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# Scanning Electron Microscopy vs. Focused Ion Beam

Scanning electron microscopy (SEM) and focused ion beam (FIB) are two similar systems that have different advantageous properties. SEM utilizes a beam of electrons, while FIB uses a focused beam of gallium ions. FIB produces accurately etched (milled) or deposited material onto a surface, analysis, or circuit modifications. SEM uses electrons to image a surface with high magnification and very high resolution.

Any atom that is smaller than half of a wavelength of light is too small to see with a light microscope (optical system). However, electrons have shorter wavelengths so we are able to image structures that are much smaller than the diffraction limit of light to see what is going on at the nano-scale.

Scanning electron microscopy is a method of imaging a sample by using high energy beam of electrons. In a typical SEM, an electron beam is thermionically emitted from an electron gun fitted with a tungsten filament cathode. The electrons interact with the atoms on the surface of the specimens generating a variety of signals. The signals reveal the information about the texture, chemical composition, and crystalline structure of materials making up the sample. Since the whole process is operating in a vacuum chamber, the sample must not contain any water. Moreover, the stage where the sample mounted must be grounded so that any generated current can be dissipated. Low conductive sample must be coated with ultrathin coating of electrically conducting material, commonly gold.

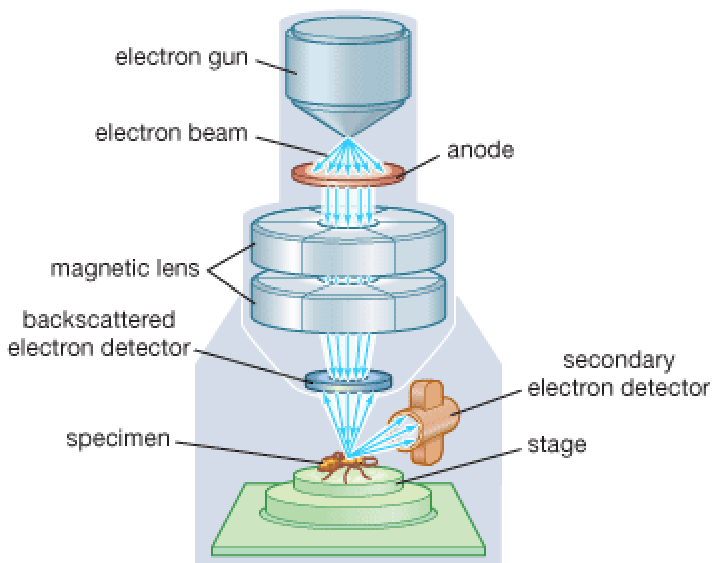


Figure1: Scanning Electron Microscope [1]

Secondary electrons and backscattered electrons are created when the energy beam interacts with the sample. These electrons are collected by a variety of detectors to give information about the sample. Secondary electrons can be detected by an Everhart-Thornley detector. Different surfaces on the sample will produce different brightness of the signals to the detectors resulting in well-defined, three dimensional images. Backscattered electrons are used to determine the crystallographic structure of the sample.

Scanning electron Microscopy has high magnification from 10 to 500,000X. By 2009, the world's highest SEM resolution was 0.4nm at 30kV. SEM can be applied to a wide range of application in the study of solid materials such as electronic properties of semiconductors. Many modern SEM are highly portable and safe to operate. SEM also has some disadvantages; the sample must be solid and small to fit into the microscope chamber with maximum size in horizontal dimension of 10cm and vertical dimension of 4cm. Samples are likely to outgas at low pressure. Also, some light elements cannot be detected by EDS detectors. Many instruments cannot detect elements with atomic numbers less than 11.

Focused Ion Beam (FIB) is the process of directing energized gallium ions, through two electrostatic lenses to a wafer or material. It can be utilized for the removal (milling) or deposition of a material. FIB is used for ion milling, sample imaging, and circuit editing.

Ion milling, using an FIB, can produce a cross-section that is impossible to create otherwise. Accelerated gallium ions are directed at a sample, etching away the exposed material to create very clean holes and surfaces. A gas can also be introduced into the process to etch certain materials faster or to deposit metal or oxide. As these energized ions collide with the surface, sputtering occurs. Sputtered material, secondary ions or neutral atoms, leave the surface, while secondary electrons are generated on the surface. These generated electrons can be scanned to give an image with resolution in the nanometer range. Sputtering or ion milling is induced when the ion beam is operating at high beam currents. Imaging of the sample is done by running the ion beam at low beam currents.

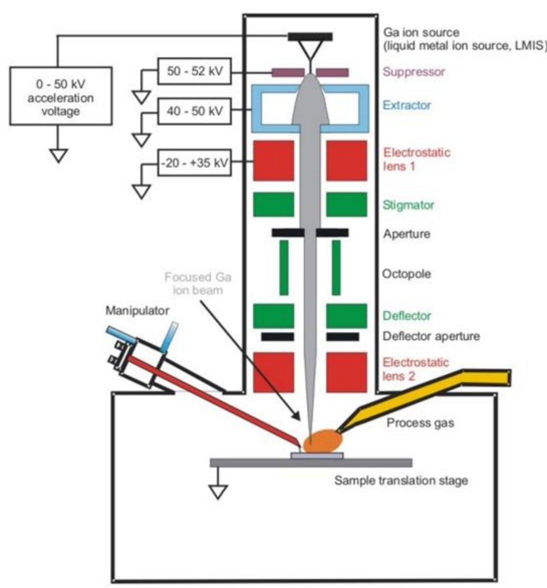


Figure 2: FIB machine [4]

FIB is advantageous because of its ability to produce a cross- section of very small specified areas. It has a fast, high- resolution imaging capability with a good grain contrast. FIB has the strength of being a versatile system that supports multiple additional tools. FIB does have limitations, including the possibility of the imaging process ruining the subsequent analyses. More limitations are the probability of needing a vacuum for the FIB process, that there may be residual gallium left, and the ion beam damage could cause a decrease in the resolution.

FIB analysis is ideal for the sample preparation for SEM, STEM (scanning transmission electron microscopy), and TEM (transmission electron microscopy), because of how accurately a cross-section of a sample can be produced. Because of the ability to produce a high resolution cross-sectioned image of a sample, small, hard to reach features are able to be cross-sectioned that are otherwise impossible to do so. FIB can form probe pads and edit on-chip circuit. The relevancy of the FIB analysis system in industry reaches to biomedical/ biotechnology, data storage, optics, semiconductors, and telecommunications.

After a batch of wafers has been fabricated and a failure or flaw has been detected, FIB has the ability to make modifications to the circuits. FIB can cut traces or add metal connections, by imaging, etching, and depositing materials on an integrated circuit. FIB can perform very precise modifications because the ion beam has a 5 nm resolution. A navigation system can be added to the FIB, giving the ability to find the specific features to be edited. The circuit edit process is not only quick and easy, it is also much cheaper to edit a circuit than to fabricate all new ones.

Circuit edit by FIB is considerably faster and less expensive than creating a whole new set in a fabrication lab. Circuit editing is not limited by a single modification, multiple could be made. After a modification has been made, the circuit can be tested on standard testing equipment. FIB circuit editing has the limitations that backside edits are time consuming and the modifications get more complex as the features of circuits become smaller. FIB circuit modifications are ideal for repairing mistakes in a circuit design by connecting or disconnecting lines. The modifications to the circuits can be made to optimize performance. The relevant industries for FIB circuit editing are Si and III-V integrated designers and manufacturers.

A common machine is a dual beam system, which combines the SEM and FIB. A dual beam has the FIB's ability for precise ion milling and deposition of material, while also keeping the SEM's ability to capture high resolution images of the samples. A dual beam system allows for a non-destructive imaging, done by the SEM, and the FIB controls the accurate milling. Dual beam systems keep the advantages of SEM and FIB and combine their abilities into one machine.

References

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