U.S. NATIONAL SCIENCE FOUNDATION
2415 EISENHOWER AVENUE
ALEXANDRIA, VIRGINIA 22314

NSF 24-038

Dear Colleague Letter: Funding Opportunities for Engineering Research in Microelectronics and Semiconductors

December 27, 2023

Dear Colleagues:

With this Dear Colleague Letter, the U.S. National Science Foundation (NSF) Directorate for Engineering (ENG) encourages the submission of research and education proposals related to **Microelectronics and Semiconductors as an Emerging Industry**.

Semiconductors and microelectronics play an important role in the modern-day economy and are crucial for national security. Semiconductors are one of the top five exports for the U.S., and the industry directly employs approximately 300,000 people in the U.S. and supports 1 million jobs. NSF and the Engineering Directorate have a long track record of supporting basic research in the broader area of semiconductors, ranging from materials to devices to systems. From an applications point of view, there are many challenges that lay ahead for semiconductors to meet the needs of the next generations of systems for advanced wireless, artificial intelligence, advanced manufacturing, computation and storage, secure communications, quantum technologies, autonomous vehicles, smart homes, smart and connected health, micro-grids, and clean energy, to name a few.

NSF and the Engineering Directorate invest in research and education activities in the area of semiconductors that align with the needs of the nation and support the CHIPS and Science Act of 2022, White House strategies, and other policy directives (such as the 2022 report from the President's Council of Advisors on Science and Technology, *Revitalizing the U.S. Semiconductor Ecosystem*) to enable U.S. leadership, spur economic growth, and advance jobs in microelectronics and semiconductors.

ENGINEERING DIRECTORATE INTERESTS

The Directorate for Engineering encourages the submission of all types of research and education proposals related to microelectronics and semiconductors, including proposals in the following areas:

Advanced packaging: Packaging methods to enable electrical, optical, magnetic, and superconducting sub-system and system designs that provide power, protection, cooling, and interconnect functions to advanced semiconductor devices.

Heterogenous integration: Methods for heterogeneous integration that bring together dissimilar materials or devices on a common platform to achieve desired electrical, optical, thermal, or spintronic properties, or that bring together different chip technologies to reduce the signal delay times between devices and chips.

CMOS+X: Three-dimensional heterogeneous integration approaches that combine silicon technology with emerging devices via advanced packaging processes and leverage unique semiconductor combinations for advanced electronics, optoelectronic, magnetic, and superconducting circuits and devices with new capabilities.

Devices based on 2D materials: Development of innovative devices that use 2D materials (graphene, black phosphorus, van der Waals heterostructures, 2D quantum materials, 2D magnets, 2D piezoelectrics, and others).

Wide-bandgap and ultrawide-bandgap semiconductor devices and circuits: Wide-bandgap (WGB) and Ultrawide-bandgap (UWBG) semiconductors have many advantages over their narrower-bandgap counterparts in high-power, radio frequency (RF), optoelectronic, quantum information, and harsh-environment application. The electrical and thermal properties of WBG and UWBG semiconductors enable the design of circuits and systems with performance well beyond what can be obtained using their narrowband counterparts, such as silicon.

Semiconductor optoelectronic and magneto-electronic devices: Semiconductor devices to generate, control, and detect photons and spins in photonics and magnetics. With advances in materials, sub-wavelength patterning, and heterogenous integration, many new optoelectronic and magneto-electronic devices can now be designed with high functional density for a range of applications.

Low-power devices and electronics: Fundamental and use-inspired research to further decrease power consumption of semiconductor devices, packages, and electronic systems. Reduction in power usage reduces electrical grid loads, increases battery life of mobile devices, enables edge computing, and makes thermal management easier.

Energy harvesting: Development of devices based on semiconductors, perovskites, piezoelectrics, organics, and other materials that enable energy harvesting from heat, mechanical vibrations, radiation, or other sources.

Quantum engineering using semiconductor technologies: Development of emerging device technologies — both conventional and unconventional — to overcome challenges facing the implementation of practical quantum computers and to enable the adaptation of existing semiconductor manufacturing infrastructure for quantum computers. Advanced design and modeling tools, devices that encode information in state variables other than charge (for example, spin, photon polarization, magnon amplitude and phase, Josephson flux), as well as quantum device operation based on quasi particles (such as magnon-polaron and magnon-plasmon) are also of interest.

Unconventional computing: Novel device technologies for non-Boolean computing (such as neuromorphic, Bayesian inference, probabilistic computing, and brain-inspired computing) that overcome current challenges such as slow operational speed, low device density and extreme sensitivity to device-to-device variation. Devices for non-von-Neumann architectures, processor-in-memory, and others are also of interest.

Artificial intelligence (AI) devices and chips: Development of advanced microprocessors designed to process AI tasks faster using ultra-low power and edge intelligence, and to overcome major challenges such as design and fabrication of dense high-bandwidth memory, high-density high-speed interconnects, resilience against Trojan horses, small-footprint hardware accelerators employing non-volatile components, and new memory devices.

Analog and high frequency devices: Devices for high frequency applications (millimeter waves and terahertz), analog computing and information processing.

Internet of Things (IoT) chips: Design and fabrication of IoT systems using appropriate power-efficient semiconductor device technologies for sensing, control, actuation, and communication, to meet the ever-growing demands of smart and connected devices and communities.

Devices for extreme environments: Devices that can operate under harsh environment conditions such as extremely high or low temperatures, extremely high pressure, high altitudes or outer space with cosmic radiation.

Security features in semiconductors: Hardware security features that are designed as a part of the added functionality of a chip using semiconductor technologies, and that enhance privacy, mitigate counterfeit chip production, and protect intellectual property, among other benefits.

Thermal management of semiconductor electronics: Hetero-integration with novel embedded thermal cooling solutions, thermal isolation of high power-density components, cooling solutions for hot-spot management, and low-thermal resistance interface materials development and integration.

Device characterization and modeling: Methods to characterize devices in detail by their linear and non-linear properties, power handing capabilities, noise characteristics under different operating conditions, reliability, and lifetime, and other parameters; development of equivalent models and design libraries for better understanding of devices under different operating conditions.

Environmentally sustainable manufacture of semiconductors: New semiconductor and electronics manufacturing processes that use less energy, water, and hazardous chemicals, and that reduce or preferably eliminate the use of per-and polyfluoroalkyl substances (PFAS).

Semiconductor manufacturing processes: Research areas include understanding novel reactor designs, such as chemical vapor and atomic layer deposition systems, as well as models and algorithms for the effective management of key manufacturing performance measures such as cycle time, on-time delivery, yield and supply chain management.

PROGRAMS AND CONTACTS

The Engineering Directorate encourages the submission of proposals related to microelectronics and semiconductors to the ENG core programs listed below, and to other relevant programs. To determine which program best fits a project idea, Principal Investigators are encouraged to read the program descriptions and reach out to program contacts with questions.

- **Advanced Manufacturing**: AdvancedManufacturing@nsf.gov
- **Communications, Circuits, and Sensing-Systems**: Jenshan Lin, jenlin@nsf.gov; Rosa (Ale) Lukaszew, rlukasze@nsf.gov
- **Electronics, Photonics and Magnetic Devices**: Dominique Dagenais, ddagenai@nsf.gov; Usha Varshney, uvarshne@nsf.gov
- **Energy, Power, Control and Networks**: Eyad Abed, eabed@nsf.gov
- **Environmental Engineering**: Mamadou Diallo, mdiallo@nsf.gov; Karl Rockne, krockne@nsf.gov
- **Environmental Sustainability**: Bruce K. Hamilton, bhamilto@nsf.gov
- **Mechanics of Materials and Structures**: moms@nsf.gov
- **Operations Engineering**: Georgia-Ann Klutke, gaklutke@nsf.gov, Reha Uzsoy, ruzsoy@nsf.gov
- **Process Systems, Reaction Engineering, and Molecular Thermodynamics**: Raymond A. Adomaitis, radomait@nsf.gov
- **Thermal Transport Processes**: Sumanta Acharya, sacharya@nsf.gov

The Engineering Directorate also encourages proposals for research centers, which tackle grand challenges and spur industrial innovation, and for workforce development, which provides experiential learning opportunities and opens new career paths.

- **Engineering Research Centers (ERC)**: nsferc@nsf.gov

- **Industry–University Cooperative Research Centers (IUCRC)**: Prakash Balan, pbalan@nsf.gov
- **Non-Academic Research Internships for Graduate Students (INTERN)**: Prakash Balan, pbalan@nsf.gov
- **Research Experiences for Teachers (RET)**: Amelia Greer, agreer@nsf.gov
- **Research Experiences for Undergraduates (REU)**: reu.eng@nsf.gov (REU for ERCs: reu.eng.erc@nsf.gov)

SUBMISSION GUIDANCE

Proposals submitted in response to this DCL should focus on scientific research and education relevant to the topical area of microelectronics and semiconductors. Proposal titles should begin with “**ENG-SEMICON:**” followed by any other relevant prefixes and the project name.

For consideration during fiscal year 2024, proposals to programs without deadlines should be submitted by April 30, 2024; proposals submitted later will be considered for fiscal year 2025.

NSF welcomes proposals that broaden geographic and demographic participation to engage the full spectrum of diverse talent in STEM. Proposals from minority-serving institutions, emerging research institutions, primarily undergraduate institutions, two-year colleges, and institutions in EPSCoR-eligible jurisdictions, along with collaborations between these institutions and those in non-EPSCoR jurisdictions, are encouraged.

This DCL does not constitute a new competition or program. Proposals submitted in response to this DCL should be prepared and submitted in accordance with guidelines in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) and instructions found in relevant program descriptions.

Sincerely,

Susan Margulies
Assistant Director, Engineering