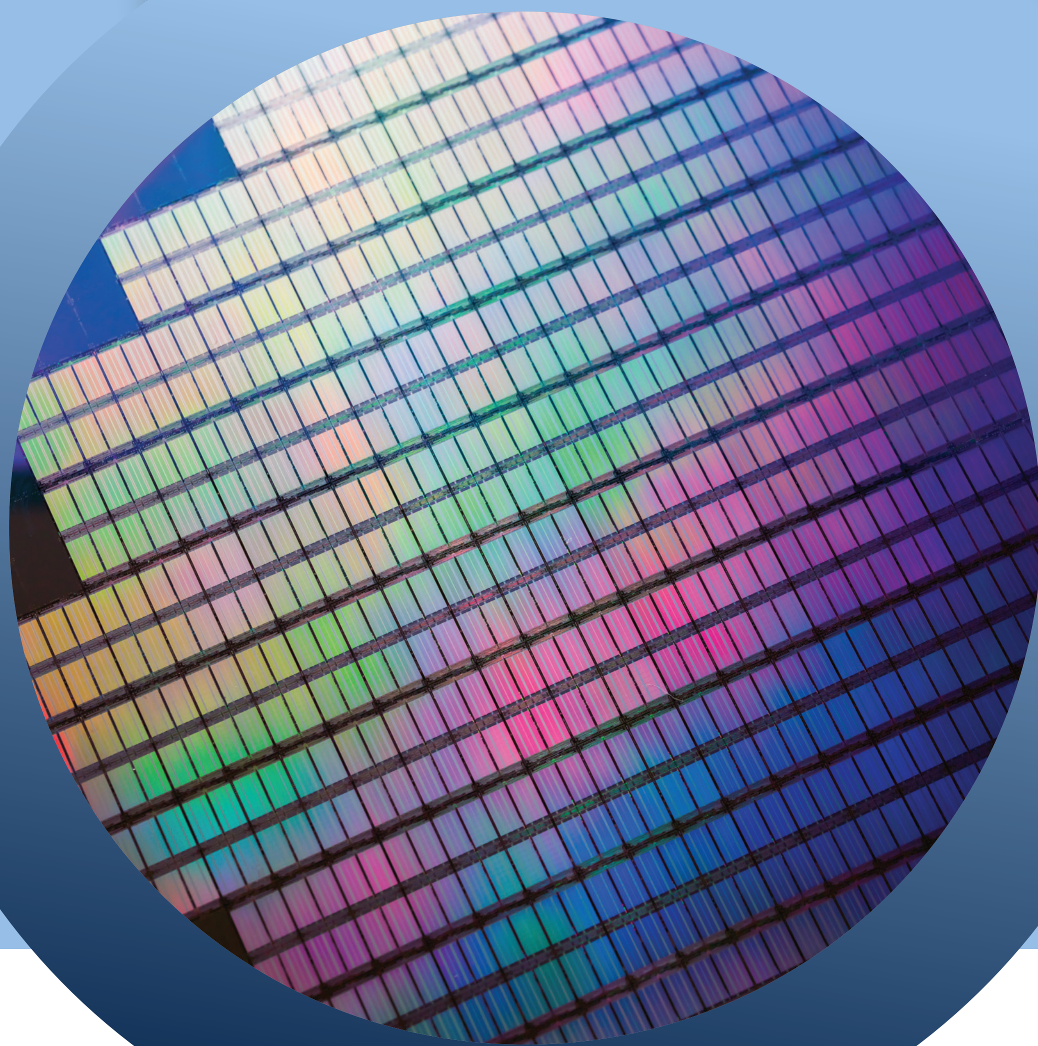
Setting a Course for America's Semiconductor Future

UNIVERSITY RESEARCH PLAYS A KEY ROLE

As an internationally recognized leader in semiconductor research and development, and as a national leader in education and development of the semiconductor workforce, Penn State University is deeply committed to promote a robust national semiconductor industry.



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Our Vision

Driven by the large diversification of the global semiconductor markets, the future generations of semiconductor devices demand a remarkably broad portfolio of materials and structures, novel multipurpose fabrication and metrology tools, sophisticated packaging solutions, and unique paradigms in education to effectively transition university research to commercialization.

As an internationally recognized leader in semiconductor research and development, and as a national leader in the education and development of the semiconductor workforce, Penn State University is deeply committed to promoting a robust national semiconductor industry. Our campus is at the epicenter of booming research and development activities linked to the advancement of semiconductor materials and devices, packaging, optics, thermal management, quantum devices, and computation. Penn State leads several nationally funded research centers where interdisciplinary teams drive innovation by addressing specific semiconductor challenges. We are part of The Commonwealth of Pennsylvania which, thanks to its long industrial tradition and its many world-class universities involved with the manufacturing of semiconductors, is the perfect ecosystem for revitalizing the U.S. semiconductor industry.

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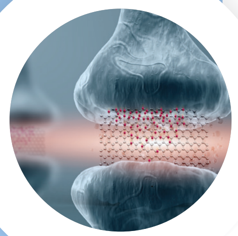
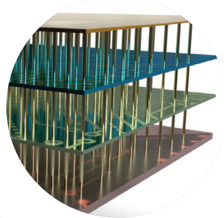
Research Strengths



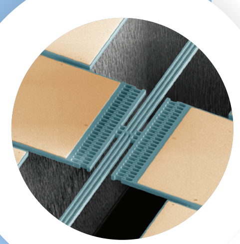
2D Semiconductors

We offer an exceptional portfolio of research programs and development in 2D materials and devices. We exploit the unique electronic, mechanical, and optoelectronic properties of atomically thin 2D semiconductors for next generations of high performance, ultra-low-power, flexible, reliable, artificially intelligent, radiation tolerant and inherently secure solid-state computing and storage devices and Internet of Things (IoT) sensors. We work collaboratively with semiconductor companies to accelerate the development of very large-scale integrated circuits (VLSI) and brain-inspired neuromorphic chips based on 2D materials that can achieve "More than Moore" scaling.



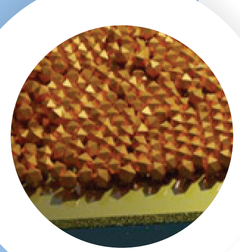
Ferroelectric Microelectronics

Our research and development programs target technology that uses the third dimension in microelectronics for non-volatile 3D memory above CMOS logic to create memory devices densely interconnected with logic to enable low-power, 3D non-von Neumann computation.



Micro-mechanical Systems (MEMS)

We are developing a new generation of micro-mechanical systems and devices that would incorporate shape-morphing materials to sense the environment, interact with each other, and perform self-coordinated tasks, with applications in communications, timing, and Internet of Things.

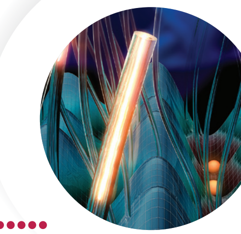


Organic Semiconductors

Organic semiconductors are an important focus of our research and development activities ranging from solar energy conversion to logic circuits. They include a variety of emerging organic semiconductor polymers, hybrid perovskite photovoltaic technologies, microscale concentrating photovoltaics, radiative cooling, and advanced antireflection coatings for the next generation of photovoltaic modules and prototyping next generation device configurations.

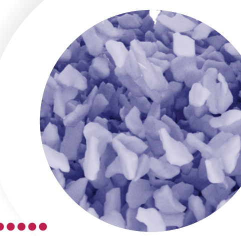
Internet of Things

We have multiple programs dedicated to fulfilling the promise of having trillions of devices connected wirelessly that dynamically share resources based on availability. Our researchers develop sophisticated piezoelectric materials for energy harvesting devices, highly directional and adaptive quantum antennas, and reduced size and power consumption CMOS circuitry and sensors to build the reliable wireless systems needed in industrial and real-world environments. We have testbed platforms enabled with industrial partnerships aiding the technological solutions for industry 4.0.



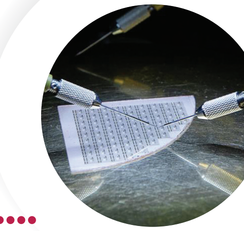
Quantum Packaging

The emerging field of quantum information technology exploits intricate quantum mechanical phenomena to create fundamentally new ways of obtaining and processing information. We are developing complex glass packaging to enable reliable access to quantum systems and materials from the macroscopic world without disturbing the quantum coherence of these delicate objects.



Packaging Solutions

We have multiple research activities focused on designing dielectric materials for high frequency and high thermal conductive interconnected substrates. These include polymers, polymer ceramic composites, and glass and ceramic substrates that can be assembled with multilayer structures and or 3D printed structures packaging devices. Combining new processing methods such as cold sintering offer unique opportunities in the integration of all classes of materials to significantly overcome limitations with traditional packaging solutions.



Wide Band Gap Semiconductors

Our faculty is exploring unique circuit architectures and diode and transistor devices that could reshape the future of semiconductors devices. We are developing wide bandgap semiconductor device and integration technologies for electronics with extreme capabilities in speed, power handling, and harsh environment hardness improving reliability. Our super heterojunction structures in GaN with switching voltages at 1.2kV open many new opportunities for novel applications.

Facilities

THE SUCCESS OF PENN STATE AS A LEADER IN THE RESEARCHING AND ENGINEERING OF MATERIALS AND DEVICES HAS ENABLED THE ESTABLISHMENT OF A ROBUST RESEARCH INFRASTRUCTURE THROUGH SHARED FACILITIES MANAGED BY THE MATERIALS RESEARCH INSTITUTE (MRI).

Most of these facilities are centrally housed in the 275,600 square-foot Millennium Science Complex at University Park where an entire wing of the building is dedicated to materials research. These facilities include the: 2D Crystal Consortium, Nanofabrication Laboratory, and Materials Characterization Laboratory.

SYNTHESIS

2DCC

NSF 2D Crystal Consortium Materials Innovation Platform

The 2DCC operates as a national resource providing access and expertise in 2D chalcogenide layered materials in the form of bulk crystal, multilayers, and one-atom thick films. It enables cutting edge research into next-generation 2D electronics and collaborates with microelectronics manufacturing companies.

FABRICATION

Nanofab

Nanofabrication Laboratory

The Nanofabrication Lab provides access to state-of-the-art nanofabrication capabilities and expertise to researchers from academia, industry, and federal research labs. The technical staff is focused on maintaining the facilities and providing guidance and training to the users. In addition to its nanofabrication expertise, the staff has broad experience in condensed-matter physics, chemistry, X-ray physics, optics, and magnetism, offering a broad knowledge base to support the user community. The Laboratory is currently developing sophisticated packaging processes for 2D and quantum materials compatible with large volume semiconductor device manufacturing. The facility has a long tradition of teaching semiconductor processes to undergraduate and graduate students, and it works closely with industry in developing processes compatible with technology transfer.

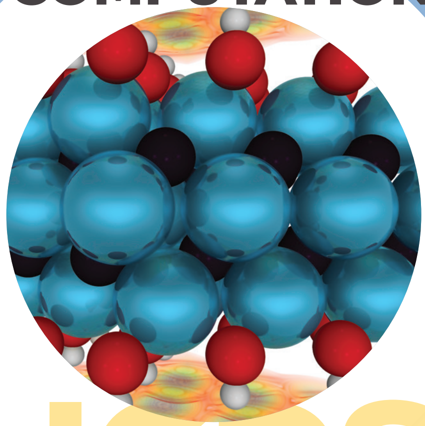
CHARACTERIZATION

MCL

Materials Characterization Laboratory

The MCL is a fully staffed, open access facility providing access to characterization equipment for materials and devices to enable advanced research while educating the next generation of highly qualified scientists and researchers. The MCL laboratories occupy more than 15,000 square feet within the Millennium Science Complex (MSC) at Penn State and are staffed by interdisciplinary scientists and engineers. Current MCL state of the art capabilities include transmission electron microscopy, scanning electron and ion microscopy, surface characterization, X-ray scattering, molecular spectroscopy, thermal analysis, particle characterization, electrical characterization, and mechanical testing.

COMPUTATION



ICDS

Institute for Computational and Data Sciences

The ICDS interdisciplinary institute at Penn State supports big data and big simulation methods for the research community. In support of the semiconductor research ICDS has a number of strategic efforts under its artificial intelligence (AI) Hub. The HPC infrastructure maintained by ICDS and its highly qualified staff also enable the handling of large data sets arising from detailed synthesis monitoring, and complex device designs that increasingly need hierarchical spatial and time analytics in their simulations.

WIDE-RANGE OUTREACH

Since 2017, MRI has worked with **100+** companies in Pennsylvania alone and **250** independent organizations

STRONG REPUTATION

NSF expenditures rankings by U.S. universities - **#1 in Materials Science** & **#2 in Materials Engineering**

INTERDISCIPLINARY NETWORKS

350+ tenured faculty working in materials across **8 colleges** and **30+ departments**

Partnerships

Workforce Development

PENN STATE PLAYS A CRITICAL ROLE IN THE MICROELECTRONICS WORKFORCE DEVELOPMENT THROUGH ITS MULTIPLE EDUCATIONAL INITIATIVES, HANDS-ON TRAINING PROGRAMS, AND INTERNSHIP OPPORTUNITIES.

These activities are designed and coordinated to attract diverse students and teachers from high schools and community colleges, technicians, master's level students, and PhD scholars. The training is coordinated with the University's world-class shared research instrumentation, innovation, and facilities to provide state-of-the-art resource access to both internal and external researchers, industrial partners, and entrepreneurs through a well-managed scheduling system, standardized use agreements, and federally compliant charge-out rates.

The Center for Nanotechnology Education and Utilization (CNEU) was created in 1998 to address the needs of Pennsylvania semiconductor industry for skilled workers and, since then, has been dedicated to preparing workers across the full range of micro- and nanofabrication applications needed to advance the semiconducting manufacturing workforce. In collaboration with Pennsylvania colleges, universities, and industries, the Center offers a two-year program to teach the manufacturing methods used by the semiconductor industry. Presently, about 1,000 of its students have moved on to work in semiconductor companies.

The Center for Nanotechnology Applications and Career Knowledge (NACK) is an advanced educational and workforce development center supported by the National Science Foundation (NSF). The NACK mission is to assist in the continued development of a robust nationwide infrastructure for nanomanufacturing workforce development. The key feature of NACK's mission is to continue to support the development and sustenance of U.S. nanomanufacturing workforce education by further growing nano-education partnerships nationwide, by enhancing dissemination of nanofabrication educational resources, and by providing key national infrastructure.

SUCCESS

PENN STATE VALUES THE INPUT FROM UNIVERSITIES, CORPORATIONS, INDUSTRY, AND GOVERNMENTAL AGENCIES ON DRIVING CURRICULUM AND TRANSLATING BASIC SCIENCE DISCOVERIES INTO MARKETABLE PRODUCTS. WE ROUTINELY INVITE KEY PARTNERS TO PROVIDE FEEDBACK AND PARTICIPATE IN RESEARCH SYMPOSIUMS, INNOVATION EVENTS, AND STUDENT ACTIVITIES TO FACILITATE CONNECTIONS TO TOP TALENT.

GOVERNMENT AGENCIES

INDUSTRY AND CORPORATIONS

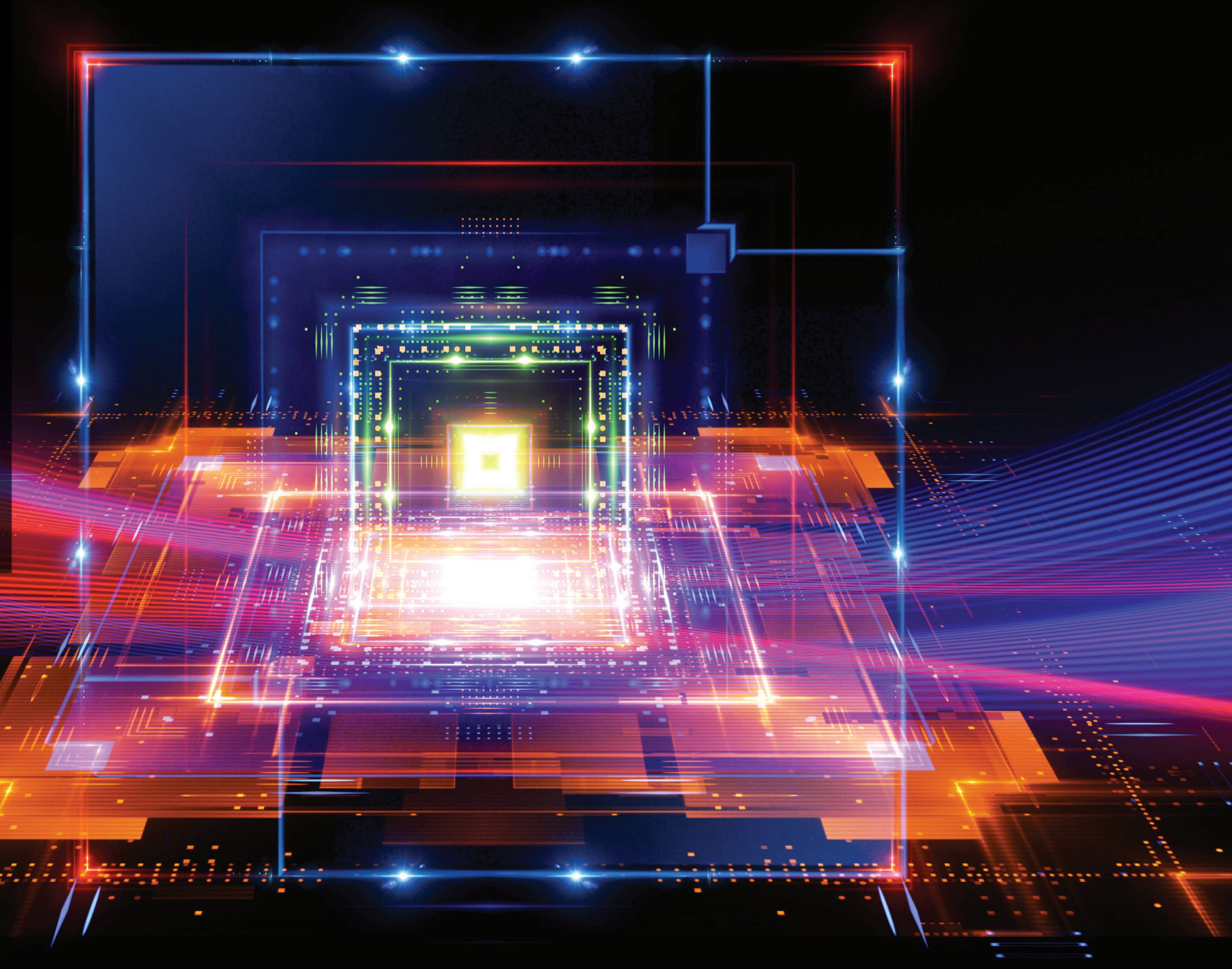
UNIVERSITIES AND COMMUNITY COLLEGES

Looking Forward

We at Penn State are convinced that a coordinated national effort involving educational, scientific, federal, and industrial communities could generate a new paradigm for workforce development that will restore the preeminence of the U.S. in microelectronics. These communities could work synergistically in regional hubs to develop novel educational protocols specifically designed to accelerate technology commercialization. The hubs would enable partnerships between the private sector, academia, and federally funded R&D centers; facilitate the creation of advanced manufacturing, metrology, and prototyping facilities; and supervise the education and training of the workforce in specific areas of the semiconductor enterprise.

Multiple regional hubs distributed across the country could efficiently complement their activities to accelerate the development of novel materials, devices, and systems by offering industrial members access to high-yield, well-characterized prototyping facilities.

These hubs would have a transformative impact on how the U.S. advances semiconductor manufacturing, would help newcomers get into the microelectronics industry, and would set a fast course for America to regain leadership in the semiconductor industry.



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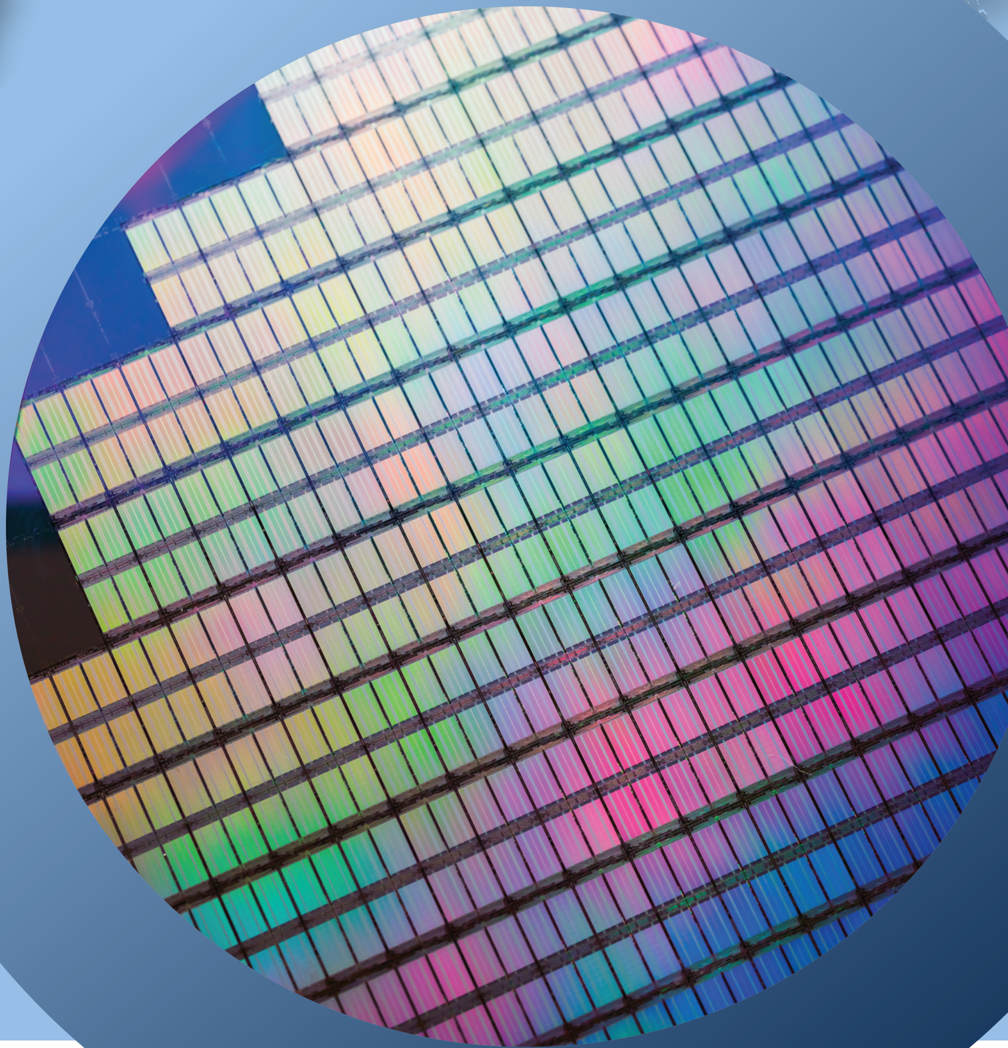
As an internationally recognized leader in microelectronics/semiconductor research and development, and as a national leader in education and workforce development, Penn State University is deeply committed to reinvigorating and promoting a robust national presence with appropriate university, government, and industrial partners. We will help lead and rebuild preeminence in chip R&D, workforce growth, and manufacturing capacity for the next generation devices.



PennState

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U.Ed. RES 22-07