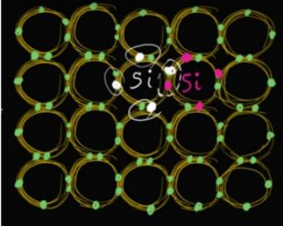


6.	What are semiconductors? (18)
Target group	Pupils, optional teachers
Age pupils	14–18
Duration	2 hours (final result of experiment after 24 hours)
Overview	Students will create and observe copper sulfate crystals, then create a model of what is happening at a molecular level and apply these findings to other substances. Students will learn about how semiconductors are produced, and be exposed to other industrial and commercial uses for these materials.
Materials	• Beaker • Computers with access to YouTube and Flipgrid • Copper (II) sulfate pentahydrate (70 g) • Dissecting microscope (to observe crystals, if not available an image can be shown from the Internet) • Erlenmeyer flask • Foil • Funnel with cotton wool • Hot water (100 mL) • Plastic twine • Student Handout semiconductors
Essential Questions	1. How can we use naturally occurring materials to make electronics? 2. How does a crystal structure grow? 3. What is the relationship between semiconductors and crystals?
Engage	Activating Prior Knowledge • Students will share their knowledge of crystals, molecular lattice structures, and semiconductors by individually completing Section A on the Student Handout • Students compare and contrast their observations with a peer and complete Section B on the student handout semiconductors. (NGSS SEP: Asking Questions and Defining Problems) • Each pair of students shares one at least one answer and the teacher will generate a class list of knowledge, notices, and wonderings. (Culturally Responsive Practice: Teacher encourages and accepts all answers from the class celebrating the different ideas and background knowledge students are contributing to this lesson)
Explore	• Exploring and Creating Crystals • Teacher will introduce explore section by sharing the following big ideas with students: • Show video: “You are the future in semiconductors!” → https://vimeo.com/639743392 • Semiconductors are basically used in all technology. • The process of making a semiconductor involves sand and crystals • We are going to model the crystallization process with another substance (copper sulfate) • Students work in groups to observe copper sulfate crystals (set up by the teacher at least 24 hours prior) and complete Section C on the student handout semiconductors. (NGSS SEP: Asking Questions and Defining Problems) • Students work in groups to create copper sulfate crystals and observe the crystal lattice structure under a dissecting microscope. Students complete Section D on student handout semiconductors. (NGSS SEP: Planning and Carrying Out Investigations)
Instructions	Students start here and watch a short video of the experiment “How to grow a copper sulfate crystal (simple experiment)” before start on their own.

	→ https://www.youtube.com/watch?v=FFR4nei9qv8 Procedure: • Add 70 grams of copper sulfate pentahydrate into a beaker. • Pour 100 mL of hot water over it and stir for 10-15 minutes (or until the powder is dissolved). • Once the powder is dissolved, use the funnel with cotton wool to filter the solution into an Erlenmeyer flask. • Transfer the liquid from the Erlenmeyer flask to a beaker and cover with foil for 24 hours. • After 24 hours: carefully pour the liquid from the beaker in an Erlenmeyer flask to expose the crystals that have formed.
Explain	• Connecting Copper Sulfate Crystals to Silicon Crystals • After students compare and observe the copper sulfate crystals and create their own, the teacher will guide them through a class discussion connecting the copper sulfate crystals to silicon crystals. Students will watch a short video “<i>From Sand To Silicon: The Making of a chip / Intel</i>” on semiconductors and complete cloze notes in Section E on the <i>student handout semiconductors</i>. (NGSS SEP: Developing and Using Models) → https://www.youtube.com/watch?v=Q5paWn7bFg4 • Key for Explain section: ○ Teacher Research Consultants, LLC ○ The copper sulfate crystal formation is similar to the crystal formation of silicon crystals. Silicon can be found in silica sand after it is separated into silicon and oxygen. ○ Silicon crystals can be used to create the substrate for semiconductors. ○ Semiconductors are used in a variety of technologies such as cell phones, computers, and artificial intelligence. ○ What would it look like if we zoomed into silicon crystals? Copy the diagram from the board: Silicon Crystal Schematic:  • We can't make crystals from sand in class because it requires a lot more heat (over 3000 degrees Fahrenheit). • We used copper sulfate to make crystals because they are easy and safe to work with. Scientists in a lab manipulate silicon which can then be used in technology. • Let's learn more about this process now.
Elaborate	From Silicon Crystals to Semiconductors • Students will watch a segment (beginning-7:30) Khan Academy video Khan Academy Semiconductor “<i>Semiconductor introduction</i>” → https://www.youtube.com/watch?v=60Qz051rD_w Introduction and complete Section F on the <i>student handout semiconductors</i> as a class. (NGSS SEP: Constructing Explanations and Designing Solutions) • Teacher will share with students the variety of people that are involved in creating semiconductors and highlight Dr. Anuja DaSilva, a material scientist. → https://docs.google.com/document/d/1xfX8OJTl9cqsqw_BWl3lPczvTEZ_wGOZR_mid_QY2v8E/edit?tab=t.0 (Career Highlight: Material Scientists study the structures and chemical properties of various natural and synthetic or composite materials, and work to determine ways to strengthen or develop new materials for use in a variety of products.)

	• Key for Elaborate section: ○ How many valence electrons does silicon have? What is important about these electrons? -> 4 valence electrons and they are important because they are able to react with other elements ○ Which element would have more free electrons: copper or silicon? -> Copper ○ Which is a better conductor of electricity, copper or silicon? Why? -> Copper because the electrons can move freely ○ What is added to silicon to allow the electrons to move more freely? What is this process called? -> Impurities (other elements, like phosphorus or boron) and this is called “doping” ○ When silicon is doped with phosphorus, what can begin to flow? -> Current can begin to flow ○ What does the term “semi” mean? Based on what you just watched, how does this apply to the term “semiconductor”? -> “Semi” means “partial” or “half”. A semiconductor refers to something that can partially conduct electricity.
Evaluate	Putting it all together • Students create a 3 to 5 minute Flipgrid based on the questions found in Section G on the <i>student handout semiconductors</i>. (NGSS SEP: Constructing Explanations and Designing Solutions) (Culturally Responsive Practice: Students are given a choice of what questions they can answer. Students can pick the questions that they feel most confident about and interested in.) • Questions from Section G: ○ How can we use naturally occurring material to make electronics ○ How does a crystal structure grow? ○ What is the relationship between semiconductors and crystals? ○ What is a semiconductor? Why is it important to me? ○ What type of scientists work on creating semiconductors? ○ Would you like to work in the semiconductor industry? Why or why not?
Extend	• Students could watch the video “<i>How Semiconductors Work</i>” and create their own questions with key → https://www.youtube.com/watch?v=33vbFFFn04k Students could watch the rest of the video Khan Academy Semiconductor Introduction “<i>Semiconductor introduction</i>” (about five minutes remaining) → https://www.youtube.com/watch?v=60Qz051rD_w • Students can explore another material scientist, <i>Frances Ross</i>, to learn more about her background and current research. (Career Highlight: Material Scientists in the semiconductor industry require creativity and can have artistic connections in the design of materials.) → https://www.bnl.gov/newsroom/news.php?a=26342
Evidence	participant count; Q&A summary