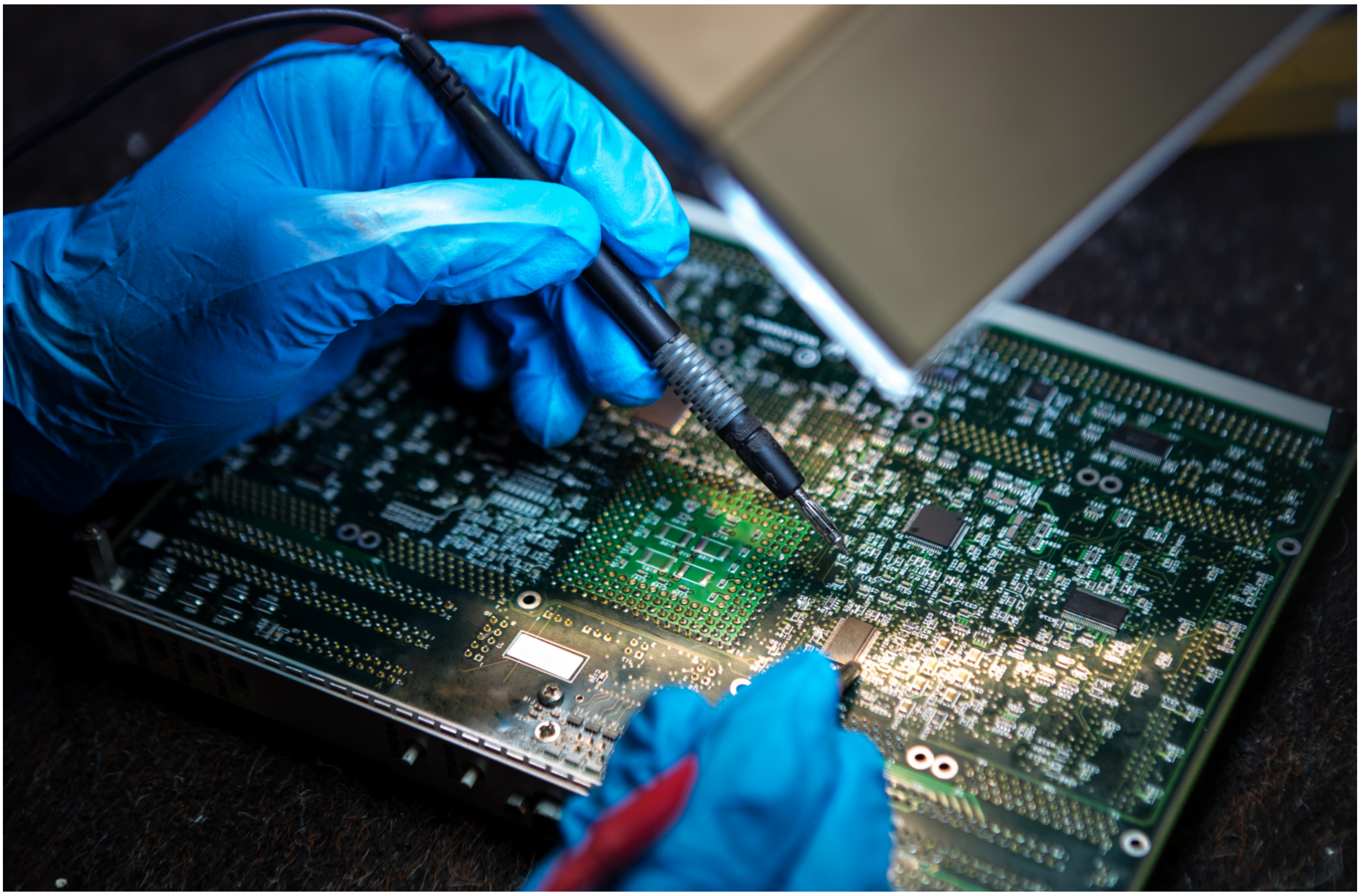
SEMICONDUCTORS

Lesson 2: The Magic of Raw Materials and Design



~~Facilitator~~ **Guide**

How to Prepare for This Lesson

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About This Facilitator Guide

This facilitator guide provides instructors with the information needed to guide students through the digital version of The Magic of Raw Materials and Design.

Before You Get Started

Before you get started with this lesson, please be sure to do the following:

- Read through the facilitator guide
- Review the Rise lesson
- Prepare any resources needed for the lesson

Using Editable PDFs

Most lessons include using an editable PDF for students to capture responses to questions and other activities.

Guiding language is included in the lesson to help students access and use the editable PDFs where they appear.

Students who will be using Chromebooks will need to use the Print to PDF function to save their editable PDFs to their devices. Here's how to do this:

1. Open the editable PDF and select Ctrl + P.
2. Open the file destination where the file will be saved.
3. Select "Save as PDF."
4. Select "Print." Your document is now "printed" as a PDF file, which will save your work.

PDFs cannot be submitted via the Rise interactives. If you plan to collect these documents for career planning portfolios or grading, you will need to coordinate that with your students.

Unit Overview and Alignment of Learning Targets

This unit contains five lessons, as follows:

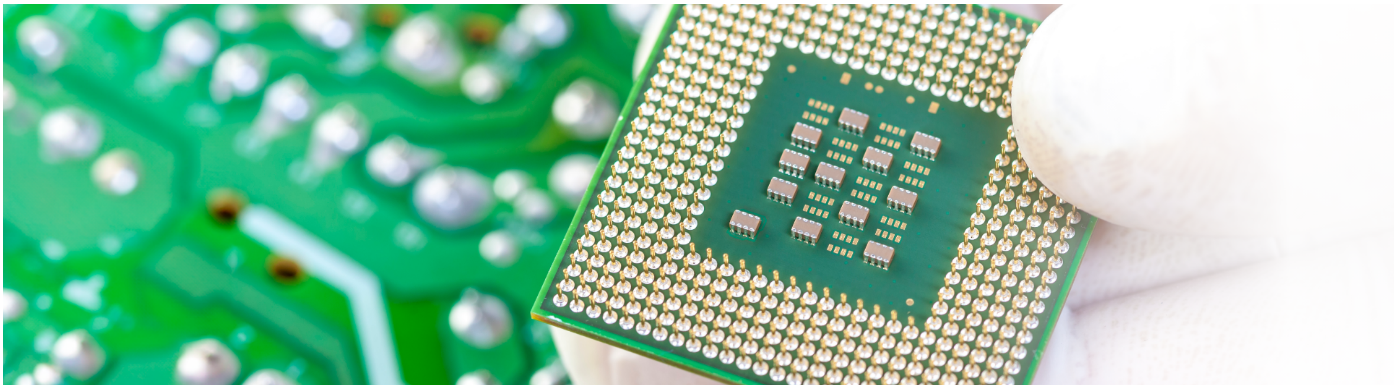
- Lesson 1: Introduction to Semiconductors
- Lesson 2: The Magic of Raw Materials and Design
- Lesson 3: Fun With Front End Design and Machinery
- Lesson 4: A Beginner's Guide to Back End Assembly and Functions
- Lesson 5: The Future of the Semiconductor Industry and My Place in It

For students to get the most value from this unit, please plan on implementing all lessons in this unit in sequential order.

Tracking Completion of Lessons

If you are using SCORM Cloud or Canvas with the lessons in this unit, completion tracking options are available. If you are not using either platform, please determine if and/or how you plan to track the completion of lessons by the students.

Lesson 2: The Magic of Raw Materials and Design



Lesson 2 Components

Pacing

The lesson is designed to extend over multiple class periods to build the background knowledge students need to explore careers and to be able to answer the lesson's guiding question. You may tailor the lesson to meet the needs of the class. If you choose to teach the lesson in its entirety, plan where you will stop after each session. Prepare an appropriate debrief for that class and a way to reengage students in the activities for the next class session.

Materials

N/A

Be sure to review any Extension Activities that may be suggested at the end of this lesson and consider when and how your students will complete them.

Guiding Questions

The guiding question is intended to provide a focal point for each lesson. This lesson's guiding questions are as follows:

- How are semiconductors designed, and what materials are essential for their creation?

Lesson Overview

In this lesson, we will take a closer look at how semiconductors are created and the raw materials required to make them. We will also look at typical kinds of semiconductor devices that you might find in everyday technology. Finally, we will explore the software packages used in designing semiconductors.

Vocabulary in This Lesson: Flip Card Activity

The flip card activity is designed to familiarize students with key vocabulary terms and definitions for this lesson. These vocabulary words are bolded throughout the lesson. Students must flip each card to proceed with the lesson.

Ingot:
An ingot is a block of material, often oval in shape, made from metals, silicon, or other substances that are mined and melted down.

Wafer:
Thin and round sheet cut from an ingot made from a material used in creating semiconductors (like silicon or gallium). Imagine slicing a sausage into rounds. The sausage is the ingot, and the wafer is the rounds.

Silicon Mining:
The process of digging or dredging silicon from rock or sand and transporting the raw material to a plant for processing.

Silicon:
Silicon has to be melted down after being mined in order to be used to create semiconductors. This material has electrical properties that make it useful for the construction of electronic parts. You can't make dough for bread without flour, can you?

CAD (Computer-Aided Design, aka Mathematical Modeling):
The method of using computer software to design and simulate systems to make it easier to build the systems in the real world. Have you ever used a 3D printer? First, you need to design and simulate it on your computer to make sure it would come out like you imagined. That's an example of CAD.

Learning Targets

By the end of this lesson, students will be able to do the following:

- Explain the significance of raw materials in semiconductor manufacturing
- Identify the role of semiconductors in modern technology
- Identify the basic principles of semiconductor design
- Summarize the semiconductor design process

Semiconductor Production Process Explained

In this section, students will watch a YouTube video on how semiconductors can be made from sand.

Raw Materials Used in Semiconductors

In this section, students will explore the raw materials used in making semiconductors. The information is presented in a Rise course component called a process block, where students can navigate through the steps or sections by selecting the arrows on the left or right side.

Afterward, students will complete the associated matching activity in Rise by dragging the beginning of each sentence from the left column to its partner in the right column.

1. Pure silicon is … melted down and purified before it is made into an ingot.
2. Gallium is … always combined with another compound.
3. Metals are … used as conductors.
4. Plastics are … found in many places in the manufacturing process.
5. Cardboard and paper are … used in shipping semiconductor parts between manufacturing facilities.

How Are Microchips Made?

In this section, students will watch a video that explains the semiconductor manufacturing process, starting from raw materials and detailing their transformation into microchips.

You can also share the following additional resources with the students.

Additional Resources

- Showing the production of a silicon ingot
- Explaining the manufacturing process
- Showing a microchip on a microscope

What Semiconductor Devices Are Found in Everyday Technology?

The graphic character, Sami, will introduce the topic to students and explain how semiconductors are integral to many devices they use at home.

Let's Explore the Semiconductor Devices in Your Home

In this section, students will explore various semiconductor devices found in their homes. A collage of four images is displayed in a Rise course component called a labeled graphic block. Students can select the markers in each image to access relevant content.

Let's Check Your Knowledge

In this section, students will complete the multiple-choice questions related to the previous topic.

What Is Involved in Semiconductor Design?

In this section, students will explore key software packages and their applications in semiconductor design. The information is presented in a Rise component called a tab block, allowing learners to navigate between tabs by selecting each one.

Ask students to select and explore one of the software packages that interests them.

You can also guide students to download the following software programs for home exploration and explain what each link offers.

- **Autodesk Fusion for Education:** The link takes students to the Autodesk education software site, which provides information on Fusion, its features, and what is available to educators and students. Students can explore the site but focus on Fusion Electronics. For a deeper dive, you can guide students to download Fusion for free from the educator site and explore the software. https://www.autodesk.com/education/edu-software/fusion

- **AutoCAD Educational Website:** The link will direct students to the Autodesk student free educational resources website, which showcases all the AutoCAD resources available to support students. Most Autodesk programs can be downloaded and explored for free with an educational email, and the site provides numerous resources for learning the software. It also explores careers where the software is extensively used. You can further enhance learning by downloading the software and exploring it in class. https://www.autodesk.com/education/students (free with an educational email)
  - **Tinkercad (Autodesk):** Tinkercad is a simplified version of AutoCAD's offerings, serving as a visual educational tool similar to an educational toy. It is available for free with an educational email. Note that while Tinkercad introduces important concepts and provides useful resources, it is primarily intended for educational purposes and is not widely used outside the education field. https://www.tinkercad.com/classrooms-resources

- **MATLAB and Simulink Lookalike Octave:** The link directs students to the MATLAB and Simulink website, which explains the software and its functions. Since purchasing Simulink is expensive, students (and educators) interested in exploring the software should download the free open-source software OCTAVE, which can be programmed and used similarly to MATLAB and Simulink.

  While there isn't a dedicated kids' section, there are numerous YouTube videos demonstrating how to use it, along with an extensive library of resources.
  - Octave
  - The Octave Wiki Page

- **Mathcad:** The Mathcad link directs students to the Mathcad site, where they can learn about its features and applications, including a video showcasing the software and the careers it supports. Students interested in exploring Mathcad can download it for free through an educator license available on this website. Mathcad Free Educator License

Finally, let students know that there are many additional software packages used for designing and building semiconductor devices beyond those listed here.

Let's Talk About It

In this section, students will use the editable PDF to respond to the following questions:

- What raw materials are used in semiconductor manufacturing?
- What are the different kinds of semiconductor devices? Do they all do the same job?
- What is the difference between the software packages discussed in this lesson?

Let's Talk About It

In this section, students will reflect on the following questions. This can be done as a full class discussion, in small groups, or as a pair-and-share activity. Facilitate the discussion and offer guidance and support throughout the activity.

- What do you think it would be like to work in a silicon refinery or quartz mine?
- What do you think you might need to know?

Thinking About Your Future

Students will see the following statement in Rise: In this lesson, you explored a career in the semiconductor industry.

Before moving on to the next lesson, take some time to reflect on these questions:

- Was there anything that surprised you about the types of devices that are made from semiconductors?
- In reviewing the semiconductor design process, which part interested you the most?
- In looking at the different software packages, which one would you like to learn more about? What intrigued you about it?

Career Pathways

Share the following with your students: It's never too soon to start exploring future career options!

Students can access the resources at this link: My Future AZ.

Lesson Completion

At the end of the lesson, students will see the following message in Rise:

In future lessons, you will learn about the different aspects of the semiconductor industry. Topics will include front end design, photolithography and etching, and packaging and back end design.

Extension Activities

Activity 1:

Making Rock Candy, connected to the process of seeding silicon ingots

Prepare the sugar syrup before class. The activity with students should then take 5–10 min.

You can also share the following additional resources with the students if time permits.

Additional Resources

- #300mm Silicon #Wafer Manufacturing Process
- Showing the actual process of mining silicon and transforming it into ingots

Materials

- Sugar
- Water
- Wooden skewers or candy sticks
  - For standard Wilton lollypop sticks, these work well: Wilton lollypop sticks.
  - Rock candy sticks with a ball end that can make them easier to hang can be purchased here: rock candy sticks with ball end.
- Glass jar
- Plastic wrap

- Paper plates
- Parchment paper
- Masking tape
- (optional) Large clothespins
- (optional) Food coloring
- (optional) Flavoring

Prep Before the Lesson

Day 1:

1. Soak wooden skewers or candy sticks in water.
2. Have plates and sugar ready to go.
3. Place a long piece of parchment in a space in the classroom that will not be disturbed. Make a long strip of masking tape under the parchment, and label it with the student's names. Students will place their prepared seed crystals on the parchment above their name.
4. Have a video of the silicon refinery ready to watch.

Day 2:

1. Sugar syrup: 10 cups of sugar to four cups of water works well.
    a. Bring water to boil.
    b. Add sugar half a cup at a time and dissolve in water until it becomes harder to dissolve the sugar.
    c. Once all of the sugar is dissolved, allow it to simmer on heat for 10 minutes.
    d. If you would like to add color or flavor to the rock candy, do so at this point.
    e. Keep warm until class time.
2. Clean glass jars.
3. Place a piece of plastic wrap tight over each jar and make a hole, alternatively, you can use a large clothespin in place of plastic wrap. This is just to hold the wooden skewers in place.

Vocabulary

Recall the following vocabulary from the lesson:

Ingot: An ingot is a block of material, often oval in shape, made from metals, silicon, or other substances that are mined and melted down.

Silicon Mining: The process of digging or dredging silicon from rock or sand and transporting the raw material to a plant for processing.

Wafer: Thin and round sheet cut from an ingot made from a material used in creating semiconductors (like silicon or gallium). Imagine slicing a sausage into rounds. The sausage is the ingot, and the wafer is the rounds.

Questions to Ask Before the Activity

1. How do you think silicon ingots are made?
2. Can we grow a crystal like a silicon ingot at home?
3. What do you think a seed crystal is?

Procedure Day 1

1. Have students watch the video at the following link: silicon ingot production video.
2. Explain to students that to make a silicon ingot, manufacturers first create a seed crystal. This gives the silicon crystals something to grow on and allows manufacturers to decide the final size and length of the final silicon ingot.
3. Tell students that today they will be making their own seed crystals so that they can make their own ingots. For safety reasons, their ingots will be made of sugar instead of silicon.
4. Tell students not to touch any of the materials that will be handed out.
5. Hand out a pre-soaked wooden skewer, lollypop stick, or rock candy stick to each student.
6. Hand out a paper plate to each student
7. On each student's paper plate, pour a little sugar; it only needs to be enough for them to coat their stick.
8. Instruct students to take their wooden sticks and roll them in the sugar so that they are all coated.
9. Ask students to lift their seed crystals and make some observations about them.
10. Have students place their sticks on the prepared parchment paper above the masking tape line with their names.
11. Seed crystals need to dry overnight before they can be used for rock candy.

Procedure Day 2

1. Explain to students that once the seed crystals are prepared, the refinery must melt the silicon before they can produce an ingot. Explain that students will be using melted sugar instead of melted silicon to create their own ingots. Tell students that they need to be careful as the sugar is warm.

2. Hand out jars prepared with plastic wrap or clothespins to each student.
3. Have students put their names on the jars by using masking tape and Sharpies.
4. Have students retrieve their seed crystals and return to their chairs.
5. Ask students to make some observations about their seed crystals. What do they notice? What changed about the seed crystal from the previous class period?
6. Carefully pour sugar syrup into each student's jar.
7. Tell students to carefully insert their stick into the jar through the plastic wrap or secure it with the clothespin.
8. Explain to students that the manufacturers must be careful with their silicon seed crystals so that the ingot is properly produced.
9. Move all the jars to a space where they will not be disturbed.
10. Let the jars sit for several days until the crystals grow. Then, have students remove their sugar "ingots" and make observations.

Questions to Ask After the Activity

1. How careful did you need to be when you were putting your seed crystal in the sugar syrup?
2. How do you think it might feel to work in a silicon refinery now that you've performed a similar process?
3. What kind of skills do you think someone would need to create good silicon ingots?
4. Do you think you could change the process to make the crystals bigger? Could you make them grow faster? What do you think you might need to change?

Thinking About Your Future

Talk to students about what interested them about the activity. Explain that many people work in creating silicon ingots. All kinds of specialties are required to make silicon ingots, some careers are Metallurgists, Geologists, Heavy Machinery Operators, Mechanics, Electricians, Chemists, and many more.

Activity 2:

Piezoelectric Generator Extension Activity

Materials

- Piezo disc transducers (can be purchased from here)
- Electrical tape (can be purchased here)
- LED bulbs (can be purchased here)

The estimated materials cost for a class of 30 students is $30.

Prep Before the Lesson

Print enough copies of the diode diagram for each student in class.

Use wire strippers to remove half an inch of the plastic insulation from the metal wires on the piezo disks. Be careful not to cut the wires.

Materials need to be purchased in advance. Be sure to have at least a few extra piezo disks as rough students can sometimes crack the disks, which will result in a circuit that doesn't work.

Students can choose their own LED bulb colors; however, you should have piezo disks and electrical tape ready to hand out. One tape spool per two students should be just fine; it can be helpful to have a single color of tape so that students aren't waiting to get the color they want.

Vocabulary

1. **Piezoelectric:** Refers to a device that produces an electrical signal from pressure or force. In other words, if you squeeze it, it will transfer that energy in the form of electricity.
2. **LED** (light-emitting diode): A special kind of semiconductor device that emits light and also prevents energy from flowing in the wrong direction.
3. **Blocking:** When a diode prevents energy from moving within a circuit.
4. **Current:** When electrical energy moves within a circuit.
5. **Anode:** The positive-side electrode on a diode. (In electronics, the positive-side wire is often red.)
6. **Cathode:** The negative-side electrode on a diode. (In electronics, the negative-side wire is often black.)

Questions to Ask Before the Activity

1. How do you think a semiconductor device works?
2. Can you make a light bulb light up with just your fingers?
3. How do you think a diode works?

Procedure

1. Explain to students that diodes have an anode and a cathode. The anode is the positive side of the diode, and the cathode is the negative side.
2. Show students on the diagram how the anode is the long leg or "lead" of the diode, and the cathode is the short leg or "lead."
3. Have students cut a thin piece of electrical tape and put it on the short leg close to the LED bulb. It should not cover most of the wire; it should just be a little flag telling the student which leg is which. Make sure that they mark the correct leg, as they will use this to figure out how to wire up their bulbs.
4. Have students wrap the black wire from their piezo disk tightly around the leg they marked with electrical tape. Make sure that the copper wire is in contact with the metal of the leg, or it will not work.
5. Have each student use some electrical tape to tape over the black lead so that the leg and the lead are connected. Remind students to be careful not to crush their piezo disks.
6. Have each student wrap the red wire from their piezo disk tightly around the leg that was not marked with the electrical tape (the long leg or the anode of the diode). Once again, make sure the copper is in contact with the metal of the leg.
7. Have each student use some electrical tape to tape over the red lead and the leg so that they are connected and the connection is strong.
8. Now, instruct your students to gently squeeze the piezo disk. It can be helpful to put one finger on each edge of the disk and use the thumb to squeeze the center of the disk. This avoids damage to the disk and ensures maximum force from the hand. Their LED should light up whenever they squeeze the disk.
9. Have your students carefully unwrap the leads and repeat Steps 4–7 only with the diode reversed. Tell them to try squeezing their disks. No matter how hard they squeeze, the LED shouldn't light up. Explain that this is what is called "blocking" and is what makes a diode so special. If the diode is reversed in the circuit, it will not allow any current to flow, and the circuit won't "work" in that direction.
10. Students can now fix their circuits and return the diode to the correct position. You can decide whether they are allowed to take their piezoelectric generators home.

Questions to Ask After the Activity

1. What happened when you squeezed the piezo disk?
2. How do you think this could be used beyond lighting up an LED? (Let students discuss ideas.)
3. What did you learn about diodes? Did the diode work when you reversed the leads?

Thinking About Your Future

Talk to students about what interested them about the activity. Explain to them that many different careers explore various parts of the piezo generator. Electrical and Computer Engineers design the circuits that use the components, Materials Scientists and Chemical Engineers design the compounds that are used to make the piezoelectric sensor, and Technicians often build and test circuits like the ones they made. Electricians work on circuits, too; only their circuits aren't usually so small.