chambers contain workspace volumes of 50 × 28 × 30 cm and can operate from -70°C to 180°C.

Highly Accelerated Stress Test (HAST) Chamber

The Highly Accelerated Stress Test (HAST) Chamber is used to evaluate humidity resistance for electronic components. A pressure vessel allows for a humidity range of 75% to 100% relative humidity up to 143°C. Signal terminals allow for measurement of samples while they are enclosed within the pressure vessel. The chamber contains a workspace volume of 38 × 26.7 × 28 cm.

Electrodynamic Shaker with Environmental Control

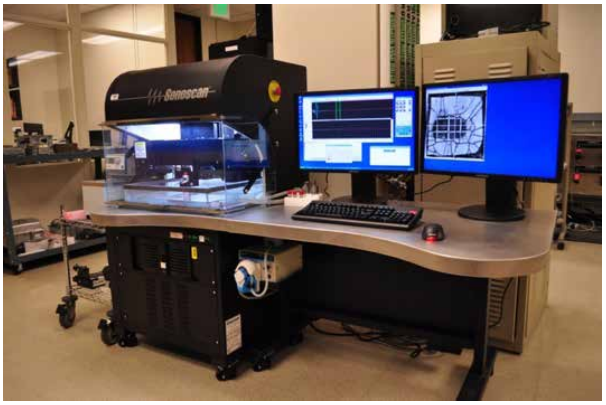
The combination of thermally induced stresses with humidity and vibration stresses can highlight weaknesses within a package design that cannot be identified with thermal tests alone. The Accelerated Drive Cycle Platform is a single-axis electrodynamic shaker with an AGREE-style environmental chamber. The environmental chamber can operate from -40°C to 180°C and 95% relative humidity up to 85°C. It can be placed directly over the electrodynamic shaker or its slip table for simultaneous temperature, humidity, and vibration control. The shaker has a rated sine force of 6,800 lbf at 92 g, random force of 6,800 lbf at 65 grms, or shock force of 13,500 lbf at 153 g and a displacement up to 3.0 inches.

High-Temperature Oven

For high-temperature thermal aging of components, a ceramic oven has the capability of heating samples up to 800°C through radiative heat. Internal dimensions of the oven are 35 × 23 × 25 cm (L × W × H). A feed-thru port is also located on the top of the oven for external monitoring equipment to directly connect to samples during tests.

C-Mode Scanning Acoustic Microscope

The C-Mode Scanning Acoustic Microscope (C-SAM) is an instrument that uses ultrasound in the frequency range of 5 to 230 MHz to nondestructively inspect samples for defects. The technique relies on the acoustic impedance mismatch of materials and can generate images within a sample based on scattering, refraction, and/or absorption of the acoustic signal within various material layers. Ultrasound cannot travel through air or a vacuum; therefore, it can find voids, cracks, and/or delamination of layers within a sample.

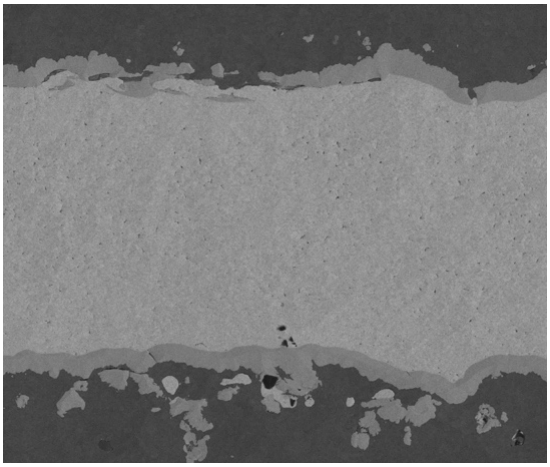


Computerized Tomography (CT) Scanner

CT scanner technology allows for non-destructive, high-precision, and high-speed inspection for applications in energy storage, power electronics, photovoltaics, hydrogen, and basic sciences. This state-of-the-art X-ray imaging system housed in the Materials Characterization Lab in the ESIF is capable of advanced 2D X-ray inspection, 2D CT slice reconstruction, CT volume reconstruction for 3D inspection, 3D internal and external surface scanning, measurement, and analysis tools, 360-degree rotation, and tomography scanning.

Scanning Electron Microscopy

In basic scanning electron microscopy (SEM), a beam of highly energetic (0.1-50 keV) electrons is focused on a sample surface. This can produce several interactions including the emission of secondary electrons, backscattered electrons, photons, and X-rays; excitation of phonons; and diffraction under specific conditions. Topography of the surface under observation can be recorded with resolution on the order of 1–2 nm and magnification range from 10x to 500,000x. An energy-dispersive X-ray spectroscopy (EDS) detector can capture high-resolution compositional maps.

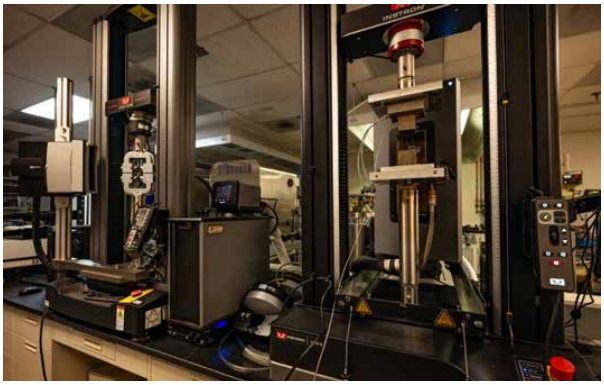


Digital Microscope and Elemental Analyzer

The digital microscope allows imaging of a sample's surface features at high levels of magnification. Lenses can enlarge an object 20x to 2,500x of its original size. A motorized X-Y axis stage allows for sample features larger than the microscope's field of view to be digitally stitched together. In addition to the optical microscope, this setup includes a Keyence EA-300 which utilizes laser-induced breakdown spectroscopy (LIBS) to perform material elemental analysis.

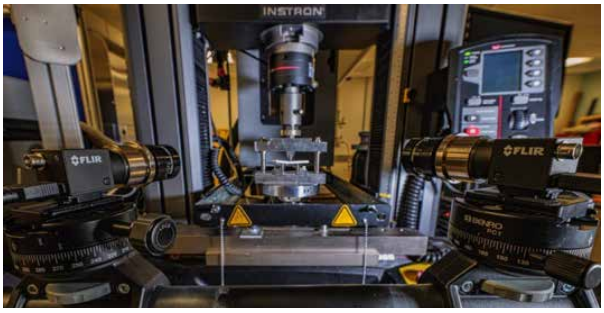
Dual Column Tabletop Universal Testing System

An Instron 5966 dual column testing system is configured with 100 N and 10 kN load cells. With appropriate fixtures, tensile, compression, shear, flexure, peel, tear, cyclic, and bend tests can be performed. An environmental chamber has a temperature range from -100°C to 350°C for capturing temperature-dependent material properties. A noncontact video extensometer is used for strain measurements. A shear test fixture is used for obtaining material properties of solders and other bonded interface materials.



Digital Image Correlation (DIC) System

Digital image correlation is an optical-numerical measuring technique, which offers the possibility of determining complex shape, displacement and deformation fields at the surface of objects under any kind of loading. A camera system monitors a speckled pattern on the surface of a part. Changes in displacement are measured and strains can be calculated through software.

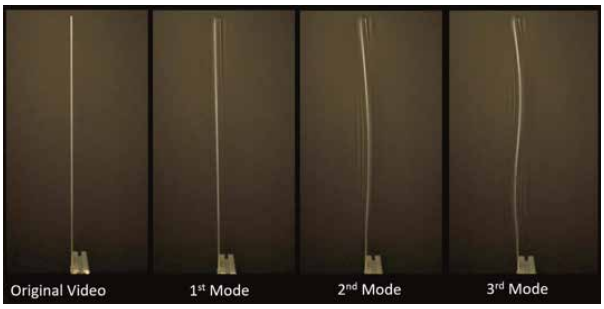


Pressure Mapping System

Applying a uniform pressure over a large area is a very difficult task, and qualifying the pressure distribution has been difficult due to traditional static measurements. The Tekscan pressure mapping system provides real-time pressure feedback to quickly validate experiments.

Phase-Based Motion Magnification

Researchers can conduct rapid condition assessment and enable real-time insights into component performance through video magnification. The technology captures 100 times the full-field structural dynamics, such as natural frequencies, mode shapes, and damping ratios, using video of vibrating structures. This provides deeper performance insights earlier in the design and validation phase.



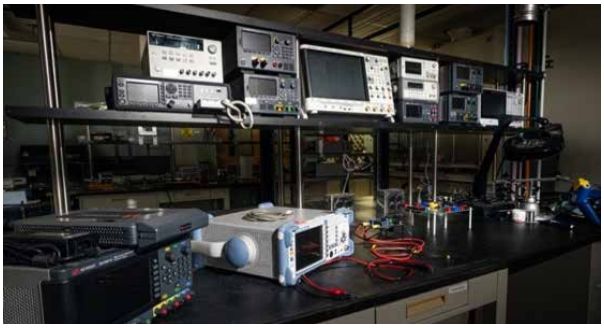
Micro- and Power Electronics Measurement and Characterization

Power Device Analyzer/Curve Tracer

The Keysight B1505A Power Device Analyzer/Curve Tracer can perform various types of IV, CV, pulsed IV, and transient characterization of high-power devices up to 10 kV of reverse voltage and up to 1,500 A of on-state current with a resolution of sub-pico amps. An accessory probe-station can characterize bare semiconductor dies and patterned wafers while a ThermoStream can control sample temperatures between -100°C to 300°C. Multi-frequency AC measurements for inter-electrode device-capacitances can be performed for a wide frequency range from 1 kHz to 5 MHz.

Electronics Analysis Equipment

The APEEM group employs a wide range of electronic analysis equipment such as: the Keyence InfiniiVision 4000 X-series oscilloscope, Vector network analyzer, spectrum analyzer, arbitrary function generator, LCR meter, power supplies, and electronic loads. With this equipment, APEEM can test components such as advanced gate drivers, device health monitoring components, and custom-built converters.

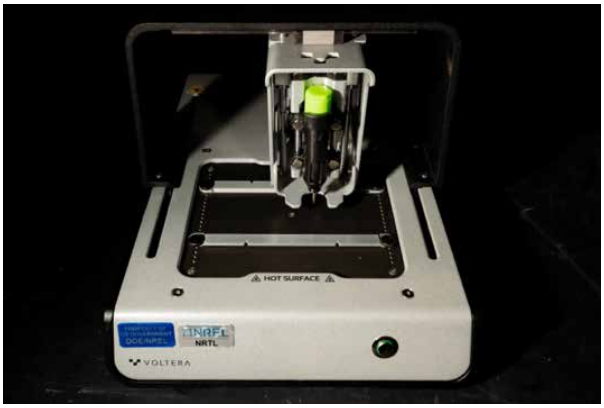


Bi-directional power supplies

Two 15000W bi-directional power supplies allow the APEEM group to perform high-powered functional analysis on inverters and converters without wasting energy or heating up the laboratory space from standard resistive loads. The bi-directional power supplies can provide a source and a sink for the energy required to characterize converters and it is able to put that energy back into the power grid to operate more efficiently. These, combined with the standard 1500W Keysight power supply offer substantial testing power.

Two-sided Printed Circuit Board (PCB) prototyping

The Voltera V1 allows the APEEM group to produce prototype two-sided printed circuits by utilizing a conductive ink dispensing system, hot plate, and through-hole drill all in one package. This system is also able to print circuits on flexible substrates such as Kapton tape to accommodate 3D architectures.



C-Mode Scanning Acoustic Microscope

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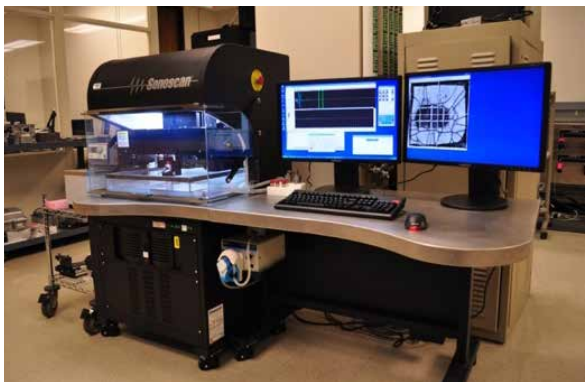
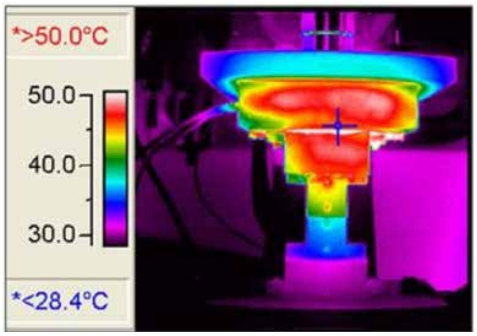


Infrared (IR) Imaging

The infrared camera is used to understand the temperature distribution in devices and equipment for a variety of applications. This is a very useful tool to identify hotspots in an integrated circuit. Therefore, this characterization ensures temperature uniformity to semiconductor devices and integrated circuits for performance and reliability.



Wire Bonder

The TPT HB30 Heavy Wire Bonder is capable of bonding round wires from 100 µm to 500 µm and ribbons sizes up to 300 × 2000 µm with a bond force between 50 -1800 cN. This wire bonder is a programable semi-automatic system which provides consistency and accuracy between samples. The Z and X axes are automated to allow for repeatable loop profiles that can consist up to 10 movement steps.

Vacuum Solder Reflow Station

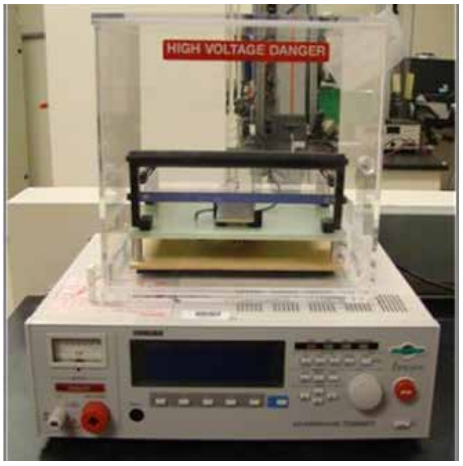
The vacuum solder reflow station allows for building high-density PCBs with surface-mount components as well as power electronic package development through the synthesis of flux-free and void-free solder joints. Heat is applied to a sample by a resistive graphite heating element and the process temperature is controlled by a ramping temperature controller with preprogrammed reflow recipes. An external vacuum pump and argon gas are used to control the chamber pressure. Samples up to 11.5 × 9 cm can be placed within the chamber and heated up to a maximum operating temperature of 450°C.

ABC1000 Dual Channel Power Supply

The ABC1000 is a bi-directional, programmable computer-controlled two-channel DC power supply. It provides power up to 125 kW, with a voltage range of 8 to 420 VDC and a current range of ±1000 A. Bi-directional power receptacles are distributed throughout the lab to connect the ABC1000 to test benches including the cooling test loops and environmental chambers. This is an ideal test system for a wide range of high-power DC loads. In addition to evaluating power electronics, it can be used for energy storage testing, including fast charging and fuel cell systems testing.

High-Potential Tester

The high-potential (hipot) tester measures the electrical insulating properties or dielectric strength of sample substrates such as aluminum nitride direct-bond-copper (DBC) substrates. When subjected to temperature cycling and/or thermal shock, the substrates can fail via cracking, fracture, or delamination. These failure sites provide pathways of lower resistance for electric current. An increase in electrical conductivity in the hipot tester signals a failure of the substrate.



Transient Thermal Tester

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High-Power Semiconductor Device Measurement

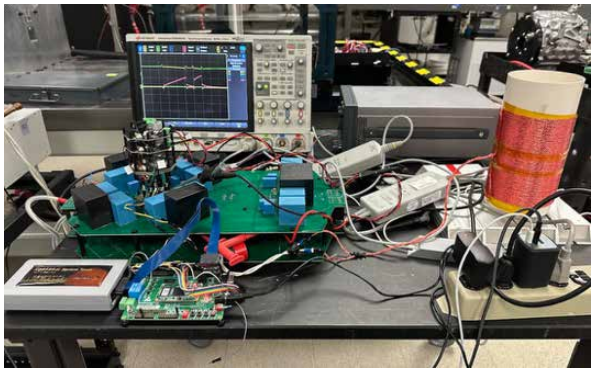
The SIGNATONE PowerPro probe station is a high-power semiconductor device measurement system capable of characterizing bare semiconductor devices at voltages up to 10kV and currents up to 4kA. The probe station utilizes the Keysight B1505A Power Device Analyzer/curve tracer to characterize bare and partially packaged semiconductors.

AC High-Voltage Test Equipment

The Phenix 6CP50/10-3 is a high-voltage AC hipot/dielectric tester. It is capable of voltages up to 50KV AC. This equipment is used to ensure the dielectric strength of the test article can withstand the high voltages associated with power electronics.

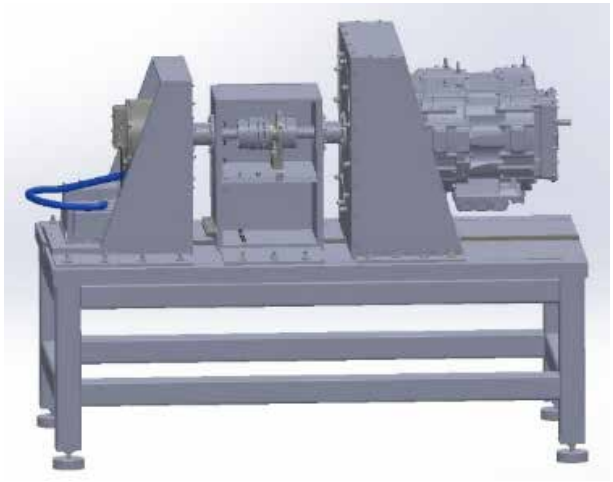
Power Module/Power Device Double-Pulse Test Equipment

The in-house double-pulse test bench is a system for evaluating the transient switching performance of power semiconductor switches. The capacity of this bench is up to 2kV DC and 500A DC. The test bench has a modular design. A common DC bus board is shared with all samples while multiple customized doughter boards accommodating various sample footprints are bridged to the bus board using low-inductance lamination.



Dynamometer (under development)

APEEM is building a dynamometer with up to 250 kW power rating. The setup with a high- voltage enclosure will be used to test and characterize power electronics for driving low speed (up to 6,000 rpm), high-torque electric motors suitable for medium- and heavy-duty vehicle applications.



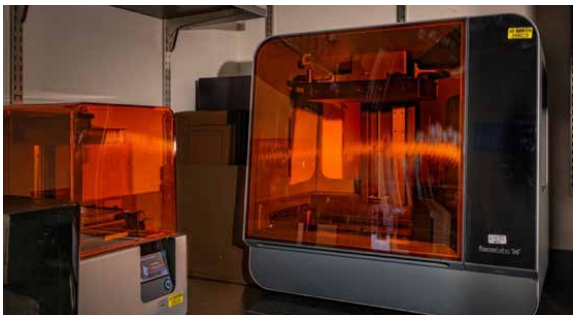
Prototype Fabrication

Computer Numerical Control (CNC) Router

The Carbide 3D Nomad 3 is a desktop CNC machine with a working area of 20 cm (X and Y) and working depth of 7.6 cm (Z). This machine has a 130 W spindle motor with a maximum speed of 24,000 rpm and can be used for PCB etching, rapid prototyping, and substrate etching. The Nomad can machine both 2D and 3D parts and can handle parts up to 29.5 kg.

Stereolithography (SLA) Printer

The Formlabs Form 3L is a stereolithography (SLA) 3D printer with a build volume of 33.5 × 20 × 30 cm (W × D × H). SLA printing has the advantage of high precision, fine details, and being liquid/airtight without further post processing. The printer has a wide variety of resins to choose from based on requirements of maximum loading, resistance to deformation, or stability under high temperatures.



Wire Bonder

The TPT HB30 Heavy Wire Bonder is capable of bonding round wires from 100 µm to 500 µm and ribbons sizes up to 300 × 2000 µm with a bond force between 50 -1800 cN. This wire bonder is a programable semi-automatic system which provides consistency and accuracy between samples. The Z and X axes are automated to allow for repeatable loop profiles that can consist up to 10 movement steps.

Electro-mechanical Hot Press with Vacuum / Inert Environment

This custom-built hot press is capable of applying up to 12 kN of force and reaching temperatures up to 300°C. It is housed inside of a large vacuum chamber to achieve bonding under both vacuum and inert gas environments. This capability is used to bond materials such as sintered silver, sintered copper, carbon nanotube interface materials, polyimide materials and more.

Vacuum Solder Reflow Station

The vacuum solder reflow station allows for power electronic package development through the synthesis of flux-free and void-free solder joints. Heat is applied to a sample by a resistive graphite heating element and the process temperature is controlled by a ramping temperature controller with preprogrammed reflow recipes. An external vacuum pump and argon gas are used to control the chamber pressure. Samples up to 11.5 × 9 cm can be placed within the chamber and heated up to a maximum operating temperature of 450°C.

Vacuum Oven

The vacuum oven with integrated hot plate allows for synthesis of flux-free and void-free solder joints for samples that would not fit within the vacuum solder reflow station. An external vacuum pump and argon gas are used to manually control the chamber pressure. The hot plate has a footprint of 140 × 20.5 cm and is capable of heating continuously up to 375°C and intermittently to 400°C.

Industrial Grade 3D Printer

The Ultimaker Factor 4 is an industrial grade 3D printer capable of printing a unique range of composite plastics. These unique carbon-fiber based plastics will increase the speed at which groups can fabricate and test prototype designs by allowing them to print metal-equivalent parts on demand. The printer can also use the high-temperature thermoplastic polyphenylene sulfide (PPS) and the water-soluble support material polyvinyl alcohol (PVA).

High-Precision Laser Cutter

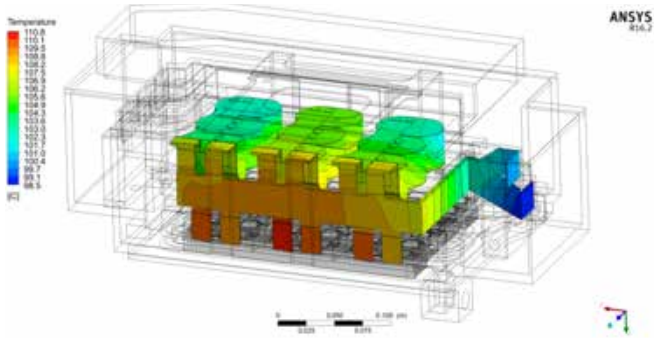
The Glowforge Plus laser cutter allows for the rapid creation of solder masks, PCB templates, and other items that require a high level of cutout precision. The solder masks can be used on custom designed PCB used for applications such as gate drivers and other control circuits.

Modeling Capabilities

Modeling and simulation are performed using the industry standard software including ANSYS Mechanical Enterprise for thermal, reliability, and structural finite element analysis and ANSYS Fluent for flow analysis, conjugate heat transfer, and computational fluid dynamics. Mutiphysics modeling tools within Siemens are also used. Customized tools written in MathWorks MATLAB extend the functionality of ANSYS for design exploration and optimization. Computational hardware includes state-of-the art workstations and NLR's current flagship HPC system, Kestrel.

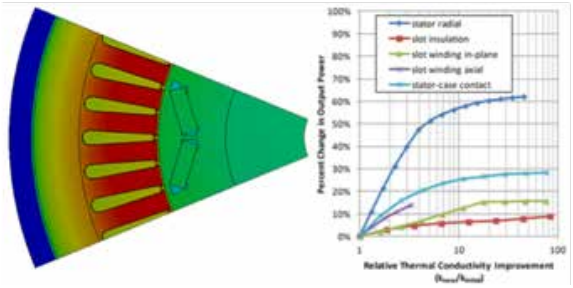
Inverter Thermal Management

Inverter-scale thermal model showing component temperatures.



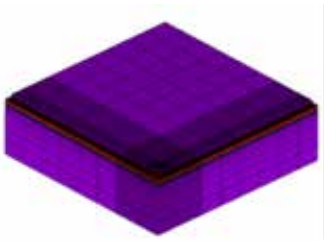
Electric Machine Thermal Management

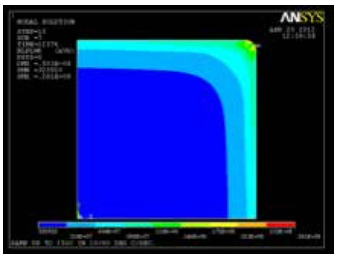
Electric machine thermal models are utilized to find thermal bottlenecks and optimize designs.



Packaging Thermo-Mechanical Reliability

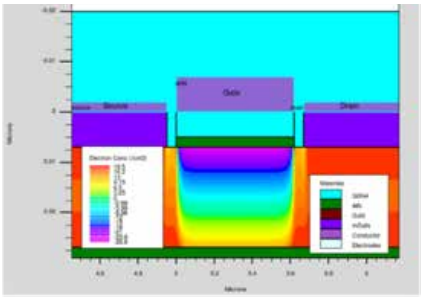
Viscoplastic material models are applied to substrate-attach materials to estimate the lifetime of solder, sintered silver, and other materials.





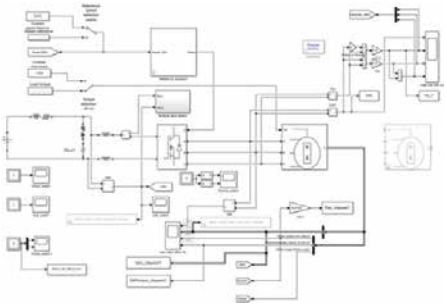
Power Device Modeling

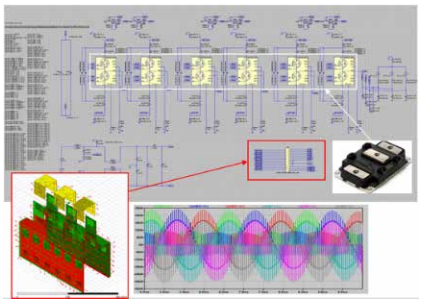
Semiconductor computer-aided modeling is performed at micro-and nanoscales for emerging wide-bandgap (WBG) and ultra-wide-bandgap (UWBG) devices.

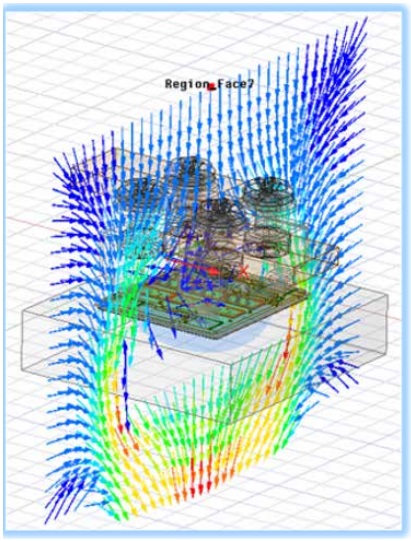


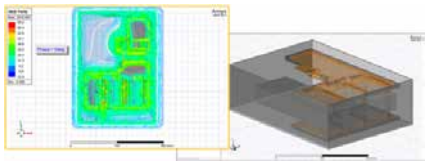
Multi-level and Multi-physics Co-Analysis of Power Electronics System

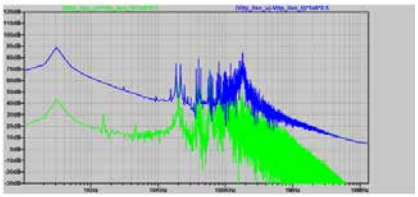
System, circuit, and component-level electrothermal co-analysis using a high-fidelity simulation tool inventory can provide accurate and precise simulation results for each aspect of the power electronics system in every phase and offer insight into performance optimization.





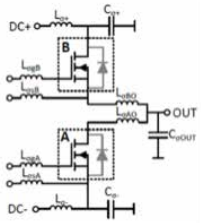






Electro-Magnetic Design for Power Electronics Packages

Electrical and electro-magnetic modeling is performed, and parasitics extraction is performed for high-frequency, low-loss WBG (and UWBG) power modules.



Partner with NLR

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NLR/BR-5700-97708 • February 2026