Semiconductors
@Purdue
FALL 2022
For more information on Semiconductors at Purdue, please visit our website at:
https://engineering.purdue.edu/semiconductors

or email Cristina Farmus at:
cfarmus@purdue.edu or semiconductors@purdue.edu

Cover photo:
Scifres Cleanroom in the Birck Nanotechnology Center at Purdue
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Purdue Is Ready for Semiconductors

Purdue University is uniquely positioned to offer a full range of options for partners interested in semiconductors and microelectronics: research and development, workforce development, and business growth. As a world class university that moves fast and gets things done, Purdue pursues excellence at scale, with the largest engineering college (over 15,000 engineering students) ever ranked among the top 5 in the U.S.

Purdue University is home to large scale, impactful, interdisciplinary research and learning. A strong, critical mass of researchers sets Purdue apart by spanning the full stack of semiconductors R&D from materials and devices, to circuits, systems, architecture, and advanced packaging integration. Novel information processing architectures such as neuromorphic computing, compute-in memory, and probabilistic computing are core strengths, and additional strengths in new memory technologies and reliability are directly relevant to the challenges of DRAM and NAND scaling. Purdue currently leads three Semiconductor Research Corporation funded multi-university research programs and recently launched the Center for Secure Microelectronics Ecosystems. Strong connections to industry, such as DoD, NIST, and NSF, support one of the nation's largest semiconductors research programs.

Purdue's reputation as an R&D trailblazer is matched by its leadership in workforce development. We offer a full suite of degrees and credentials options for semiconductors training, ranging from traditional on-campus courses to a new set of degrees, competitive internships, innovative Learning While Working program, flexible online courses, and virtual labs and experiences. Purdue leads the Scalable Asymmetric Life Cycle Engagement (SCALE), a five-year, DoD-sponsored national coalition of 17 universities aimed at addressing the urgent need to develop a highly skilled U.S. microelectronics workforce to bolster national security. SCALE is being managed in partnership with the Naval Surface Warfare Center Crane Division (NSWC–Crane) as a nationally coordinated network of government, industry, and university partners. For the new Semiconductor Degree Program, Purdue was honored to receive endorsements from 17 CEOs of leading semiconductor companies. In May we launched the Purdue Semiconductor Degree Leadership Board, an elite group of 24 semiconductor industry executives that will provide visionary input into the Purdue Semiconductor Degrees Program and other workforce development programs designed and implemented by Purdue.

Purdue is an agile, collaborative university with an interwoven industry, academic, and social ecosystem. Bringing more microelectronics manufacturing to Indiana is a high priority, and Purdue is working with the Indiana Economic Development Corporation (IEDC) on both state and federally funded programs targeted at semiconductor manufacturing. The Purdue Research Foundation (PRF) supports Purdue’s land-grant mission to improve the world through its technologies and graduates. PRF moves ideas to the marketplace, patents and commercializes technologies, protects Purdue’s intellectual property, and provides connections and placemaking opportunities for industry.

Just over the summer, Purdue announced a partnership with SkyWater Technologies to build a $1.8B fab in West Lafayette, IN, and another partnership with MediaTek, who is building the company’s first semiconductor chip design center in the Midwest, to be housed on Purdue’s campus. This is just the beginning of what we envision to be a strong semiconductor ecosystem. We have the expertise, leadership, and resources to advance the semiconductors industry and contribute to the U.S. microelectronics preeminence.
Semiconductors was in the DNA of Purdue and Indiana: MOSFET was invented in 1959 by a Boilermaker engineer, Mohamed Atalla, and the father of Silicon Valley, Fred Terman, was a Hoosier. Today, the university and the state are ready to become one of the top five destinations for semiconductors industry and sources of semiconductors talent in the U.S. With over 50 leading faculty across multiple schools, Purdue is launching the nation’s first comprehensive suite of degrees devoted to semiconductors, leading DoD SCALE workforce consortium and three of the nine SRC funded JUMP and nCORE centers, pioneering key research areas, and working with IEDC, NSWC-Crane, and state-wide partners to welcome leading companies throughout the semiconductors supply chain.”
What Purdue Offers

- Advanced Research & Development facilities with more than 400 research labs on the West Lafayette campus, including the Scifres Nanotechnology Laboratory, the second largest clean room in academia.

- Advanced Packaging and Heterogeneous Integration, Novel approaches to information, emerging memory technologies, reliability, and sustainability of electronics.

- Exceptional faculty with 21 members of the National Academy of Engineering.

- Innovative faculty and staff with 12 National Academy of Inventors Fellows in the Purdue College of Engineering.

- A pipeline of globally competitive talent needed to innovate and thrive with over 11,000 engineering undergraduate and 2,000 graduate students.

- A business-minded university with an interwoven business and social ecosystem, backed by Purdue Research Foundation track record of meeting industry partners’ needs with space, logistics, and community connections.

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*Notable Purdue Rankings*
Semiconductor History

Indiana and Purdue have a long record of impacting semiconductor history, as exemplified by three outstanding individuals: Karl Lark-Horovitz, who pioneered work in solid-state physics that played a role in the invention of the transistor, Frederick E. Terman, the Father of Silicon Valley, and Mohamed M. Atalla, who co-invented the MOSFET metal–oxide–semiconductor field-effect transistor, or MOS transistor.

**Karl Lark-Horovitz** was a Purdue professor and Head of the Department of Physics. Through his work and that of many others at Purdue, the field of semiconductor research was expanded greatly. In the 1940s he turned his attention to solid state physics, a then new area of theory and research. He was the first to recognize the benefits of using germanium as the material with which to work. Observations of the changing resistance of a semiconductor under an applied voltage helped point the way to the discovery of the transistor. Of equal importance was the research done on materials preparation, as well as the investigation of fundamental properties of semiconductors. The first transistor at Bell Laboratories was actually demonstrated in 1947 using a germanium crystal grown in the Purdue lab and supplied to Bell Laboratories.

**Frederick E. Terman** was born and spent his childhood in Indiana. As a professor at Stanford, in 1951 he spearheaded the creation of Stanford Industrial Park whereby the University leased portions of its land to high-tech firms. Companies such as Varian Associates, Hewlett-Packard, Eastman Kodak, General Electric, and Lockheed Corporation moved into Stanford Industrial Park and made the mid-Peninsula area into a hotbed of innovation which eventually became known as Silicon Valley.

**Mohamed M. Atalla** was an Egyptian-American engineer, physical chemist, cryptographer, inventor, and entrepreneur. Born in Egypt, he was educated at Cairo University in Egypt and then Purdue University, before joining Bell Laboratories. He was a semiconductor pioneer who made important contributions to modern electronics. He is best known for co-inventing the MOSFET (metal–oxide–semiconductor field-effect transistor, or MOS transistor) in 1959, with his colleague Dawon Kahng, which along with Atalla’s earlier surface passivation and thermal oxidation processes, revolutionized the electronics industry.
Tom Sonderman Reveals SkyWater Plans for West Lafayette Expansion

Reporter: What details can you share about SkyWater’s plans to open a fab in West Lafayette? Technical, manufacturing focus, number of employees, timing, etc.

Sonderman ➤ Now that the CHIPS act has been signed into law, we are actively working with the State of Indiana and Purdue to seek CHIPS funding from the U.S. Department of Commerce. Once the funding is secured we anticipate breaking ground in 2023 and expect it will take 30-36 months to begin production. Our current plans are to build a facility that is approximately 650,000 sq. ft. with 100,000 sq. ft. of cleanroom space. We are considering several scenarios for how we will build out the new fab, including wafer size, node size and technology platforms. Ultimately these decisions will rely heavily on the needs of our customers and development partners. As time goes on there will be more clarity about what will go into the fab. We will begin hiring technicians and engineers as we begin operations. As the business scales up at the Indiana facility, we will ramp up hiring to meet those needs. At full capacity, we estimate the site will support 750 jobs in a variety of roles.

Reporter: What are the top reasons SkyWater chose Indiana and West Lafayette as the site for the company’s expansion?

Sonderman ➤ Indiana is an ideal location for SkyWater to build a new fab due to its robust business culture, manufacturing know how and commitment to innovation and education. Purdue is creating a very strong microelectronics ecosystem with the launch of the Semiconductor Degrees Program earlier this year and the work that is already being done at the Birck Nanotechnology Center. The intent of the CHIPS and Science Act of 2022 is not only to increase semiconductor manufacturing in the U.S., but to also develop the workforce and support innovation acceleration. Between the state, Purdue and SkyWater, we can address all of these needs.

Reporter: What type of partners do you expect to attract for a successful semiconductor ecosystem in the region?

Sonderman ➤ We are excited about customers interested in partnering with SkyWater as we define and build out new capabilities. This announcement has created interest from materials suppliers, equipment suppliers and the general ecosystem required to support a semiconductor environment. In addition there will be an influx of technology and innovation partnerships to augment future capabilities.

Reporter: How do you expect semiconductor education to evolve, in light of the CHIPS act provisions?

Sonderman ➤ We will work side-by-side with Purdue to help build a workforce that can support the future needs of the State of Indiana and the United States to innovate and manufacture the microelectronics that drive almost every aspect of our modern lives. Purdue has already made great strides in this respect with the launch of their Semiconductor Degrees Program. The recent focus on the CHIPS Act has created greater awareness for students who want to specialize in this area. The partnership between Purdue and SkyWater will enable those students to have a hands on learning experience. In addition, we believe that the CHIPS Act will reinvigorate domestic manufacturing, and we are excited that SkyWater, Purdue and Indiana will be an epicenter for this movement.

Reporter: What is your vision for Purdue and SkyWater’s contribution to national security through microelectronics?

Sonderman ➤ National security is the ideal on which SkyWater was founded. Purdue and their SCALE program share the same core value. Together SkyWater and Purdue will enable secure defense research and volume manufacturing.
SkyWater Technology Plans to Open Fab in West Lafayette

SkyWater Technology announced plans to open a $1.8 billion state-of-the-art semiconductor manufacturing facility in the Discovery Park District at Purdue, marking a huge step forward for the American semiconductor industry, Purdue’s thriving innovation district, and the university’s continued emergence as one of the principal drivers of the Indiana economy.

SkyWater, which expects to create 750 new direct jobs within five years after it opens, joins the likes of Saab, Rolls-Royce, major facilities and partnerships in hypersonics, Schweitzer Engineering Laboratories, Wabash, MediaTek, and others who have chosen Discovery Park District as the place to set-up or expand business, as one of the most attractive and innovative environments in the Midwest.

American jobs created will focus on research and design engineering, technology development, operations engineering, maintenance and technical support, and technicians. The new SkyWater facility will accelerate domestic semiconductor capabilities, ensure IP security, and support a more resilient and comprehensive supply chain, providing powerful competitive advantages for its U.S. government and commercial customers. By co-locating the fab at Purdue, SkyWater and its customers will benefit from close collaboration with the university and its pipeline of talent.

SkyWater is a U.S. investor-owned semiconductor manufacturer and a DMEA-accredited Category 1A Trusted Foundry. SkyWater’s Technology as a ServiceSM model streamlines the path to production for customers with development services, volume production, and heterogeneous integration solutions in its world-class U.S. facilities. This pioneering model enables innovators to co-create the next wave of technology with diverse categories including mixed-signal CMOS, ROICs, rad-hard ICs, power management, MEMS, superconducting ICs, photonics, carbon nanotubes, and interposers. SkyWater serves growing markets including aerospace and defense, automotive, biomedical, cloud and computing, consumer, industrial, and IoT. For more information, visit: www.skywatertechnology.com.
MediaTek to Open New IC Design Center at Purdue University

On June 28, 2022, Purdue University announced a partnership with MediaTek Inc., a leading global fabless chipmaker, to open the company’s first semiconductor chip design center in the Midwest, to be housed on Purdue’s campus. MediaTek and Purdue also will partner on new chip design engineering degree programs, research on artificial intelligence, and communications chip design. This collaboration is still in the works.

“This means students and faculty at Purdue will have the opportunity to interact with world class chip design talent right across the street,” said Dr. Mung Chiang, President-Elect of Purdue University, current Executive Vice President for strategic initiatives. The Purdue team worked with the Indiana Economic Development Corporation to fully leverage Purdue’s role as one of the top STEM universities to attract this new semiconductor investment.

“We believe strongly that being in Indiana means we’ll have access to some of the best engineering talent in the world,” said Dr. Kou-Hung Lawrence Loh, Corporate Senior Vice President of MediaTek Inc. and President of MediaTek USA, Inc. “Not just at Purdue, but West Lafayette is only four hours away from nearly a dozen of the top engineering schools in the country. In the post pandemic world, top candidates tell us they want to be closer to home, near family and they want to have a real house and great schools. Indiana offers all that and more.”

The Purdue partnership represents a new U.S. growth model for MediaTek USA—outside the traditional centers of gravity for chip design.

Among those who participated in the announcement were Kou-Hung Lawrence Loh, Corporate Senior Vice President of MediaTek Inc. and President of MediaTek USA (second from left), Eric J. Holcomb, Governor of the State of Indiana (third from left), Brad Chambers, Indiana Secretary of Commerce (fourth from left), and Mung Chiang, President-Elect, Executive Vice President for Strategic Initiatives of Purdue University (far right).
Industry Partners

**Design:** AMD, Apple, Cadence, Graphcore, IBM, Intel, MediaTek, Nantero, NVIDIA, Reliable MicroSystems, Samsung, Silvaco, Synopsys, Qualcomm

**Tooling:** Applied Materials, ASM, ASML, eFabless, KLA, Lam, Tokyo Electron

**Manufacturing:** Draper, GlobalFoundries, IBM, Infineon, Intel, Marvell, Samsung, Seagate, SK hynix, SkyWater, Svagos, TSMC

**Materials:** Air Liquide, Air Products, Corning, Dow, Eastman, Hemlock Semiconductors, MacDermid Alpha, Molex

**Customers:** Boeing, BAE Systems, Caterpillar, Cisco, Collins Aerospace, Cummins, Daimler, Deere & Co., Fiat Chrysler, Ford, General Dynamics, General Electric, General Motors, Google, Hewlett Packard Enterprise, Hitachi, Honeywell, Juniper Networks, L3Harris, LG Electronics, Lockheed Martin, Medtronic, Microsoft, Nokia, Northrop Grumman, One Network, Raytheon, Robert Bosch, Rolls-Royce, Saab, Siemens, SpaceX, Subaru, Tesla, Texas Instruments, Toyota, United Technologies, Western Digital, ZF Friedrichshafen AG (TRW)

How Industry Can Contribute to Developing the Semiconductors Workforce

Purdue University has already made significant investments in developing the next generation workforce for the semiconductors industry. We are looking forward to working with industry partners to take the initiative to the next level and encourage partners to contribute in many ways. Below are some examples of engagement—pick one option or all—Purdue is ready to work with you to create a customized program that fits your needs and maximizes student success. Contact Cristina Farmus cfarmus@purdue.edu to get more details.

**In Kind**
1. Commit to summer 2023 (or 2024) internships.
2. Commit to interviewing students with a GPA 3.2 and above.
3. Identify Purdue as a strategic partner university.
4. Participate in the Semiconductor Education Steering Committee to refine curriculum and training offerings, including for technicians.
5. Provide speakers for undergraduate lecture series, high school outreach and college recruiting events.
6. Host faculty at your sites to better understand current industry needs.

**Financial Support**
1. Fund scholarships for students pursuing semiconductors degrees.
2. Support the Summer Training, Awareness, Readiness for Semiconductors (STARS) 2023 UG semiconductor program ($10K per student covers stipend, lodging, and program operating fees).
3. Sponsor VIP projects (e.g. tapeout fees).
4. Donate equipment.
5. Consider establishing a named professorship.
6. Support new program/course development (e.g. MicroMasters).
7. Offer unrestricted support for semiconductor WFD.

Establish Permanent Present at Purdue

Start as small or as large as you’d like, office space available immediately.
"The foundation of U.S. semiconductor leadership is America’s talented technology workforce. It is critical we support and strengthen this workforce by creating, promoting, and investing in policies and programs that enable the training and retention of skilled semiconductor talent. I am thrilled Purdue University is taking a bold step in this mission with the creation of its new credentials and degrees focused on microelectronics and semiconductors at the undergraduate and graduate level. We strongly support these exciting and innovative initiatives."

John Neuffer, President and CEO, Semiconductor Industry Association (SIA)

"AI is the most impactful technology of our time. The automation of intelligence expands humanity’s potential, enabling once-unimagined advances across science, industry and even the arts. Leadership in this era will require a new generation of engineers and computer scientists. It’s exciting to see Purdue establish this program to prepare students for this challenge, enabling them to help shape fields from autonomous vehicles and robots to healthcare and climate science, and improve our world.“

Jensen Huang, President and CEO, NVIDIA

"I am pleased to hear about the new graduate and undergraduate credentials and degrees on microelectronics and semiconductors being launched at Purdue University. These innovative and much-needed initiatives will play a key role in satisfying the voracious demand for skilled talent in the semiconductor industry. I am confident that graduates from this program will be in much demand at Lattice and other companies in our industry."

Jim Anderson, President and CEO, Lattice Semiconductor

"As one of the world’s leading semiconductor manufacturers based in the U.S., GlobalFoundries strongly supports the efforts to grow U.S.-based semiconductor manufacturing. We recognize that to accomplish this goal, the shortage of semiconductor talent in the U.S. is a critical challenge the nation must address. I am pleased and encouraged to see Purdue University step up to this challenge by introducing a comprehensive set of degrees and credentials that will prepare students for exciting careers in semiconductors. We look forward to partnering with Purdue as these programs ramp up to support microelectronics across the U.S."

Thomas Caulfield, CEO and President, GlobalFoundries

"Today, semiconductors are more strategically and economically important to the world than ever and we need to significantly scale up the talent pipeline to support the future growth of our industry. Applied Materials is delighted to see Purdue University helping lead the charge to educate the tens of thousands of new engineers our industry needs through new degrees and credentials focused on microelectronics and semiconductors. We look forward to welcoming this next generation of innovators."

Gary Dickerson, President and CEO, Applied Materials, Inc.

"Every aspect of human existence is becoming digital, and everything digital runs on semiconductors. Increasing access to semiconductor and microelectronics education is essential for building a talented, diverse pipeline of future technologists. Intel plans to invest $100 million over the next decade to build a skilled semiconductor workforce in collaboration with universities, community colleges, and the NSF. I’m excited about Purdue’s educational credentials focused on semiconductors and microelectronics, including the new interdisciplinary master’s degree. With these timely and high-impact initiatives, Purdue is leading the way in bridging the skills gap and addressing the shortage of skilled human talent in the semiconductor industry."

Pat Gelsinger, CEO, Intel

"Semiconductors are the backbone of our digital society and global economy. Increasing investment in semiconductor education to train the next generation of technologists is vitally important for the long-term health and success of our industry. Purdue University’s new graduate and undergraduate credentials and degree programs in semiconductors and microelectronics can serve as an incubator for the ideas and innovations of tomorrow. We strongly support this initiative and look forward to welcoming Purdue graduates to Marvell in the future."

Matt Murphy, President and CEO, Marvell
“It is essential for the United States to be a self-sufficient leader in semiconductor technology, which provides the foundation for the modern world and will lead to new innovations in critical industries. Purdue University’s new credentials and degrees in microelectronics and semiconductors will help ensure that we have the large, skilled workforce that is needed to power the nation’s semiconductor future.”

Arvind Krishna, Chairman and CEO, IBM

“Semiconductor manufacturing requires a vast array of highly engineered and advanced materials and chemistries. CMC Materials and other leading materials companies look forward to supporting the expansion of semiconductors in the United States and globally. For the bold innovation in critical materials that is needed to advance technology and increase performance, a new generation of semiconductor engineers is critically needed. Purdue’s new degrees and credentials will help students develop the depth and breadth needed for an exciting new era of technology that is just beginning. Kudos to Purdue for stepping up to address this key challenge for the U.S. semiconductor industry: Go Boilers!”

David Li, President and CEO, CMC Materials

“TSMC looks forward to being part of the resurgence of semiconductor manufacturing in the U.S. Success in this ambitious and critically important undertaking will require a much-expanded semiconductor talent with the knowledge and skills needed to innovate in a post-Moore’s Law era. Purdue’s innovative and comprehensive new suite of semiconductor degrees and credentials is exactly what is needed – at exactly the right time. We at TSMC look forward to working with Purdue to make this program a model for the nation.”

Mark Liu, Chairman, TSMC

“Differentiated technologies that address a growing diversity of applications will characterize the next wave of electronics. This next wave will be driven by creative engineers with a broad understanding of microelectronics from materials, devices, and circuits to systems, packaging, and qualification. SEMI is delighted to partner with Purdue as part of the American Semiconductor Academy initiative, and I am pleased to see the university leading the way with the kind of comprehensive and innovative program that the semiconductor industry critically needs.”

Ajit Manocha, President and CEO, SEMI

“Recent events have taught us all how critical chips are and how fragile supply chains can be, but a re-energized U.S. microelectronics landscape will require more than just building more fabs. As Moore’s Law slows, new ways to advance the performance of electronics systems are needed, and this will require a new generation of bold and creative semiconductor engineers to pioneer equally as bold and creative semiconductor devices. I applaud Purdue in addressing this challenge with a comprehensive set of new semiconductor degrees and credentials that will help prepare a new generation of semiconductor engineers and address a critical need for Nantero and other companies.”

Rob Snowberger, CEO, Nantero

“SkyWater sees tremendous value in partnering with Purdue University. They have tremendous faculty, researchers, and facilities around semiconductor creation. Their student body is developing into the workforce of the future, and with the new degree programs dedicated to semiconductors, those are just the graduates that SkyWater needs.”

Thomas Sonderman, President and CEO, SkyWater

“We are entering an exciting new era of semiconductors with unprecedented demand driven by the need to execute artificial intelligence (AI) compute workloads. Graphcore is transforming the AI compute domain through innovative technologies that are going to be transformative across all industries and sectors with a real potential for positive societal impact from drug discovery and disaster recovery to decarbonization. Sustaining the rapid pace needed to have such an impact is going to require a big increase in the size of the semiconductor talent pool. I am excited to see Purdue leading the mission to educate the next generation of semiconductor workforce leaders by launching an innovative set of credentials and degrees. I expect this initiative to be a real difference-maker.”

Nigel Toon, CEO, Graphcore

“Electronics is more and more often the differentiating factor in products, but the cost and complexity of design is exploding. As Efabless works to make custom chip design affordable and accessible to more companies, a critical challenge is the shortage of microelectronic talent. I applaud Purdue University for stepping up to this challenge. Purdue’s new degrees and credentials meet prospective talent where they are with education and opportunity. This will help the next generation of students develop the knowledge, skills, and experience needed for an exciting new era of electronics.”

Mike Wishart, CEO, Efabless

“We, at SRC, have sponsored more than 16,000 undergraduate and graduate research scholars and have a stated mission of building a diverse, inclusive, and highly trained workforce for tomorrow. Purdue’s new credentials and degrees on microelectronics and semiconductors represent excellent and much-needed initiatives in semiconductor workforce development. We have a strong partnership with Purdue in the microelectronics revolution and look forward to further expanding this partnership to address the enormous possibilities for the industry and our country.”

Todd R. Younkin, President and CEO, Semiconductor Research Corporation (SRC)
Purdue has launched the Semiconductor Degree Leadership Board, an elite group of executives from leading semiconductor companies that will provide visionary input into the Purdue Semiconductor Degrees Program and other workforce development programs designed and implemented by Purdue.

We are proud to list as inaugural members the following:

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<td>Senior Vice President of Technology, Engineering, and Quality</td>
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<td>William Chappell</td>
<td>Chief Technology Officer of Azure Global and Vice President of Mission Systems</td>
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<td>Keyvan Esfarjani</td>
<td>Executive Vice President</td>
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<td>Deirdre Hanford</td>
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<td>Brian Harrison</td>
<td>Senior Vice President</td>
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<td>Raghib Hussain</td>
<td>President of Products and Technologies</td>
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<td>Steve Kosier</td>
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<td>Om Nalamasu</td>
<td>Chief Security Officer</td>
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<td>Executive Vice President and General Manager for U.S. Research and Development</td>
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<td>NVIDIA</td>
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<tr>
<td>Patrick Wilson</td>
<td>Vice President</td>
<td>MediaTek</td>
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<tr>
<td>Philip Wong</td>
<td>Willard R. and Inez Kerr Bell Professor, ECE</td>
<td>Stanford University</td>
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<tr>
<td>Jie Xue</td>
<td>Vice President of Supply Chain Operations</td>
<td>Cisco Systems</td>
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<tr>
<td>Anthony (Tony) Yen</td>
<td>Vice President</td>
<td>ASML</td>
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</tbody>
</table>
Purdue’s reputation as an R&D trailblazer is matched by its leadership in workforce development programs for semiconductors. Several programs described below attest to a strong University culture, a tradition of innovation in workforce development, and an array of recent successes related to microelectronics training at scale.

**Semiconductors Degrees and Certifications**

A comprehensive new undergraduate semiconductor program is being launched. The undergraduate experience will begin with “Introduction to Semiconductors”, a guarantee of internships or co-op experiences to semiconductor undergraduates, continuing to semiconductor minors and concentrations, and a 5-year BS/MS program that will give students additional semiconductor knowledge and experience. The new interdisciplinary MS degree will be the only such degree focused entirely on semiconductors and microelectronics offered at any of the top-10 ranked Engineering Colleges in the country. These credentials and degrees will be available both for on-campus and online students.

<table>
<thead>
<tr>
<th>TYPE OF DEGREE OR CREDENTIAL</th>
<th>RESIDENTIAL</th>
<th>ONLINE</th>
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</thead>
<tbody>
<tr>
<td>Interdisciplinary, 6-in-1 MS Degree</td>
<td>✓</td>
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<tr>
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<td>Stackable Certificates</td>
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<tr>
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</tr>
<tr>
<td>Introduction to Semiconductors Freshman Course</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Internships, Co-Ops, and Learning While Working**

Purdue runs one of the largest and best undergraduate industry internship and co-op programs in the nation. Besides the inaugural semiconductor suite of degrees, Purdue has also created a Learning While Working program, enabling students to work towards their degrees while working full time. A good number of companies are subscribing to this model, running in parallel with internship and co-op programs.

https://www.opp.purdue.edu/

**Partnerships**

Recognizing the need to contribute to the entire range of microelectronics workers, Purdue is partnering with Ivy Tech Community College to develop several programs aimed to increase the number of technicians and also to strengthen the pipeline for four-year degrees. Ivy Tech has more than 40 locations across Indiana and teaches classes in more than 75 communities serving nearly 100,000 students annually. Ivy Tech is the largest public postsecondary institution in Indiana and the largest singly-accredited statewide community college system in the country.
Introduction to Semiconductors Course

Purdue University has developed Introduction to Semiconductors, an interactive, seminar based, one-credit hour course to introduce semiconductor technology, its role in our life, impact, and career opportunities to science and engineering students.

This course has been developed by a team led by Purdue Office of Professional Practice, College of Engineering faculty, and industry partners. This course will be offered starting with Spring 2023 with an anticipated enrollment of 150 students. During its launching semester, the course will cover the following topics:

1. Logic microprocessor—heart of digital world
2. Memory technology—storing all our data
3. Designing semiconductor electronics
4. Semiconductor manufacturing equipment
5. Semiconductor modeling tools
6. Semiconductor manufacturing facilities
7. Sustainable semiconductor manufacturing processes
8. Non-silicon semiconductor electronics
9. SkyWater—Opportunities coming to the Greater Lafayette area
10. Automobile industry and semiconductors
11. Digital healthcare technology and semiconductors
12. Fabless model
13. Panel discussions with Purdue alumni founders of semiconductor related starts-ups

Every week there will be one fifty-minutes session where industry representatives from diverse technological backgrounds will discuss relevant semiconductor products, company profiles, career prospects, and skills. During each session, 15 minutes will be dedicated to engage in a discussion with the students.

The Purdue team is also creating tutorials with micro-lectures, animation, and videos on a variety of semiconductor technology topics that the students will preview before each lecture. Students will complete brief quizzes and prepare for each lecture. Towards the end of the semester, students will write a paper on a topic of their choice showing their knowledge on the subject, as well as how it may relate to their career interests. We will utilize pre and post course surveys to understand the impact the course is making on students’ career interests.

After successful completion of the course requirements, students will be offered opportunities to develop deep-tech skills like IC design, fabrication, and packaging, and semiconductor device and materials characterization through the Purdue Summer Training, Awareness, and Readiness for Semiconductors (STARS) pilot program which will launch in summer 2023 on campus. This is in alignment with Purdue’s commitment to develop a semiconductor workforce through comprehensive and quality learning experiences.

We welcome your feedback and participation in this pioneering program to excite our students about semiconductor technology. We are confident that the Purdue offering will be foundational to address our national need for more semiconductor professionals in the coming decades.

For any details, please contact Cristina Farmus, Chief of Staff to the EVP, at cfarmus@purdue.edu.
Workforce Development Online Programs

Purdue Engineering Online

Purdue University provides several options to achieve a world-class education online. Online learning and hybrid degree programs give students access to outstanding faculty and top-quality curriculum in a convenient, flexible format. Purdue Engineering offers a wide range of options for semiconductors online training, ranging from individual courses and online Master’s degrees, to sophisticated simulations and virtual tools.

Online Masters Programs

The Master of Electrical & Computer Engineering (MSECE) is ranked the number one online electrical engineering graduate program by U.S. News & World Report, 2022. Students can specialize with courses in microelectronics and nanotechnology, automatic controls, energy sources and systems, fields and optics, and Very-Large-Scale Integration (VLSI) and circuit design.

The online master’s in engineering offers Purdue prestige with the flexibility working professionals need to complete their studies. Online students learn from the same faculty who teach the on-campus programs. Our world-class professors help students develop innovative thinking approaches to address practical and complex problems. Throughout the program, a dedicated faculty advisor and a team of professionals help students plan their degree and support their envisioned career path.

https://engineering.purdue.edu/ECE/Academics/Online

nanoHUB

nanoHUB.org is the premier place for computational nanotechnology research, education, and collaboration. nanoHUB has been funded and supported by NSF since 1995, with the mission to lower the barrier to accessing and using sophisticated computer aided-design (CAD) tools. The nanoHUB site hosts a significant and growing collection of simulations for nanoscale phenomena that run in the cloud and are accessible through a web browser.

Purdue has developed and demonstrated a scalable solution for virtual learning and research. Annually Purdue’s nanoHUB is currently serving over 12,000 in-classroom students with immersive learning experiences in semiconductor devices and materials through easy-to-use Apps and millions of visitors with educational materials.

The nanoHUB science gateway offers millions of users a vast array of resources for semiconductors workforce development programs, including free textbooks, open source software, and immersive programs such as a virtual fab. Users can log in and run industry-strength CAD tools without the need to download, install, license, support, and maintain the software. They are accessible from web browsers and run via a distributed computing network at Purdue University. The simulation tools are available to users as both stand-alone tools and part of structured teaching and learning curricula.

https://nanohub.org/groups/semiconductoreducation

vFabLab

Purdue now offers free access to vFabLab, the only virtual fab environment with state-of-the-art semiconductor manufacturing equipment for training purposes. Conceptualized and developed by Prof. Muhammad Mustafa Hussain of Purdue ECE, this training resource is linked to the nanoHUB and accessed by users all over the world.

https://vFabLab.org
SCALE DoD Microelectronics WFD Center

Purdue University is leading a five-year, DoD-sponsored national initiative aimed at addressing the urgent need to develop a highly skilled U.S. microelectronics workforce to bolster national security. Comprising of 17 partner universities across the country, Scalable Asymmetric Life Cycle Engagement (SCALE) is a $19.2 million public-private-academic partnership formed to advance the technical capabilities of the domestic microelectronics workforce, and to motivate talented STEM undergraduate and graduate students to pursue federal government careers in the semiconductor field.

SCALE is being managed in partnership with the Naval Surface Warfare Center Crane Division as a nationally coordinated network of government, industry, and university partners, with regional execution. Faculty from across Purdue’s College of Engineering are collaborating with experts from 16 other universities, the DoD, NASA, the Department of Energy NNSA labs, and the defense industry to create a microelectronics workforce focused on national security needs.

The workforce development program provides microelectronics modules, mentoring, public- and private-sector internship matching, and targeted research projects for college students interested in these microelectronics specialty areas:

- Radiation hardening
- Heterogeneous integration/advanced packaging
- System-on-a-chip electronics
- Embedded systems security/artificial intelligence (AI)
- Supply chain awareness

For more information on SCALE Workforce Development, please visit: https://www.purdue.edu/discoveryparkSCALE/index.php
Birck Nanotechnology Center is a user facility supporting over 300 users in a 186,000 square foot R&D facility with the second largest university cleanroom. It is home to 220 resident graduate students, 60 faculty and more than 40 engineering, scientific and administrative staff. Research groups come from six academic colleges including College of Engineering and College of Science.

For a virtual tour of Birck Nanotechnology Center, go to: https://www.purdue.edu/discoverypark/birck/

The Scifres Nanofabrication Laboratory (Class 1)

The nanofabrication cleanroom, located in the Birck Nanotechnology Center, consists of 25,000 sq. ft. of bay-chase cleanroom, with 20% of the bays operating at ISO 3 (Class 1), 50% operating at ISO 4 (Class 10), 15% operating at ISO 5 (Class 100), and the remaining 15% operating at ISO 6 (Class 1,000). The three-level structure consists of a full subfab, the cleanroom level, and an air-handling level above the cleanroom. A perforated raised floor ensures unidirectional airflow and bulkhead-mounted equipment separates operational functions from maintenance functions. A combination of careful control of the airflow path, multiple stages of filtration, careful choice of materials, and non-ionic-steam humidification ensure the control of both particulate and molecular contamination.

For a virtual tour of the Scifres Nanofabrication Cleanroom, go to: https://tinyurl.com/ScifresTour
Research Centers

**C-BRIC**  The Center for Brain-inspired Computing (C-BRIC) is funded by SRC and DARPA under the JUMP center program. Led by Professors Kaushik Roy (Director) and Anand Raghunathan (Associate Director), C-BRIC has a mission to deliver key advances in cognitive computing that will enable a new generation of autonomous intelligent systems such as self-flying drones and interactive personal robots. C-BRIC is led by Purdue and includes researchers from 11 universities working on neuro-inspired algorithms and theory, neuromorphic computing fabrics, and distributed intelligence. C-BRIC brings together experts from machine learning, computational neuroscience, theoretical computer science, integrated circuits and systems, distributed computing, robotics, and autonomous systems to pursue improvements in cognitive systems that are difficult for these communities to achieve independently.

**CHIRP**  The Center for Heterogeneous Integration Research on Packaging (CHIRP) is co-directed by Ganesh Subbarayan of Purdue and Bahgat Sammakia of SUNY Binghamton. CHIRP’s mission is to enable the building of future Systems-in-Package through Heterogeneous Integration. The areas of CHIRP research focus include design enablement, global interconnects, power delivery, thermal management, modeling, metrology, and reliability that together optimally address the power, performance, area, and cost metrics of systems. CHIRP also works to educate engineers who can design and build heterogeneously integrated systems. The center was established in 2019 with support from ARM, Intel, IBM, MediaTek, NXP, Samsung, and Texas Instruments, and has since funded over $6M in projects. CHIRP engages nearly 20 investigators from Purdue and SUNY Binghamton.

**NEW LIMITS**  The NEW Materials for Logic, Memory and InterconnectS (NEW LIMITS) center is directed by Professor Zhihong Chen. The center’s vertically integrated mission is to develop synthesis, integration, and evaluation schemes for new materials that will be used in unique logic, memory, and interconnect applications to enable novel computing and storage paradigms beyond the capabilities of conventional CMOS. The key idea is to utilize the properties of 2D material systems that are NON-EXISTENT in traditional 3D materials to achieve the performance or realize the novel functionalities that existing technologies are not able to offer. The center covers the following research vectors: material and device research, nanofabrication and advanced manufacturing processes, innovative metrology and characterization, and simulation and modeling.
CSME | The Center for a Secure Microelectronics Ecosystem (CSME) was launched with support from founding companies TSMC and Synopsys in conjunction with support through a U.S. Department of Defense (DoD)-funded workforce development program. CSME is co-directed by Professors Joerg Appenzeller and Anand Raghunathan. CSME is a first-of-its-kind global partnership of academia, industry, and government to advance research and workforce development in designing secure microelectronics. Its aim is to enable the creation of secure semiconductor chips and related products, from the foundry to the packaged system, based on a zero-trust model. CSME will provide advanced training opportunities to SCALE participants, while SCALE will support CSME through graduate traineeships, addressing the urgent need for engineering graduates with secure microelectronics skills.

ICC | The Institute for Cognitive Computing aims to advance the field of cognitive computing through cross-layer innovation spanning brain-inspired computing models, algorithms, architecture, and hardware fabrics. The institute brings together faculty with diverse backgrounds to pursue these goals by facilitating collaborative research and training the next generation workforce in this critical domain.

CTRC | The Cooling Technologies Research Center (CTRC) is a graduated National Science Foundation Industry/University Cooperative Research Center and addresses pre-competitive, longer-term research and development issues in the area of high-performance heat removal from compact spaces.
Research Excellence

Purdue research in semiconductors spans the “full stack” from materials and devices, to circuits, systems, and architecture.

Advanced Packaging and Heterogeneous Integration

*Co-directed by Professors Handwerker and Subbarayan*

Purdue is home to one of the nation’s leading programs in advanced packaging and heterogeneous integration. Purdue co-leads the Semiconductor Research Corporation’s Center for Heterogeneous Integration Research in Packaging (SRC CHIRP), the only advanced packaging center in the SRC portfolio. In addition, Purdue leads the SRC n-CORE NEW LIMITS: NEW materials for Logic, Memory and InTerconnectS Center, co-funded by SRC members and NIST to develop synthesis, integration, and evaluation schemes for new BEOL materials for unique logic, memory, and interconnect applications to enable novel computing and storage paradigms beyond the capabilities of conventional CMOS. Complementing the above two SRC centers is the Cooling Technologies Research Center (CTRC), a graduated National Science Foundation Industry/University Cooperative Research Center (NSF/IUCRC), that has conducted leading-edge research on the thermal management of electronics for nearly 25 years. The Purdue team is addressing a critical research gap—the need to enable quick-turn, top-down packaged system development is an ability to automatically convert design intent into packaging strategy, materials selection, appropriate thermal solutions, and package circuit layout.

With a total of 24 faculty in advanced packaging across Purdue’s College of Engineering, the Purdue team is focused on developing game-changing technologies such as electrical-thermal-mechanical deep co-design tools and techniques to translate design intent into automated package circuit layout. Specific research activities include Machine Learning (ML) assisted computational models that match multiphysics behavior of packages accurately, low power interconnects, advanced power-delivery solutions, innovative thermal solutions for die stack as well as package-level cooling, and advanced x-ray metrologies that enable real-time defect metrology, while also meeting the reliability and manufacturing yield goals so necessary for translating R&D to technology innovation. The goal of Purdue research is to enable a 50 times reduction in system realization time from architectural design to packaging.

Novel Approaches to Information Processing: Cognitive Computing

The boundary between memory and processing that was drawn clearly in the early days of computing by von Neumann still defines virtually all modern computing platforms, but the gap between processor and memory speeds has grown to create the daunting “memory wall” that threatens to stymie further progress in computing system performance. Further, the energy cost of moving data between DRAM and processors in the roughly 100 million computer servers in the world exceeds the output of over two Hoover Dams! After decades of progress in computing systems, we must revisit the von Neumann paradigm. Professors Roy and Raghunathan lead research on new approaches to information processing in C-BRIC, the $36M SRC/DARPA Center for Brain-inspired Computing and in the Institute for Cognitive Computing. The goal is to deliver key advances in cognitive computing to enable a new generation of autonomous intelligent systems.
Cognitive computing brings together leading researchers from the fields of machine learning, computational neuroscience, theoretical computer science, neuromorphic hardware, distributed computing, and robotics and autonomous systems. Artificial Intelligence (AI) Hardware, another area of particular strength at Purdue, is also within the scope of the SRC/DARPA Center for Brain-inspired Computing. Eight faculty members from the School of ECE, with an ongoing search targeting two new hires, contribute to this effort. A major part of C-BRIC is focused on Compute-in-Memory (CiM) for efficient AI and data analytics. Computing-in-Memory (CiM) fundamentally blurs the distinction between processing and memory by bringing them closer, and in the extreme embedding processing capabilities within memory arrays. Besides radically improving the performance and energy efficiency of computing systems, CiM has the potential to enable entirely new categories of products and markets. Purdue researchers have pioneered several advances in the design of CiM systems and demonstrated them through tape outs of chips. A few of the recent tape outs include a 35.5 – 127.2 TOPS/W dynamic sparsity-aware reconfigurable-precision Compute-in-Memory SRAM macro for machine learning and a 65nm digital Compute-in-Memory Macro with fused weights and membrane potential for spike-based sequential learning tasks.

Atomic-Scale Engineering of Semiconductor Materials and Devices

Under the leadership of Professor Ye, Purdue faculty are actively engaged in the exploration of novel electronic materials and devices for post-Moore era semiconductor technologies. One of the utilized technologies is called atomic layer deposition (ALD). ALD is a thin-film deposition technique with atomic-scale controllable accuracy based on the sequential use of a self-limiting chemical process; it is a subclass of chemical vapor deposition. ALD became an enabling technology for the continuation of Moore’s law by integrating high-k dielectrics in Si CMOS processes. ALD is a key process in fabricating semiconductor devices in particular as the dimension of state-of-the-art device technology is approaching single-digit nanometer length scales.

In the past decades, we have been working actively on ALD dielectrics and their integration on traditional and novel semiconducting channel materials including Si, Ge, III-V compound semiconductors, 2D materials, and oxide semiconductors. Beyond high-k and higher-k dielectrics, we also have explored ALD-grown ferroelectrics such as HfZrO2 for emerging logic and memory applications (IEDM 2021). More recently, we pioneered the use of the ALD technique to form atomically thin oxide semiconductor channels with remarkable performance including unprecedented ultra-high drain currents and transconductances among all field-effect transistors based on any semiconductor materials (Nature Electronics 2022). ALD interlayers can also be used a phonon spectrum match buffer to enhance the thermal dissipation and electrical-thermal co-design of atomic-scale electronic devices.

Beyond graphene and transition metal dichalcogenides (TMDs) 2D materials research, Purdue faculty pioneered phosphorene (ACS Nano 2014) and tellurene (Nature Electronics 2018), two special elemental van der Waals 2D monolayers of phosphorus and tellurium with thickness less than one nanometer. We systematically studied their electrical, optical, thermal, and mechanical properties and their applications for electronic devices. More interestingly, we are able to form a single atomic chain of tellurium atoms towards the smallest semiconductor channel (Nature Electronics 2020).

These efforts are enabled by the Birck Nanotechnology Center, which is a state-of-the-art facility that allows atomic-scale nanomaterial synthesis and prototype atomic-scale fabrication and characterization.
Research Excellence (cont’d)

Novel Approaches to Information Processing: Probabilistic Spin Logic

Probabilistic Spin Logic (PSL) is a novel approach for information processing that is being explored by a team led by Professors Datta, Chen, and Appenzeller. The majority of today’s digital circuitry is based on building blocks called bits that are deterministically 0 or 1. At the other end of the spectrum are quantum computers consisting of qubits which occupy some superposition of 0 and 1. The probabilistic-bit occupies a niche between these extremes, sharing qualities with both the classical-bit and the quantum-bit. The p-bit fluctuates probabilistically between 0 and 1, and can be pinned to one or the other state based on the magnitude and sign of its input. For a popular description see IEEE Spectrum at https://ieeexplore.ieee.org/abstract/document/9393992.

Just as a bit is only useful when in conjunction with other bits, p-bits can be correlated to form p-circuits. These circuits can be programmed to tackle a variety of problems that are often targeted by quantum computing, such as optimization, inferencing, and data encryption and decryption—without, however, the need for ultra-low temperatures. It is in the variety of applications, and the classical nature of the p-bit, that this building block comes to life, providing orders of magnitude improvement in performance (see Applied Physics Letters at https://aip.scitation.org/doi/full/10.1063/5.0067927) over standard CPU and GPU implementations.

To date the Purdue team has published many other breakthroughs (for an overview see https://ieeexplore.ieee.org/abstract/document/8995804), most notably an experimental demonstration of optimization and invertible logic using unstable magnetic tunneling junctions (MTJs), see Nature (https://www.nature.com/articles/s41586-019-1557-9), and the feasibility of MTJs to demonstrate that complex circuit operations are achievable in realistic hardware systems. This is particularly exciting because it demonstrates the feasibility of fabricating compact energy-efficient hardware p-bits by modifying existing magnetic random access memory (MRAM) technology.

For more information, see: https://www.purdue.edu/p-bit/.
To learn about a company commercializing this technology, see: https://ludwigcomputing.com/.
Emerging Logic, Memory, and Interconnect Technologies

Purdue Professors Alam, Appenzeller, Chen, Janes, and Ye are actively engaged in the exploration of emerging logic, memory, and interconnect technologies. Purdue's leadership is apparent from the support that these faculty receive from the Semiconductor Research Corporation (SRC) through center-level activities such as the nCORE NEW LIMITS Center (directed by Professor Chen) and JUMP, where Purdue PIs are involved in the ASCENT Center. In particular, these faculty have focused on experimental demonstrations of the above technologies based on novel materials including low-dimensional materials and ferroelectrics.

Professor Ye has been at the forefront of exploring novel materials for ferroelectric memory applications, and oxide-based channel materials such as In2O3 for back-end-of-line (BEOL) in-memory computing that requires transistors with ultra-low standby power specs and high on-current capabilities. Professor Ye has worked in strong collaboration with Professor Alam, who focuses on the reliability physics of these unexplored novel active device elements.

Professors Chen and Appenzeller have experimentally demonstrated that novel low-dimensional materials such as transition metal dichalcogenides (TMDs) with body thickness less than one nanometer can be utilized as channel materials in ultra-high performance transistors and offer performance beyond what silicon technologies can offer. Their work highlights the excellent scalability of devices from TMDs for the next generations of logic computing units.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9372049

The same sub-1nm thickness also proved highly promising for the use of TMDs as diffusion barriers in future back-end-of-line (BEOL) interconnect technologies.

https://aip.scitation.org/doi/10.1063/5.0013737

Professors Chen and Appenzeller also observed that MoTe2 (a member of the TMD family) based memories give rise to a novel type of phase change switching that is controlled by electric fields. This is a low-power, fast switching memory that combines the characteristics of resistive random access memories (RRAM) and phase change memories (PCM).

https://www.nature.com/articles/s41563-018-0234-y

These efforts on emerging technologies are enabled by the Birck Nanotechnology Center, which is a state-of-the-art facility that allows prototype fabrication and characterization at scale.
Reliability of Semiconductor Logic and Memory Devices

Under the leadership of Professor Alam, Purdue is well-known for fundamental work on the reliability physics of semiconductor logic and memory devices, both for application-specific consumer electronics and radiation-hardened secure electronics for defense applications. A variety of test equipment available at the Birck Center would support the development of new performance/reliability characterization techniques for DRAM and Flash memories.

It is well known that bit errors (and “repeated-read” security failures) increase significantly as DRAM transistors are scaled below 28-32 nm node because the stored charge at the capacitor node and the leakage through the access transistor are sensitive to transistor scaling. Radiation-induced charge loss and SILC-related gate leakage are concerns that must be addressed. Similarly, next-generation 3D NAND Flash memories will continue to grapple with read-margin, retention, and endurance issues arising from: (a) the threshold-voltage variation due to ambient temperature-sensitivity of polysilicon channel mobility, (b) threshold-voltage fluctuation due to trapping/de-trapping in the tunnel oxides, and (c) the reduced channel cross-section and enhanced field making the bottom cells susceptible to correlated HCI, TDDB, and radiation damages. There is an opportunity to develop a more efficient ECC because the bit-flips in 3D NAND Flash are likely to be correlated. Further, for the Compute-in-Memory (CiM) applications involving both logic and memory transistors, classical ECC may not be relevant.

In short, Purdue can support the development of new characterization techniques and physics-based reliability models for HCI, SILC, TDDB, and radiation-related reliability issues of DRAM and Flash memories. These reliability models will be informed by a deep understanding of the cross-layer design considerations, including those arising from heterogeneous integration (HI) that defines the thermal and stress-related cross-talk among various components.
Sustainability of Electronic Ecosystems

Sustainability is a core value at Purdue, as evidenced not only in green buildings and clean energy, but also in creating technologies that make the world a better place. Under the leadership of Professor Handwerker, Purdue is committed to the "Double Bottom Line" to care for people and the planet through the development of new technologies.

Purdue has a strong tradition in quantifying the economic, environmental, and societal impacts of the decisions made in early-stage R&D on the ultimate impacts in the realized products and their global supply chains. We welcome collaborations in coupling sustainability R&D at Purdue with the supply chains, technology developers, and decision-makers of companies. Three examples of recent collaborations that could serve as models are:

1. DOE Critical Materials Hub in which Purdue provides quantification of both commercialization potential and environmental impact of technologies being developed by researchers from four DOE Labs, ten companies, and eight universities;

2. iNEMI Project on Value Recovery from End-of-Life Electronics, co-led by Purdue, in which Seagate, Google, Microsoft, Cisco, and others demonstrated nine circular economy technologies for remanufacturing, reuse, and recovery of rare earth magnets in hard drives; and

3. NSF graduate education and training program on Design for Globally Sustainable Electronics in which DBL is a central tenet, with a customizable curriculum based on partner company needs. For the latter, these courses are part of the new MS in Semiconductors and Microelectronics at Purdue and the undergraduate certificate in Semiconductors.

Finally, Purdue not only has deep expertise in R&D but also in workforce development to address issues of local, regional, and global concern, including but not limited to clean energy, smart grids, system design and operation for Net Zero, and developing leadership for creating and operating sustainable systems.
Faculty

Heterogeneous Integration and Advanced Packaging

John Blendell
*Professor, School of Materials Engineering*
Modeling and measurement of microstructure development using advanced characterization techniques to predict reliability.

Nikhilesh Chawla
*Ransburg Professor, School of Materials Engineering*
Four-Dimensional (4D) materials science with a particular emphasis on the deformation behavior of advanced materials at bulk and small length scales characteristic of advanced packaging.

Chelsea Davis
*Assistant Professor, School of Materials Engineering*
Molecular visualization of interfacial mechanics, including adhesion, friction, and wetting novel measurements of polymer interfacial properties and mechanics.

John Howarter
*Associate Professor, School of Materials Engineering and Environmental and Ecological Engineering*
Reducing the operational energy footprint of polymer membranes through material design.

Carol Handwerker
*Reinhardt Schuhmann Jr. Professor, School of Materials Engineering and Environmental and Ecological Engineering*
Alloy and process design for bonding and heterogeneous integration, stress relaxation in thin films kinetics of diffusion, and migration processes at interfaces circular economy pathways for electronics.

Amy Marconnet
*Associate Professor, School of Mechanical Engineering*
Transport phenomena in multi-scale, heterogeneous materials and systems fundamentals of nanoscale thermal transport electronics cooling and thermal management.

Liang Pan
*Associate Professor, School of Mechanical Engineering*
Scalable nanomanufacturing: lithography and imaging optical and magnetic data storage nanoscale energy conversion, transfer, and storage for alternative energy.

Ganesh Subbarayan
*Professor, School of Mechanical Engineering and Co-director, SRC Center for Heterogeneous Integration Research in Packaging (CHIRP)*
Heterogeneous Integration and Advanced Electronics Packaging with a focus on thermomechanical behavior, reliability, and electrical-thermal-mechanical co-design.

Tiwei Wei
*Assistant Professor, School of Mechanical Engineering*
Advanced Semiconductor Packaging and Heterogeneous Integration with a focus on processing, materials, and architecture development, Chip-Package Interactions, Reliability, and Efficient thermal management technologies.

Justin Weibel
*Associate Professor, School of Mechanical Engineering*
Electronics cooling and packaging phase-change transport phenomena microscale and nanoscale surface engineering for enhanced thermal transport.

Xinghang Zhang
*Professor, School of Materials Engineering*
Synthesis of nanomaterials, radiation damage in nanostructured materials, mechanical behavior of nanostructured metals, and dynamics of metal bonding.
Sensors and Thermal Imaging

Peter Bermel
Elmore Associate Professor, Elmore Family School of Electrical and Computer Engineering
Nanophotonics, including photovoltaics, lighting, thermal physics, sources, detectors, and switches.

Rahim Rahimi
Assistant Professor, School of Materials Engineering
Scalable manufacturing processes of flexible electronic devices that can empower technologies for health-care and environmental monitoring.

Ali Shakouri
Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist exploring quantum electronics, mutual interaction of heat, light, and electricity in nanomaterials and devices, lock-in imaging and advanced image processing with applications to nanoscale thermal measurements and roll-to-roll process monitoring.

Dana Weinstein
Associate Dean of Graduate Education, College of Engineering and Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist exploring new mechanical designs and efficient transducers to make MEMS resonators with high resonance frequency, low motional impedance, strong transducer coupling coefficient, low bias drift, and wide programmable range.

MEMS and Photonics

Sunil Bhave
Associate Director of Operations, Birck Nanotechnology Center and Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist exploring inter-domain coupling in Opto-mechanical, Spin-Acoustic and Atom-MEMS devices to design and fabricate inertial sensors, clocks, frequency combs, and computing and microwave sub-systems.

Mahdi Hosseini
Assistant Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist investigating quantum interaction of light with atoms and its role in quantum optical communication, computation, and sensing. Working towards developing a hybrid and scalable platform for future quantum optical technologies.

Dimitri Peroulis
Michael and Katherine Birck Head, Reilly Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist focusing on reconfigurable analog/RF electronics for adaptive communications, signal intelligence, and harsh-environment sensors.

Minghao Qi
Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist interested in Nanotechnology, especially 3D nanofabrication and low-cost nanolithography micro and nanophotonics, with emphasis on 3D photonic crystals and integrated Si photonic circuits thermophotovoltaics and solar cells.

Xianfan Xu
James I. and Carol L. Shuttleworth Professor, School of Mechanical Engineering, by courtesy in Elmore Family School of Electrical and Computer Engineering
Ultrafast optical and nanoscale optical technologies applied to energy transfer study and development of advanced manufacturing methods.
Faculty (cont’d)

New Devices, Materials, and Fabrication

Ashraf Alam  
Jal N. Gupta Professor, Elmore Family School of Electrical and Computer Engineering  
Experiments and simulations of reliability aspects in novel logic and memory devices. Also investigates radiation damage of devices and circuits.

Joerg Appenzeller  
Barry M. and Patricia L. Epstein Professor, Elmore Family School of Electrical and Computer Engineering and Scientific Director of Nanoelectronics  
Experimentalist working on low-dimensional transport for logic and memory applications. Also designs, fabricates, characterizes and analyzes novel devices and circuits from transition metal dichalcogenides (TMDs), carbon nanotubes (CNTs) and magnetic tunnel junctions (MTJs).

Shubhra Bansal  
Associate Professor, School of Mechanical Engineering  
Bansal research group works on dimensionally modified halide perovskite and chalcogenide compound semiconductors. The goal is to develop novel functional materials, advanced device packaging, interconnection technologies and physics-based degradation models for lifetime prediction.

Thomas Beechem  
Associate Professor, School of Mechanical Engineering  
Experimentalist that characterizes various materials and devices employing time resolved, low-temperature photoluminescence, Raman spectroscopy, and near IR ellipsometry.

Alexandra (Sasha) Boltasseva  
Ron and Dotty Garvin Tonjes Professor, Elmore Family School of Electrical and Computer Engineering  
Experimentalist working on optical meta-materials and quantum materials.

Zhihong Chen  
Mary Jo and Robert L. Kirk Interim Director, Birck Nanotechnology Center and Professor, Elmore Family School of Electrical and Computer Engineering  
Experimentalist working on novel materials for logic and interconnect applications. Also an expert in developing concepts for back-end-of-line (BEOL) heterogeneously, monolithically integrated memory applications.

Supriyo Datta  
Thomas Duncan Distinguished Professor, Elmore Family School of Electrical and Computer Engineering  
Known for pioneering the non-equilibrium Green function (NEGF) model widely used in the semiconductor industry to model nanoscale electronic devices. Also known for creative proposals that inspired new fields of research like negative capacitance devices, spintronics, and probabilistic bits.

Muhammad Hussain  
Professor, Elmore Family School of Electrical and Computer Engineering  
Design and development of advanced complementary metal oxide semiconductor (CMOS) electronics and integration of highly manufacturable, widely deployable and low cost futuristic electronic systems for logic computing, handheld/wearable smart gadgets, defense, healthcare, environmental monitoring, robotics, and automation.

David Janes  
Professor, Elmore Family School of Electrical and Computer Engineering  
Nanoscale electronic devices, molecular/semiconductor devices, microwave devices, and characterization.

Haitong Li  
Assistant Professor, School of Electrical and Computer Engineering  
New memory device technologies and circuit designs for energy-efficient computing, spanning experimental, design, and system integration aspects for creating nanotechnology-inspired hardware chips.
New Devices, Materials, and Fabrication (cont’d)

Mark Lundstrom
Interim Dean, College of Engineering
Don and Carol Scifres Distinguished Professor, Elmore Family School of Electrical and Computer Engineering and Senior Advisor on Microelectronics to Executive Vice President for Strategic Initiatives
Physics, modeling, and simulation of electronic and thermal transport in semiconductor devices.

Mike Manfra
Bill and Dee O’Brien Distinguished Professor of Physics and Astronomy; Professor, Elmore Family School of Electrical and Computer Engineering; Professor, School of Materials Engineering; Scientific Director, Microsoft Quantum Lab Purdue
Quantum physicist developing novel qubit hardware in semiconductor and hybrid superconductor/semiconductor systems. Work includes semiconductor growth, mesoscopic device fabrication, and low temperature electron transport.

Issam Mudawar
Betty Ruth and Milton B. Hollander Family Professor, School of Mechanical Engineering
Sensible and evaporative heating of thin films, pool boiling, flow boiling, jet-impingement cooling, spray cooling, micro-channel heat sinks, heat transfer enhancement, heat transfer in rotating systems, critical heat flux, and capillary pumped flows.

Pramey Upadhyaya
Assistant Professor, Elmore Family School of Electrical and Computer Engineering
Theorist exploring magnetism, classical and quantum spintronics, next-generation information processing and bio-devices.

Haiyan Wang
Basil S. Turner Professor, Elmore Family School of Electrical and Computer Engineering and School of Materials Engineering
Design and processing of functional nanocomposite thin films for microelectronics, optoelectronics, high-temperature superconductors, solid oxide fuel cells, plasmonics and photonics, ferroelectric and ferromagnetic applications, and radiation tolerant materials.

Peide (Peter) Ye
Richard J. and Mary Jo Schwartz Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist with a deep understanding in various atomic layer deposition solutions. Also interested in novel ferroelectric materials for ferroelectric memory and oxides for novel logic and BEOL applications.
Faculty (cont’d)

Simulation and Modeling

Edwin Garcia  
*Professor, School of Materials Engineering*  
Microstructural modeling of multifunctional materials, including solder-based interconnects microstructural evolution and phase transformations in confined geometries reliability and optimization of FeRAMs, and portable power sources.

Dan Jiao  
*Synopsys Professor, Elmore Family School of Electrical and Computer Engineering*  
CAD design expert exploring computational electromagnetics, modeling and simulation of micro- and nano-scale integrated circuits, high-speed VLSI circuit design and analysis, high-performance VLSI CAD, applied electromagnetics, signal and power integrity, fast and high-capacity numerical methods, scattering and antenna analysis, and bio-electromagnetics.

Gerhard Klimeck  
*Director of the Network for Computational Nanotechnology; Reilly Director of the Center for Predictive Materials and Devices; and Professor, Elmore Family School of Electrical and Computer Engineering*  
Theorist working on modeling of nanoelectronic devices, genetic algorithm based optimization, and image processing.

Marisol Koslowski  
*Assistant Head for Engagement and Partnerships and Professor, School of Mechanical Engineering*  
Finite Elements and Phase Field simulations of stress relaxation, kinetics, and diffusion in thin films. Integration of thermal, electrical, and mechanical fields to predict failure in electronics.

Tillmann Kubis  
*Katherine Ngai Pesic and Silvaco Research Associate Professor, Elmore Family School of Electrical and Computer Engineering*  
Theorist exploring equilibrium and non-equilibrium phenomena in nanodevices and molecules. This covers electronic and phonon band structures as well as heat, charge, and spin transport in nanodevices.

Carol Handwerker  
*Reinhardt Schuhmann Jr. Professor, School of Materials Engineering and Environmental and Ecological Engineering*  
Alloy and process design for bonding and heterogeneous integration, stress relaxation in thin films kinetics of diffusion, and migration processes at interfaces circular economy pathways for electronics.

Inez Hua  
*Professor, School of Civil Engineering and Environmental and Ecological Engineering*  
Environmental sustainability, water pollution control, and the environmental fate of organic contaminants; water consumption in supply chains; sustainable electronics and environmental sustainability in engineering education.

Sustainability and Life Cycle Analysis
Sustainability and Life Cycle Analysis (cont’d)

Ganesh Subbarayan
Professor, School of Mechanical Engineering and Co-director, SRC Center for Heterogeneous Integration Research in Packaging (CHIRP)

John Sutherland
Fehsenfeld Family Head, Environmental and Ecological Engineering
Environmentally responsible design and manufacturing, sustainable systems, decision-making for sustainability, manufacturing, corporate social responsibility, and sustainability education.

Fu Zhao
Professor, School of Mechanical Engineering and Environmental and Ecological Engineering
Environment friendly design and life cycle engineering for sustainable electronics, sustainable energy, and manufacturing high-performance buildings.

Integrated Circuits and Systems Design

Sumeet Gupta
Elmore Associate Professor, Elmore Family School of Electrical and Computer Engineering
Theorist exploring device-circuit co-design in emerging nanotechnologies for Boolean and non-Boolean computing, spintronics, low power variation tolerant VLSI design, and device-circuit modeling.

Byunghoo Jung
Professor, Elmore Family School of Electrical and Computer Engineering
VLSI designer of circuits and systems for wireless sensing applications.

Saeed Mohammadi
Professor, Elmore Family School of Electrical and Computer Engineering
Experimentalist exploring nanoscale electronic devices including devices based on carbon nanotubes and nanowires, nanoelectromechanical devices, RF devices, device characterization and modeling, RF and microwave circuits, low-power electronics, 3D integration, optoelectronics, and nanofluidic and vacuum electronic.

Anand Raghunathan
Professor, Elmore Family School of Electrical and Computer Engineering
Kuhardware for AI and machine learning, compute near and in memory, and secure microelectronics.

Vijay Raghunathan
Professor, Elmore Family School of Electrical and Computer Engineering
Expert in embedded systems, Internet-of-things and energy-efficient and secure embedded computing.

Kaushik Roy
Edward G. Tiedemann Jr. Distinguished Professor, Elmore School of Electrical and Computer Engineering and Director of Center for Brain-Inspired Computing, a DARPA/SRC JUMP Center
Neuromorphic computing, device-circuit-architecture co-design for AI workloads, computing-in-memory, robust and secure system design, and energy-efficient integrated circuits and systems.

Shreyas Sen
Elmore Associate Professor, Elmore Family School of Electrical and Computer Engineering and Biomedical Engineering
VLSI and circuit design, sensing and communication circuits/systems, energy-harvested sensor nodes for internet of things (IoT), analog/Rf, wireless, and security.
National Policy and Global Reach

Krach Institute for Tech Diplomacy at Purdue

The Krach Institute for Tech Diplomacy at Purdue leverages the expertise of Purdue University and diplomatic leaders to bridge the knowledge and experience gaps between innovators and policymakers. The Institute's objective is to ensure that leaders of the United States and like-minded nations are able to understand critical emerging technologies and make informed laws and policy decisions. As a critical technology for national security, semiconductors is one of the focus areas for the Institute.

Krach Institute and Purdue experts provide research results and training to policymakers, diplomats, and other key stakeholders that are vital to U.S. foreign policy and national security interests. Training programs are designed for busy professionals who are not technical experts—courses will be offered in a variety of formats ranging from asynchronous, self-paced, short-term modules to intensive, in-person, instructor-led workshops in which many participants will have the opportunity to analyze issues together as a cohort.

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https://techdiplomacy.org/

Indiana Economic Development Corporation’s Taskforce for Accelerating Microelectronics Production & Development

The Indiana Economic Development Corporation (IEDC) launched the Accelerating Microelectronics Production & Development (AMPD) task force. AMPD, created to bolster the state’s efforts to become a leading state in the semiconductor industry, accelerates and supports microelectronics research and innovation in Indiana by securing commercial semiconductor and federal funding opportunities.

Comprised of industry experts, Indiana’s leading universities and public institutions, AMPD leverages Indiana’s advantages to attract significant investments by connecting semiconductor companies with local resources and assets, including skilled talent, prime real estate, and competitive investment packages.

For details please contact James Costa, SVP, Innovation & Semiconductor Strategy at IEDC: JCosta@iedc.IN.gov.
Purdue Semiconductors Info Session

Come learn about what Purdue has to offer in semiconductor degrees and courses. Hear from industry leaders about careers and other opportunities in semiconductors.

**When**  
Tuesday, September 13 | 6PM-8PM

**Where**  
Wilmeth Active Learning Center 1055 (WALC)

**Topics**  
6PM  
- Purdue Semicon导器 Degree and Course Overview  
- Industry Overview and SkyWater Plans  
- Semiconductor Companies Profile  
7PM  
- Industry and Student Networking

**Speakers**  
Dr. Mark Lundstrom, Purdue College of Engineering Interim Dean  
Tom Sonderman, SkyWater President and CEO

**COMPANIES REPRESENTED**
- Air Liquide America  
- Amazon  
- AMD  
- Applied Materials  
- ASM America  
- ASML  
- Cisco  
- Crane Aerospace & Electronics  
- GlobalFoundries  
- Hemlock Semiconductor  
- Infineon Technologies  
- Intel  
- KLA  
- Lam Research  
- Marvell  
- Micron Technology  
- NSWC–Crane Division  
- Reliable MicroSystems  
- Samsung Austin Semiconductor  
- Sandia National Labs  
- SkyWater Technology  
- Synopsys  
- TEL – Tokyo Electron  
- Texas Instruments  
- TSMC

This event is open to Purdue engineering and non-engineering students.

Register for the Info Session at: https://bit.ly/SEMIOVERVIEW

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