U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
HEARING CHARTER

Strengthening the U.S. Microelectronics Workforce

Tuesday, February 15, 2022
10:00 am – 12:00 pm
Zoom

PURPOSE

On Tuesday, February 15, 2022, the Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing to understand the critical workforce needs of the U.S. microelectronic manufacturing sectors as part of the ongoing investments in increasing domestic production. The Subcommittee will examine current semiconductor workforce and training pipelines; explore gaps between current and future workforce needs; and discuss strategies to expand and diversify the microelectronics workforce.

WITNESSES

- **Ms. Shari Liss**, Executive Director, SEMI Foundation
- **Dr. Osama Awadelkarim**, UNESCO Chair Professor and Director of the Center for Nanotechnology Education and Utilization (CNEU), Pennsylvania State University
- **Dr. Tsu-Jae King Liu**, Dean and Roy W. Carlson Professor of Engineering, University of California, Berkeley

OVERARCHING QUESTIONS

- What are the major challenges that have led to the workforce shortfall in the microelectronics industry?
- How can we raise awareness about microelectronics career opportunities across all levels of education?
- What are the effective pathways to prepare professionals for the workforce, including access to hands-on experiences and apprenticeships?
- How can we increase diversity, equity, and inclusion within the semiconductor workforce?
- Where should Congress focus efforts workforce development efforts to meet the growing needs of the microelectronics manufacturing sector?

MICROELECTRONICS OVERVIEW

Advanced microelectronics are a primary driver of economic growth and scientific advancement. These devices enable nearly everything in our modern lives —from smartphones and cars to nuclear weaponry. Microelectronics is a term describing all aspects of the miniaturization of electronic circuits and components, from fundamental research to design to manufacturing. Semiconductors are a subset of microelectronics. Most modern semiconductors are integrated circuits, also called "chips", which are sets of miniaturized electronic circuits composed of active discrete devices (e.g., transistors), passive devices (e.g., capacitors), and their interconnections, all of which are layered on a thin wafer of semiconductor material (e.g., silicon).

Semiconductor production includes three segments: (1) design, (2) manufacturing/fabrication, and (3) assembly, testing, and packaging (ATP).[1] In some cases, these steps are all performed by a single company, called an integrated device manufacturer (IDM). Other semiconductor companies, called fabless firms, only do design in-house. Fabless firms purchase fabrication services from a semiconductor factory and ATP services from an outsourced semiconductor assemble and test company. Additionally, the semiconductor production process requires several types of inputs, including materials, manufacturing equipment, software, and intellectual property, some of which is produced only outside of the United States.

U.S. Microelectronics Manufacturing Capacity Went Abroad

Over the last few decades, much of the U.S. microelectronics manufacturing capacity has been offshored. The U.S. share of global semiconductor manufacturing decreased from 37 percent in 1990 to just 12 percent today.[2] This occurred in part because it became cheaper to fabricate semiconductors abroad, and many semiconductor companies moved these labor-intensive elements of their supply chain to Asia. For example, Taiwan accounts for 47 percent of the global capacity to manufacture advanced logic semiconductors, such as those used in smart phones or data centers.[3] Other companies simply stopped manufacturing semiconductors themselves, becoming "fabless" design companies.

With the decrease in U.S. manufacturing came a subsequent loss of the U.S. semiconductor workforce, especially the technical workforce. Today, many countries in Asia have a competitive advantage over the United States in terms of high-skilled workforce capacity for semiconductor manufacturing. This lack of available technical workers is part of the reason that the United States does not have a single state-of-the-art fab capable of making the most advanced microelectronics. Efforts to expand and diversify the U.S. microelectronics workforce will be a critical piece of the effort to bring microelectronics manufacturing back to the United States.

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[1] Michaela Platzer et al., "Semiconductors: U.S. Industry, Global Competition, and Federal Policy," Congressional Research Service, October 26, 2020.
[2] Antonio Varas et al., "Government Incentives and U.S. Competitiveness in Semiconductor Manufacturing," Semiconductor Industry Association, September 2020.
[3] Varas et al., "Government Incentives and U.S. Competitiveness in Semiconductor Manufacturing."

SEMICONDUCTOR JOB TYPES AND PIPELINES

The American semiconductor industry employs an estimated 277,000 people in a wide range of technical jobs with unique skills and educational backgrounds.[4] Although there is significant breadth across employers and technology sectors, it is useful to segment jobs into the following categories to understand the broader education and workforce training strategies.

- Production - Comprising 38% of semiconductor sector jobs this category includes line workers and factory technicians.[5] While training is very specific to the job, positions may often require technical coursework including fundamental mathematics and physics. Training for production occupations may be well suited to certificate and associate degree programs at community and technical colleges, apprenticeships, or other on the job training. Examples of this job include assemblers, fabricators, maintenance, and repair workers. Production employees are able to easily move jobs between companies as well as to adjacent sectors, such as battery or solar manufacturing.[6]
- Engineering – Making up 24% of jobs in the industry this category includes engineers, software developers, research staff, and chip designers. Employees in this category typically hold a bachelor's degree or higher in electrical or computer engineering. R&D and design staff typically have advanced degrees with experience in academic research. Highly skilled staff may also have degrees in other physical and mathematical disciplines. Employees in this sector, especially those with advanced technical skills, like data science and artificial intelligence, are highly sought by companies and are able to easily move throughout the semiconductor industry.
- Management, sales, and business operations – This group comprises all other aspects of semiconductor operations. Industry specific training typically occurs on the job, though employees with knowledge of the field are able to move between companies.

WORKFORCE DEMOGRAPHICS

To successfully grow domestic microelectronics manufacturing, the field will need to successfully attract, train, and retain a large and diverse workforce. In comparison to other sectors, the semiconductor industry currently lags in employing Black and Hispanic men, and women of all races and ethnicities. In 2021, the Semiconductor Industry Association (SIA) reported that Black employees held 4% of all jobs in the semiconductor workforce, compared to 10% and 12% of all manufacturing fields and all employment sectors respectively.[7] Similarly, Hispanic employees made up 13% of the workforce compared to 17% and 18% of the same categories. Moreover, less than a quarter of employees in the semiconductor workforce are women, and in a majority of companies women filled less than 1% of leadership roles.[8] Together

[4] "Chipping In: The Positive Impact of The Semiconductor Industry On The American Workforce And How Federal Industry Incentives Will Increase Domestic Jobs," Semiconductor Industry Association, May 2021.

[5] "Challenges and Opportunities Facing Semiconductor Workforce," Semiconductor Industry Association.

[6] Research and Technology Subcommittee Staff communications with industry and educators

[7] "Chipping In: The Positive Impact of The Semiconductor Industry On The American Workforce And How Federal Industry Incentives Will Increase Domestic Jobs," Semiconductor Industry Association, May 2021.

[8] "GSA: Women in the Semiconductor Industry," GSA and Accenture, 2019.

these data show a distinct employment discrepancy between the semiconductor industry and the American workforce, yet also indicate opportunity for growing the workforce.

The American semiconductor industry relies heavily on international talent. Approximately 40% of employees in engineering occupations within the semiconductor industry are foreign born, and most commonly originate from India, China, and Vietnam.[9] Most foreign-born employees are educated at U.S. universities before joining the industry. Industry representatives have repeatedly identified immigration policy as a barrier to growing the semiconductor workforce and have recommended policy reforms as remedy[10,11,12], including eliminating per-country green card caps, a measure proposed in the *America COMPETES* package that recently passed the House of Representatives.[13]

The semiconductor workforce demographic trends mimic those in related advanced degree programs in the United States. Specifically, women, and Black and Hispanic men are significantly underrepresented in electrical engineering and computer science programs, while international students make up about 80% of graduate students in these programs.[14]

OTHER WORKFORCE CHALLENGES

In comments to the National Institute of Standards and Technology on strengthening the semiconductor workforce, SIA listed a number of workforce-related challenges facing the industry: a lack of supply of U.S. workers with advanced education, a lack of academic programs supporting emerging technologies, high competition among tech industries for high skilled workers, low awareness of the semiconductor industry among graduate students in STEM, a lack of hands-on training to prepare graduates for work on the manufacturing floor, a lack of diversity in STEM, and retention issues due to cultural differences between young workers and the older workforce.[15] As in many other industries, the pandemic has only worsened the semiconductor industry's supply of high skilled workers.

Universities and colleges across the country will play an essential part of training the future semiconductor workforce; however, very few fully equipped programs exist today. There are many challenges to creating successful programs across all education levels, from technician certificates to postdoctoral training. Nearly all programs have limited access to equipment, which

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[9] Will Hunt and Remco Zwetsloot, "U.S. Strengths and Priorities for the High-End Semiconductor Workforce," the Georgetown Center for Security and Emerging Technologies, September 2020.

[10] Need for Green Cards for Highly Skilled Workers: Hearing before the U.S. House of Representatives Subcommittee on Immigration, Citizenship, Refugees, Border Security, and International Law of the Committee on the Judiciary, 110th Congress (2008). Link

[11] "Current and Future Workforce Needs to Support a Strong Domestic Semiconductor Industry," Semiconductor Industry Association, comments to National Institute of Standards and Technology, August 15, 2018.

[12] Will Hunt and Remco Zwetsloot, "U.S. Strengths and Priorities for the High-End Semiconductor Workforce," the Georgetown Center for Security and Emerging Technologies, September 2020.

[13] America COMPETES Act of 2022, H.R. 4521, 117th Congress, Link.

[14] Hunt and Zwetsloot, "U.S. Strengths and Priorities for the High-End Semiconductor Workforce."

[15] "Current and Future Workforce Needs to Support a Strong Domestic Semiconductor Industry," Semiconductor Industry Association, comments to National Institute of Standards and Technology, August 15, 2018.

may be highly specialized and expensive to acquire and maintain. Facility sharing, virtual instrumentation, and partnerships with industry can provide access to essential hands-on training. New programs will need to develop or obtain specialized curricula as well as the ability to attract and retain faculty and other instructors qualified to teach microelectronics. Other challenges include program connections to industry to ensure student job placements. Notably, low awareness of semiconductor careers has hindered enrollment across training programs of all levels. Many of these issues will greatly benefit from industry-university partnerships, curricula and best-practice sharing, coordination among programs, and new approaches to creating workforce training programs.

SEMICONDUCTOR INDUSTRY WORKFORCE PROGRAMS

Companies are developing training pipelines for semiconductor job placement and are creating new pathways for participation. For example, SEMI, a trade organization representing over 2,400 electronics manufacturers and suppliers, created the SEMI Career and Apprenticeship Network (SCAN). This national network aims to build a reproducible apprenticeship model to expand job awareness; recruit, train, and support building a diverse workforce, including targeting outreach to veterans; and help the industry accommodate a changing workforce. Industry is also focusing efforts on building enthusiasm for STEM in K-12 education, which will help prepare students for any technical job within the semiconductor industry whether she will become a technician or a cutting-edge chip designer. Early engagement and high school math and science coursework are crucial.

FEDERAL PROGRAMS SUPPORTING THE SEMICONDUCTOR WORKFORCE

Existing Programs

The Federal government has a long history of funding semiconductor workforce activities through several agencies, including the Department of Defense, the Department of Energy (DOE), the Department of Commerce, and the National Science Foundation (NSF). These agencies fund microelectronics research that can be used to train undergraduate and graduate students and postdoctoral scholars. NSF funds several Advanced Technological Education (ATE) programs that focus on semiconductor-related training at community and technical colleges.

Several major Federal technology initiatives have supported semiconductor workforce development programs as part of their implementation. From 1988 through 1996, Congress provided approximately $870 million through the Defense Advanced Research Projects Agency (DARPA) for an industry-led research consortium to support U.S. competitiveness in semiconductor technology, known as SEMATECH.[16] While the effort was largely focused on

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[16] Platzer et al., "Semiconductors: U.S. Industry, Global Competition, and Federal Policy."

technology development, SEMATECH created several workforce related programs and helped to develop curricula for students wanting to pursue semiconductor related degrees.[17] NSF, as part of the National Nanotechnology Initiative, funds the National Nanotech Coordinated Infrastructure (NNCI), which provides access to instrumentation and training to increase nanotechnology teaching and research across the country.[18] Specifically, nanoelectronics has long been part of that initiative. In 2018 and 2020, Congress signed into law the *National Quantum Initiative Act* and the *National AI Initiative Act*, respectively. Each of these initiatives on nanotechnology, quantum, and AI support workforce programs in fields that can be applied to semiconductor design and fabrication.

The CHIPS for America Act

To re-shore chip manufacturing and to advance U.S. competitiveness in microelectronics, in December 2020 Congress enacted the *Creating Helpful Incentives to Produce Semiconductors for America Act*, or *the CHIPS for America Act*.[19] The Act establishes a grant program at the Department of Commerce that would incentivize new domestic semiconductor manufacturing facilities. It also creates novel research programs, including a National Semiconductor Technology Center (NSTC), a National Packaging Center, and a national network for microelectronics research.

While federal investments to grow domestic semiconductor manufacturing capacity will likely increase the number of semiconductor-related jobs in the United States,[20] concerns remain about the U.S. capacity to fill those jobs. The *CHIPS for America* incentives are estimated to create 42,000 new, permanent semiconductor jobs.[21]

The *CHIPS for America Act* has workforce development requirements as part of its incentives program for new facilities, and through its newly established R&D programs. However, a broader national effort not tied to specific facilities may be necessary to establish a lasting microelectronics workforce. Notably, the Department of Commerce recently issued a request for information on the implementation of the CHIPS Act, which included questions about how the programs can bolster the workforce needs of industry.[22]

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[17] Lyn Mowafy, "A Modular Approach To Semiconductor Curriculum Development," Maricopa Advanced Technology Education Center, 1998.

[18] "About NNCI," *National Nanotech Coordinated Infrastructure*, accessed February 2022.

[19] Creating Helpful Incentives to Produce Semiconductors for America Act (CHIPS for America Act), Title XCIV, The William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, H.R. 6395, 116th Congress.

[20] "The Positive Impact Of The Semiconductor Industry On The American Workforce And How Federal Industry Incentives Will Increase Domestic Jobs," Semiconductor Industry Association, webinar, May 2021.

[21] "Chipping In: The Positive Impact of The Semiconductor Industry On The American Workforce And How Federal Industry Incentives Will Increase Domestic Jobs," Semiconductor Industry Association, May 2021.

[22] Incentives, Infrastructure, and Research and Development Needs To Support a Strong Domestic Semiconductor Industry, a notice by the Commerce Department, January 24, 2022.

Funding for the *CHIPS for America Act* is included in the *America COMPETES Act* which passed the House of Representatives on Feb 4, 2022.[23] Included in the same legislative package is the Microelectronics Research for Energy Innovation Act, led by Rep. Tonko. This bill would authorize a crosscutting initiative aimed at leveraging DOE capabilities, including its National Laboratory complex and its partners in industry and academia, to tackle foundational challenges in the scientific areas relevant to microelectronics and to support workforce development related to microelectronics.

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[23] America COMPETES Act of 2022, H.R. 4521, 117th Congress, Link.