SEMICONDUCTOR MANUFACTURING

15.0616.00

TECHNICAL STANDARDS

A Technical Standards Validation Committee developed and validated these standards on March 3 and April 2, 2025. The Arizona Career and Technical Education Quality Commission, the validating authority for the Arizona Skills Standards Assessment System, endorsed these standards on July 12, 2026.

Note: Arizona's Professional Skills are taught as an integral part of Semiconductor Manufacturing.

The Technical Skills Assessment for Semiconductor Manufacturing is available TBD.

Note: In this document i.e. explains or clarifies the content and e.g. provides examples of the content that must be taught.

STANDARD 1.0 ANALYZE THE FUNDAMENTALS OF THE SEMICONDUCTOR INDUSTRY

1.1 Define semiconductor (e.g., a material with electrical conductivity between a conductor such as metal and an insulator such as glass that can switch between these states, allowing it to control electric current)

1.2 Identify examples of semiconductor applications in everyday life [i.e., household appliances (refrigerators), computers (smartphones and smartwatches), entertainment (smart TV and streaming devices), medical equipment (imaging machines), transportation (electric cars), etc.]

1.3 Describe the semiconductor work environment (i.e., traditional office or lab setting; structured and collaborative; cleanroom atmosphere; shift work and fast paced; strict compliance to safety and controls, etc.)

1.4 Identify typical responsibilities, knowledge and skills for semiconductor entry-level operators [e.g., Typically operators prepare the environment; operate, monitor, and adjust equipment, including automated manufacturing equipment; and ensure quality control and document data recordings. Knowledge and skills include a foundation in electronics, materials science, and cleanroom protocols, and statistical process control (SPC) methodology, troubleshooting, and attention to detail.]

1.5 Identify typical responsibilities, knowledge and skills for semiconductor technicians [e.g., Typically technicians operate, monitor, maintain, and troubleshoot complex machines, and test wafers for imperfections. Knowledge and skills include a blend of technical, mechanical, and safety skills and photolithography/etching processes, electrical/mechanical troubleshooting, and data analysis (SPC/DOE).]

1.6 Identify typical responsibilities, knowledge and skills for semiconductor engineers (e.g., Typically engineers process, design, test, facilities infrastructure, maintenance, and quality control. Knowledge and skills include data analysis, troubleshooting, cleanroom protocols, programming languages, strong communication skills, and teamwork.)

1.7 Summarize basic knowledge and skills needed by all levels of semiconductor workers (e.g., foundation in math, physics, chemistry, and computers; a blend of highly technical expertise and practical problem-solving ability; understanding electronics, cleanroom protocols, and statistical process control; cross-functional communication skills; and adaptability to thrive in a fast-paced environment.)

1.8 Discuss overall education and training and career pathways for workers in the semiconductor industry (i.e., completion of CTE high school-related program, proficiency in professional skills, and on-the-job training; associate degree in electronics/microelectronic technology or semiconductor manufacturing; bachelor's degree for advanced roles such as Electrical Engineering, Computer Engineering, Advanced Manufacturing, etc.)

1.9 Define the semiconductor supply chain, its benefits, and major participants and their roles (i.e., globalized network focused on new products, technological innovation, strong relationships, and strategic importance in the global economy; major participants include Europe and Japan for raw material extraction, US and UK for design, Taiwan and South Korea for chip fabrication, and China and Southeast Asia for assembly and testing, etc.)

1.10 Research trends in the semiconductor industry (i.e., the application and development of AI models and algorithms, 3D and advanced packaging technologies, sustainable and eco-friendly manufacturing; career opportunities for engineers in design, process, systems, and AI (artificial intelligence) and ML (machine learning); research for new materials, advanced processes, next-gen devices, enhanced modeling/simulation, sustainable/reliable fabrication, etc.)

STANDARD 2.0 MAINTAIN A SAFE WORK ENVIRONMENT

2.1 Comply with workplace standards, rules, regulations, and safety training provided by OSHA (Occupational Safety and Health Administration) and COHE (Control of Hazardous Energy) [i.e., safe work attire and personal protective equipment (PPE), fall protection and lifting procedures, fire protection plan, emergency plan, safety data sheets (SDSs), lockout-tagout (LOTO) safety procedures, Total Recordable Incident Rate (TCIR) reports, etc.]

2.2 Identify common safety features in industrial and manufacturing environments and explain their purpose (i.e., emergency stop buttons on equipment, physical barriers and guarded areas, warning lights and audible alarms, LOTO indicators, ergonomic workstations, etc.)

2.3 Identify safe practices when working around electrical, electronic, and chemical systems (i.e., power down equipment before authorized work, use grounded tools or wrist straps when required, avoid liquids near electrical equipment, recognize labeled chemicals and proper ventilation, etc.)

2.4 Identify safety concerns when working with pressurized mechanical, hydraulic (fluid-controlled), and pneumatic (gas-controlled) systems (i.e., strict adherence to energy isolation, proper leak detection, maintenance procedures, etc.)

2.5 Identify safety procedures when working around automated and robotic systems (i.e., adhere to restricted zones, respond appropriately to alarms, respect interlocks and access controls, never bypass safety systems, etc.)

2.6 Explain the "fail safe" component integrated in robotic and automated systems (i.e., emergency shutdowns, interlocks, and sensor-based stops, etc.)

2.7 Utilize manufacturer's instructions on how to use machines and tools correctly, store them properly, and report damage or issues

2.8 Follow cleanroom protocol, housekeeping procedures, and standardized work practices to maintain safety, cleanliness, and product quality (i.e., proper gowning and de-gowning, keeping work areas clean and organized, eliminating trip hazards, documenting issues and near misses, reporting spills, damage, or injuries, etc.)

STANDARD 3.0 EXAMINE THE FUNDAMENTALS OF SEMICONDUCTOR MANUFACTURING

3.1 Identify and define key materials and concepts of semiconductor manufacturing (e.g., Key Materials: silicon wafers, photoresists, specialized gases, and deposits; Key Concepts: photolithography, doping, and deposition/etching)

3.2 Define the six critical semiconductor manufacturing steps: deposition, photoresist, lithography, etch, ionization, and packaging

3.3 Describe each major stage of semiconductor manufacturing (e.g., design, fabrication, testing, and assembly) and explain how support systems [i.e., automation, software, infrastructure (utilities, cleanroom mechanics, and automation tools), etc.] enable production

3.4 Explain manufacturing yield, including the stages of yield loss and factors affecting yield, final test yield, and yield reliability

3.5 Identify and discuss the types of equipment used in the manufacturing process [i.e., manual equipment: computer numerical controlled (CNC) machines, 3D printers, quality control equipment, material handling tools, maintenance and repair devices, fabrication equipment, etc.]

3.6 Explain the importance of quality assurance and identify QA processes used in manufacturing (i.e., planning and standards, documentation, cathode review, test cases, staging, etc.)

3.7 Explain quality control and change management processes and procedures used to ensure manufacturing success [e.g., documentation (SOPs), specialized tools (SPC), prototyping (mockups), traceability matrix (RTM), continuous feedback loops, structured problem-solving tools, and artificial intelligence (AI)]

STANDARD 4.0 EXAMINE SEMICONDUCTOR MANUFACTURING PROCESSES

4.1 Distinguish between characteristics (i.e., unique band gap, immediate conductivity, controllable, etc.) and properties (i.e., electrical conductivity, thermal conductivity, energy conversion, etc.) of semiconductors

4.2 Describe a semiconductor wafer [e.g., thin, polished slice of high-purity crystalline material (silicon) used as a substrate to build integrated circuits and microchips]

4.3 Describe an integrated circuit (chip) (e.g., small device developed by building layer upon layer that houses components such as transistors, resistors, and capacitors)

4.4 Describe a typical wafer flow process (i.e., depositing a layer of material, photo masking a pattern, removing parts of the deposited material to leave the masked pattern on the wafer)

4.5 Define deposition (adding material); differentiate between CVD, PVD, and ALD; identify where deposition fits in the wafer flow; and explain why uniformity of deposited material matters

4.6 Describe the planarization process and why flatness matters in semiconductor manufacturing (e.g., essential for minimizing surface irregularities in integrated circuit fabrication)

4.7 Define metrology (e.g., science of measurement to ensure accuracy, consistency, and traceability) and its importance to manufacturing (e.g., reduces waste from scrap, guarantees regulatory compliance, enhances efficiency, lowers costs, and ensures product reliability)

STANDARD 5.0 EXAMINE SYSTEMS IN SEMICONDUCTOR MANUFACTURING

5.1 Differentiate between pneumatic systems (gasses like compressed air) and hydraulic systems (liquids like oil)

5.2 Discuss the advantages of a pneumatic system (e.g., cleanliness, speed and precision, simplicity and cost, and safety)

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5.3 Identify the applications of a pneumatic system (e.g., wafer transport, pick-and-place, assembly, and general automation)

5.4 Discuss the characteristics of a hydraulic system (e.g., high force/power density, precision, lubrication, and limited roles)

5.5 Identify the applications of a hydraulic system (e.g., chemical delivery and etching, wafer processing, robotics and handling, cooling systems, and precise motion control)

5.6 Explain the fluid power system and how it uses hydraulic and pneumatic gas components

5.7 Define and describe the operation of piping components and systems

5.8 Define and describe the operation of pumps

5.9 Define and describe the operation of valves

5.10 Define and describe vacuum principles

5.11 Define and describe the operation of heat exchangers

5.12 Troubleshoot piping components and piping systems, pumps, valves, pneumatic and hydraulic components and systems, and heat exchangers

5.13 Define and describe the exhaust system

STANDARD 6.0 ANALYZE THE BASICS OF ELECTRICAL AND ELECTRONIC CIRCUITS

6.1 Define the core electrical concepts [e.g., voltage (V), current (I), and resistance (R)]

6.2 Define the two circuit laws used to analyze simple circuits and explain the distribution of power (e.g., Ohm's Law and Kirchhoff's Laws)

6.3 Define N-Type and P-Type doping and explain how doping allows semiconductors to conduct electricity

6.4 Define and describe the key functions of diodes, transistors (FETs, BJTs), and integrated circuits (ICs)

6.5 Explain the use of automated equipment in circuit operations in the fabrication process [e.g., running complex machines (lithography and etching) and entering precise electrical parameters (voltages, timings, currents)]

6.6 Explain the importance of electrical currents to maintain signal integrity while the circuit is processing

6.7 Explain how power management systems regulate, protect, and monitor electrical power so that test equipment and production tools operate safely and accurately

6.8 Use key electrical principles and concepts to diagnose electrical failures (i.e., check voltage, current, resistance, Ohm's Law, and power)

6.9 Use a systematic diagnostic process to diagnose electrical failures (e.g., observation, visual inspection, power check, component level testing, and documentation review, and comparison of findings)

6.10 Identify common fault types and clues (e.g., no power, no/low voltage output, intermittent/erratic action, and excessive heat/smell/smoke)

STANDARD 7.0 UTILIZE MATHEMATICAL PROCESSES AND COMPUTER TECHNOLOGIES AND APPLICATIONS FOR DESIGN, BUILD, AND TROUBLESHOOTING

7.1 Read and interpret basic control charts to determine whether a process is operating normally or outside expected limits (i.e., identify when data points fall outside control limits, recognize trends that show a process drifting over time, know when to report abnormal patterns to a supervisor or technician, etc.)

7.2 Explain diagrams and basic technical drawings to understand equipment, processes, and systems (i.e., process flow diagrams, equipment schematics, simple system layouts, etc.)

7.3 Identify common electrical measurement tools and describe their safe and appropriate use in troubleshooting and verification tasks (i.e., multimeter functions such as voltage, current, and resistance, etc.)

7.4 Apply basic math and unit conversions to support measurements, trends, and simple calculations used in manufacturing environments (i.e., averages, percentages, limits, unit conversions, etc.)

7.5 Explain manufacturing yield as the percentage of good output compared to total output and why yield matters in manufacturing (i.e., understand that higher yield means less waste, recognize that frequent defects lower efficiency and increase cost, explain yield in simple terms during a team discussion, etc.)

7.6 Recognize that manufacturing processes must meet specified limits and that quality control ensures products stay within those limits (i.e., identify acceptable versus unacceptable measurement ranges, understand that parts outside limits may be rejected, know that quality checks prevent defects from continuing downstream, etc.)

7.7 Differentiate among theoretical, simulation, and real-world scenarios and tests and explain how they progress from conceptual ideas to models, and finally to physical execution

7.8 Explain how specialized software such as Electronic Design Automation (EDA) is used to design semiconductor chips before they are manufactured

7.9 Explain how artificial intelligence (AI) and machine learning (ML) are used in semiconductor manufacturing (i.e., to accelerate design and simulation phases, to predict maintenance for equipment, to improve manufacturing yields, to improve overall efficiency, etc.)

7.10 Explain the lithography process to create patterns on semiconductor wafers (e.g., utilize advanced algorithms, mathematical models, and machine learning to simulate and optimize the semiconductor photolithography process)

7.11 Describe how automated and robotic systems are used to move materials and operate equipment in manufacturing environments (i.e., robotic arms moving wafers between tools, automated systems loading and unloading equipment, material handling systems transporting products safely, etc.)

7.12 Use basic software tools to view, enter, and understand production or process data (i.e., enter data into a digital log or form, view dashboards that show equipment status, read simple graphs showing trends, understand basic Python scripting, etc.)

7.13 Communicate technical information clearly using basic text and visual tools (e.g., PowerPoint presentations)

STANDARD 8.0 EXAMINE SEMICONDUCTOR SENSOR SOLUTIONS

8.1 Explain how sensors detect changes in conditions and send a signal that equipment or control systems can read and respond to (i.e., temperature sensors detect when a tool is overheating and triggers an alarm, pressure sensors monitor vacuum levels inside manufacturing equipment, gas sensors detect leaks and shut down equipment for safety, etc.)

8.2 Identify common types of sensors used in manufacturing and automated systems and describe what they monitor (e.g., temperature sensors monitor tool and system heat, pressure sensors monitor vacuum or air flow, gas sensors detect hazardous or process gases, motion or position sensors monitor robotic movement, and light sensors confirm correct alignment or presence of materials)

8.3 Describe basic advantages and limitations of sensors used in manufacturing systems (i.e., size, speed, reliability, need for calibration, drift over time, etc.)

8.4 Identify and describe how sensors are used in everyday technology (i.e., smartphone brightness and orientation, building climate control, and vehicle air quality and pressure sensors) and manufacturing environments (i.e., equipment temperature, cleanroom air quality, and process gas monitoring)

8.5 Explain how environment, cleanliness, speed, and reliability impact the sensor type choice (i.e., pressure sensors are used in vacuum equipment instead of a mechanical gauge, optical sensors are chosen where non-contact measurement is needed, etc.)

8.6 Configure and operate a basic automated system that uses sensor feedback to maintain set condition (i.e., thermostat maintaining a set temperature, fan system that increases speed when temperature rises, conveyor system that stops when a sensor detects an obstruction, etc.)

8.7 Observe trends and basic system data to recognize when performance is outside expected limits (i.e., a temperature reading slowly increasing over time, pressure values outside the normal operating range, repeated alarms reported according to procedure, etc.)

STANDARD 9.0 UTILIZE LEAN MANUFACTURING PRINCIPLES TO IMPROVE PROCESSES

9.1 Identify and explain the five principles of lean manufacturing (e.g., defining value, mapping the value stream, creating flow, establishing pull, and pursuing perfection)

9.2 Identify and explain tools and techniques used to implement lean manufacturing principles (e.g., 5S, Kanban, Poka-Yoke, and SMED), including data analysis tools (i.e., value stream maps, flowcharts, diagrams, etc.)

9.3 Discuss the benefits of practicing lean manufacturing principles (i.e., increased efficiency, lower costs, higher product quality, faster delivery times, and improved customer satisfaction)

9.4 Define Six Sigma and explain how it complements lean manufacturing

9.5 Use systematic problem-solving techniques [i.e., root cause and corrective action (RCCA); Define, Measure, Analyze, Improve, and Control (DMAIC), 8D Fishbone, 5 Whys, etc.]

9.6 Explain the basics of standard operating procedures (SOPs) and revisions required for a quality manufacturing system (QMS)

9.7 Explain the basics of Statistical Process Control (SPC) to monitor, control, and improve production processes

9.8 Discuss quality inspection processes and audits

STANDARD 10.0 EXAMINE THE FUNCTIONALITY OF A PLC (PROGRAMMABLE LOGIC CONTROLLER)

10.1 Define a PLC (e.g., industrial computer that automates machinery and processes)

10.2 Identify four main components of a PLC (e.g., CPU processor, memory, power supply, and input/output modules)

10.3 Explain the basic function of a PLC (e.g., to create instructions for industrial computers that manage machinery and automation processes)

10.4 Develop a flowchart that identifies and solves an automation problem

10.5 Use a PLC to troubleshoot input/output AC and DC modules

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STANDARD 11.0 ANALYZE PHYSICAL SECURITY AND CYBERSECURITY THREATS

11.1 Distinguish between physical security and cybersecurity (e.g., physical security protects tangible assets like buildings and hardware, and cybersecurity defends digital assets like networks and data)

11.2 Describe how the authentication, authorization, and accounting (AAA) security framework is used to manage network access, enforce policies, and monitor user activity

11.3 Discuss the three core principles of the CIA Triad for protecting information (e.g., confidentiality, integrity, and availability)

11.4 Identify physical concerns (e.g., facility breaches, equipment tampering, and counterfeit chips)

11.5 Identify cybersecurity concerns (e.g., intellectual property theft, ransomware and espionage, supply chain vulnerabilities, legacy systems, network complexity, and data leakage)

11.6 Identify protocols for cybersecurity threats

11.7 Identify protocols for protecting intellectual property