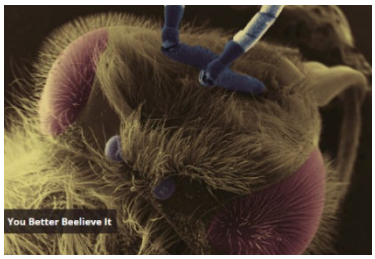
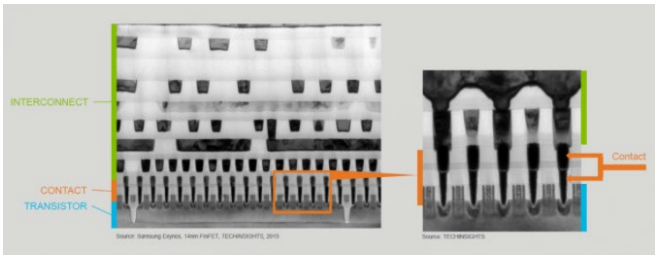
Semiconductors

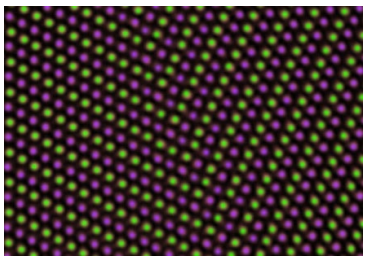
Microscopy from light to electrons



SEM image of a bee head. Credit: FAU High School Owls Imaging Lab



TEM image of Interconnect, contact, and transistor at various nodes. Credit: Applied Materials



TEM image showing atomic arrangement across a twin boundary in magnesium. Credit: Lawrence Whitmore, University of Salzburg

Why is microscopy important to society?

Electron and light microscopy have played a critical role in improving the well-being of people around the world, from the development of new medical materials to developing more efficient and powerful semiconductor devices, advancements in renewable energy, understanding the mechanism of disease, development of new materials for aerospace and defense, and exploration of new frontiers in science.

- *Semiconductor devices*: Electron and optical microscopy has enabled scientist and engineers to study the atomic structure of semiconductors, understand new materials, analyze the surface of semiconductors in detail, understand optical properties of semiconductor materials, and study nanostructures in devices.
- *Renewable energy*: Electron microscopy has helped to advance the development of renewable energy technologies, such as solar cells and batteries that are more efficient and durable. For example, transmission electron microscopy has been used to study the crystalline structure of semiconductor materials used in the most efficient solar cell (National Renewable Energy Laboratory, USA. Efficiency:39.5%). This type of solar cell uses a combination of group III and group V materials from the periodic table, i.e., uses "a sandwich" of gallium indium phosphide (GaInP), gallium arsenide (GaAs), and gallium indium arsenide (GaInAs). Each layer in this "sandwich" has been highly optimized over the decades using among other techniques high-resolution transmission electron microscopy.
- *New materials for aerospace and defense*: Electron and light microscopy has been used to study the properties of materials used in aircraft and spacecraft, leading to improvements in strength, durability, and other key characteristics.
- *Mechanism of disease*: Cryogenic electron microscopy, where a sample of interest is frozen using liquid nitrogen, has been instrumental in helping scientists understand the mechanisms of disease, including viruses and cancer. For example, electron microscopy has been used to study the structure of viruses and how they interact with host cells, leading to new insights into how viruses infect and replicate in the body.

- *New frontiers in science*: Finally, electron microscopy has enabled scientists to explore new frontiers in science, from the study of quantum materials to the development of new materials for space exploration. For example, scanning transmission electron microscopy is used here at Birck to study physical and chemical properties of quantum materials, i.e., defects, crystallinity, size, and chemistry, and relate these properties with fabrication conditions. Here electron microscopy is exposing new insights into unique characteristics and potential applications for quantum materials.

By continuing to push the boundaries of microscopy, we can continue to drive innovation and improve the lives of people around the world.

Exploration during your visit

In this hands-on demonstration, you will explore the following:

- Different types of microscopes used in semiconductor research, and how they work
- Differences between light and electron microscopes: We will explore how lenses work in both types of microscopes, and other technical differences between both tools. How are electrons and light controlled?
- Orders of magnitude and size units. We will explore different length units and the relationship between them. We will also understand how big electrons are and how light is measured. We will also ask: why is the size of electrons and light particles important when looking at different features in samples?
- Seeing the surface of a semiconductor with the scanning electron microscope. We will explore how scanning electron microscopy is used to study the surface of semiconductor materials in detail. We will discuss how this information is used in the manufacturing process to ensure that the surface is free of defects, which is critical for the proper functioning of the semiconductor devices.
- Seeing atoms with the transmission electron microscope. We will explore how electron microscopy has enabled scientists and engineers to study the atomic structure of semiconductors leading to the development of more powerful and efficient devices, such as faster computer processors, light emitting diodes (LEDs), advanced sensors, and more effective solar cells.

Exposure to cutting-edge technology: Electron microscopy is a rapidly evolving field, with new techniques and instruments being developed all the time. By learning about electron microscopy, high school students can gain valuable skills and knowledge that will serve them well when pursuing engineering and science careers and build a strong foundation for success in industry and academia.