Power Electronics Campaign

The New York State Center for Advanced Technology in Nanoelectronics and Nanomaterials (CATN2) Matching Investment Program (MIP)

The CATN2 completed six competitive funding rounds under the CATN2 Matching Investment Program (MIP) to support faculty-led projects and expand SUNY Poly's R&D and commercialization capabilities in collaboration with New York State-based companies. Total awards under this program have totaled $1,431,787, with industry and other partners providing $5,273,038 in additional resource commitments for a total program investment of $7,165,825 to date resulting in a 5 to 1 match. The MIP funding represents a portion of a $1,000,000 annual grant from Empire State Development's Division of Science, Technology, and Innovation (NYSTAR) to support SUNY Poly's CATN2's operations.

The faculty-led, industry driven research projects at SUNY Poly's College of Nanoscale Science and Engineering have focused on areas in the power electronics campaign have totaled $900,000 with $600,000 being funded by NYS companies. The following projects that support the CATN2's power electronics campaign, including primary investigators, total project budget, New York industry partner, and summary of the research to be undertaken:

Project Title: High Voltage Testing Center for Wide Bandgap Power Devices
NY-PEMC Campaign Thrust: Power Conversion
PI: Woongje Sung
MIP Award: $100,000
Total Project Budget: $300,000
Private Entity Partner(s): NexGen Power Systems
Summary:
Power semiconductor technology is enabling electrification across a wide range of applications, from transportation to power generation. At the heart of this technology advancement, wide-bandgap (WBG) power semiconductors, SiC and GaN, are replacing their Si counterparts as the power device of choice at higher power levels. Consequently, power conversion systems (PCS),

within the transportation sector, for example, benefit from power electronics composed of packaged WBG devices, such as SiC JBS diodes and MOSFETs or GaN HEMTs.

Through the purchase and installation of a semiautomatic 6-wafer probe station this project will establish a much needed high voltage testing center (HVTC) that will not only support SUNY Poly research projects, but also projects of New York Power Electronic Manufacturing Consortium (NY-PEMC) and other industrial partners including Syracuse, NY **NexGen Power Systems**.

Impact: The to be established HVTC will become a revenue generating center by providing testing services to universities and industry by expanding the voltage range for testing. Improve ability to win grant awards.

Project Title: Discrete Power Packaging and Dynamic Characterization of WBG Power Devices Using Advanced Packaging Materials
NY-PEMC Campaign Thrust: Power Packaging
PI: Adam Morgan with Woongje Sung
MIP Award: $100,000
Total Project Budget: $300,000
Private Entity Partner(s): Indium Corporation
Summary:
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In order for WBG-based power electronics to harness the full power conversion capability of the WBG semi, in terms of operating temperatures and system voltages, the surrounding packaging materials and power electronic components also must be rated for the same, if not higher, operating conditions. In collaboration with Indium Corp., this project will address the critical missing RD&D capability at SUNY Poly by developing (1) WBG power packaging design and fabrication processes, (2) HV double-pulse test (DPT) setup, and (3) power cycling test setup, where the RD&D flow for WBG power devices and power packaging.

Impact:

- Provide discrete device packaging capability/partnership within SUNY Poly ecosystem that enables full power testing of WBG devices needed for complete RD&D of the technology
- Establishes a power electronics test platform for other researchers at SUNY Poly, Indium, other institutions and companies

- Allows sharing/comparing of test data between SUNY Poly, Indium and other institutions or companies that accelerates development and commercialization of WBG devices and packaging materials to meet growing power electronics demand and could result in new revenue stream
- Develops novel advanced power packaging to meet the requirements of the next-generation of WBG devices

Project title: High Voltage & High Temperature Reliability and Ruggedness Assessment System for Wide Bandgap Power Devices
NY-PEMC Campaign Thrust: Power Switching
Principal Investigator (PI): Seung Yup Jang (PI), Woongje Sung (Co-PI)
Private Entity Partner: NoMIS Power Group
MIP Award: $100,000
Total Project Budget: $300,000
Summary:
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The goal of this project is to develop the missing capability to evaluate the reliability and ruggedness of wide-bandgap (WBG) power devices, such as Silicon Carbide (SiC) and Gallium Nitride (GaN), at high voltage and high temperature. This project builds on the capabilities developed under two previous CATN2 MIP projects which enabled SUNY Poly to build a system that includes WBG power device design, high voltage measurements, dynamic switching measurements, and packaging capabilities. To further advance the device/manufacturing technology and commercialize power devices on SiC and GaN, reliability and ruggedness assessments are very important to designers and users of these WBG power devices. Through this project, SUNY Poly can build an extension of the current system to include reliability and ruggedness evaluation, facilitating a comprehensive RD&D environment.

Impact: The funds for this project will be used to build an extension of the current high voltage test system to include reliability and ruggedness evaluation. This project will have the following non-technical impacts:

- Establishes an HV&HT reliability and ruggedness test platform for other researchers at SUNY Poly, NoMIS, other institutions and companies
- Allows sharing/comparing of test data between SUNY Poly, NoMIS, and other institutions or companies that accelerates development and commercialization of WBG power devices and to meet the growing power electronics demand

Project title: Determination of Failure Modes of MEMS Contacts and Development of Techniques to Mitigate these Failures

NY-PEMC Campaign Thrust: Power Switching
Principal Investigator (PI): Carl Ventrice
Private Entity Partner: Menlo Microsystems
MIP Award: $70,505
Total Project Budget: $235,105
Summary:
Power semiconductor technology is enabling electrification across a wide range of applications, from transportation to power generation. At the heart of this technology advancement, wide-bandgap (WBG) power semiconductors, SiC and GaN, are replacing their Si counterparts as the power device of choice at higher power levels. Consequently, power conversion systems (PCS), within the transportation sector, for example, benefit from power electronics composed of packaged WBG devices, such as SiC JBS diodes and MOSFETs or GaN HEMTs.

Industrial partner Menlo Microsystems is reimagining one of the most fundamental building blocks of electronic systems – the electronic switch. Menlo is developing the core technology around fused silica based substrate fabrication, metal MEMS and hermetic through glass vias (TGV) and beginning the early phases of product commercialization of its MEMS based switch products. To continue the technology's advancement to higher power levels, the various reliability and failure mechanisms must be thoroughly understood and quantified. *The goal of this collaboration is to characterize the behavior of a ruthenium-based film with a grown ruthenium oxide top layer across various environments and temperatures to assess the stability of the Ru/RuO2 layers. This bi-layer material stack serves as the electrical contact for the switch, which experiences electrical, mechanical and environmental failure mechanisms.*

Impact: The setup for the Menlo measurements will be used for TEL and other potential clients resulting in revenue to sustain academic research capabilities. The learning that the PI and the company supported grad student receive during the project will be leveraged for new projects by the PI and serve as workforce development for the grad student. This project will also result in the development of new techniques for testing and machining parts that will be used for this and other projects.

Project Title: Acquisition of a Photoluminescence Mapping Confocal Microscope with Submicron Resolution: from Scientific Discovery to Wafer Inspection
NY-PEMC Campaign Thrust: Power conversion
Principal Investigator (PI): Shadi Shahedipour-Sandvik
Private Entity Partner(s): Applied Materials
MIP Award: $75,000
Total Project Budget: $669,000
Summary:
Power semiconductor technology is enabling electrification across a wide range of applications, from transportation to power generation. At the heart of this technology advancement, wide-bandgap (WBG) power semiconductors, SiC and GaN, are replacing their Si counterparts as the

power device of choice at higher power levels. Consequently, power conversion systems (PCS), within the transportation sector, for example, benefit from power electronics composed of packaged WBG devices, such as SiC JBS diodes and MOSFETs or GaN HEMTs.

Wide-bandgap materials and in particular the III-Nitride family of materials continue to play a major role in realization of electronic, optoelectronic and sensing devices for applications requiring high performance in conditions of high power/high frequency/high radiation/high temperature (e.g. space power electronics) such as in Electric Vehicles and Hybrid Electric Vehicles (EV/HEV). The EV/HEV market is one of the fastest growing sectors in the automotive segment due to the goal of replacing hydrocarbon fuel-based transportation systems and reduce CO2 emissions. Being able to measure the variation in optical activity of dopants and/or activation efficiency across the wafer is critical and can be visualized using photoluminescence mapping by identifying areas of exciton/UV luminescence and areas of defect luminescence. Acquiring a Photoluminescence Mapping Confocal Microscope will permit a deeper understanding of incorporation and activation of this potential dopants, amongst others, allowing for greater relevance to the multi-billion dollar EV/HEV market.

Impact: Collaboration with several other SUNY Poly faculty will enable expansion of the use of the microscope beyond the PI's immediate projects. A sub-micron PL mapping characterization capability will better position SUNY Poly to educate the next generation of scientists and engineers (workforce), participate in the discovery process (including publication and IP development), and to serve NY State economic development by collaborating with industry.

Project title: Upgrading an existing (dormant) electromagnet system to enable enhanced functionality for temperature dependent, AC Hall capability
NY-PEMC Campaign Thrust: Power conversion
Principal Investigator (PI): Shadi Shahedipour-Sandvik
Private Entity Partner: Applied Materials
MIP Award: $100,000
Total Project Budget: $822,000
Summary:
Power semiconductor technology is enabling electrification across a wide range of applications, from transportation to power generation. At the heart of this technology advancement, wide-bandgap (WBG) power semiconductors, SiC and GaN, are replacing their Si counterparts as the power device of choice at higher power levels. Consequently, power conversion systems (PCS), within the transportation sector, for example, benefit from power electronics composed of packaged WBG devices, such as SiC JBS diodes and MOSFETs or GaN HEMTs.

This proposal seeks to upgrade an existing Lake Shore electromagnet and power supply by adding functionality as a Hall Effect system by purchasing a Lake Shore M91 FastHall Controller to interface with the electromagnet with the EMP-Oven to extend the capability to temperature dependent measurements. This upgrade will allow for high precision measurement of material carrier concentration, mobility and resistivity across a wide range of materials. This expansion would provide excellent electrical measurements, even of materials with low mobility or high resistivity. Further, the combined addition of the LakeShore M91 FastHall controller and with the EMP-Oven would add improved functionality to the existing electromagnet and allow for a wider usage for fundamental measurement of materials across the semiconductor and electronic material space.

Impact: It is anticipated that this new and unique capability will be used by other SUNY Poly faculty and (in particular) graduate students in their proposals and take advantage of it for data collection. Having an in-house temperature-dependent (and AC) Hall system is unique amongst academics (and even National labs and industry) and we will proactively assist and train others to take advantage of the capability. This added capability will greatly improve the results of the collaboration with AMAT and support the federally funded projects of the PI.

Project Title: MEMS Switch Reliability
NY-PEMC Campaign Thrust: Power Switching
Principal Investigator (PI): James Lloyd
Private Entity Partner(s): Menlo Microsystems
MIP Award: $75,000
Total Project Budget: $280,100
Summary:
Power semiconductor technology is enabling electrification across a wide range of applications, from transportation to power generation. At the heart of this technology advancement, wide-bandgap (WBG) power semiconductors, SiC and GaN, are replacing their Si counterparts as the power device of choice at higher power levels. Consequently, power conversion systems (PCS), within the transportation sector, for example, benefit from power electronics composed of packaged WBG devices, such as SiC JBS diodes and MOSFETs or GaN HEMTs.

Menlo was established as a spin-out from GE's Global Research Center with the goal and purpose to commercialize a breakthrough MEMS based ohmic switch technology and products. The company is reimagining one of the most fundamental building blocks of electronic systems – the electronic switch. The goal of this collaboration is to characterize and then improve upon the reliability and lifetime of Menlo's MEMS switch technology for both RF and power relay applications. Through the application of fundamental reliability and surface/interface physics the core failure modes (contact wear, electromigration, temperature induce material properties changes, etc.) will be characterized and modeled, baseline performance quantified, process and material improvements suggested, and reliability properties understood to enable the technology's expansion into additional markets in communications infrastructure and Industrial IoT.

Impact: While achieving a better understanding of the reliability of the MEMS switches, Dr. Lloyd's lab will be upgraded with new probe cards and other improvements that will be determined through the course of this project. Once Dr. Lloyd's team learns about the failure mechanisms they can determine what is needed to characterize those failure mechanisms. These improved capabilities will allow Dr. Lloyd to collaborate and support other CNSE faculty as well as NY based industrial partners.