

# Physics of Nanotechnology

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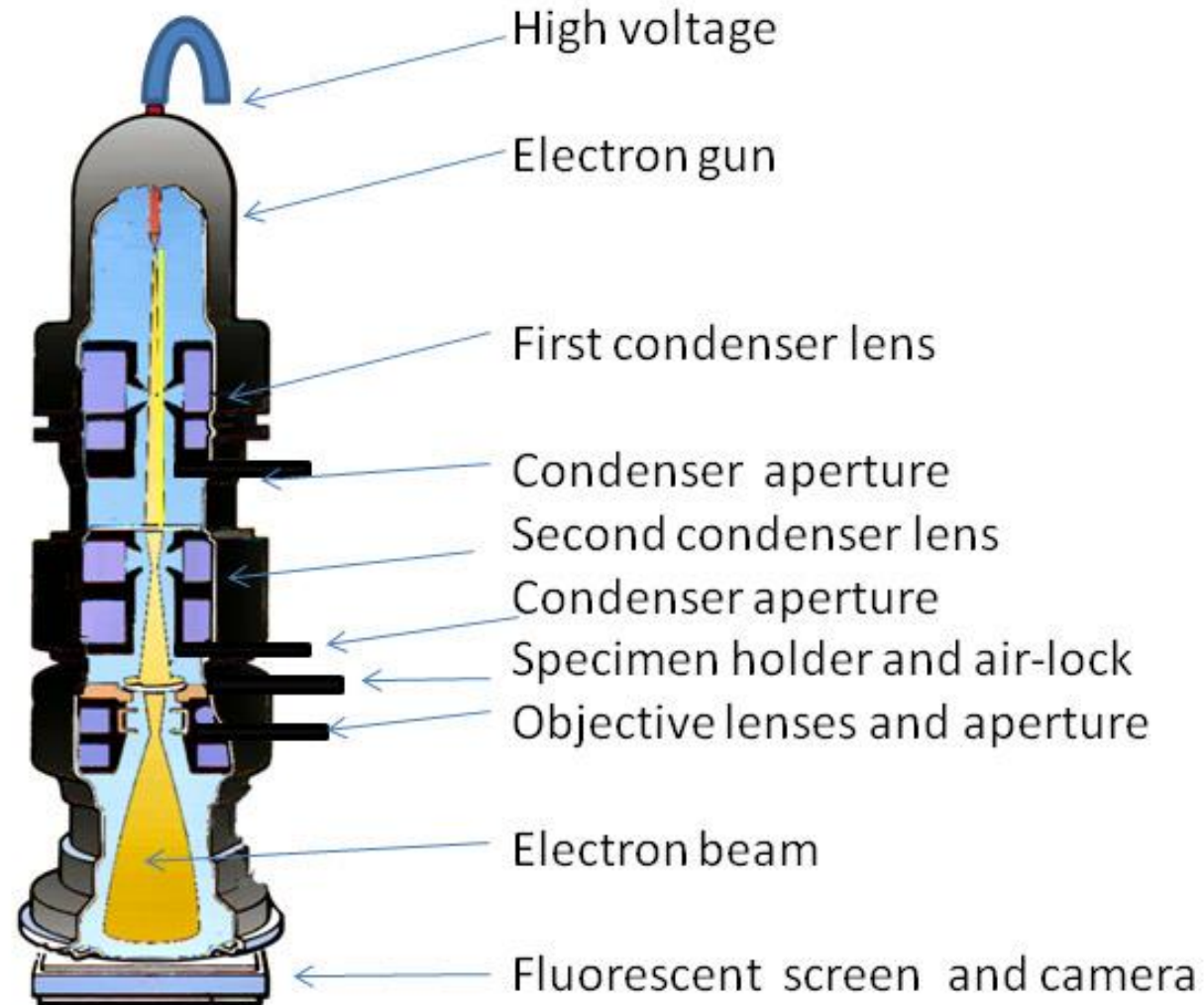
# What is a Transmission Electron Microscope?

- Transmission electron microscopes (TEM) are microscopes that use a particle beam of electrons to visualize specimens and generate a highly-magnified image. TEMs can magnify objects up to 2 million times. In order to get a better idea of just how small that is, think of how small a cell is. It is no wonder TEMs have become so valuable within the biological and medical fields.

# How Do TEMs Work?

- TEMs employ a high voltage electron beam in order to create an image. An electron gun at the top of a TEM emits electrons that travel through the microscope's vacuum tube. Rather than having a glass lens focusing the light (as in the case of light microscopes), the TEM employs an electromagnetic lens which focuses the electrons into a very fine beam. This beam then passes through the specimen, which is very thin, and the electrons either scatter or hit a fluorescent screen at the bottom of the microscope. An image of the specimen with its assorted parts shown in different shades according to its density appears on the screen. This image can be then studied directly within the TEM or photographed. Figure 1 shows a diagram of a TEM and its basic parts.

*Fig. 1 Simplified diagram of a transmission electron microscope. Drawing by Graham Colm, courtesy of Wikimedia Commons*



# The difference between SEM and TEM

- The main difference between SEM and TEM is that SEM creates an image by detecting reflected or knocked-off electrons while TEM uses transmitted electrons (electrons which are passing through the sample) to create an image. As a result, TEM offers valuable information on the inner structure of the sample, such as crystal structure, morphology and stress state information, while SEM provides information on the sample's surface and its composition.

# Which electron microscopy technique is best for your analysis?

- This all depends on what type of analysis you want to perform. For example, if you want to get information on the surface of your sample, like roughness or contamination detection, then you should choose a SEM. On the other hand, if you would like to know what the crystal structure of your sample is, or if you want to look for possible structural defects or impurities, then using a TEM is the only way to do so.
- SEMs provide a 3D image of the surface of the sample whereas TEM images are 2D projections of the sample, which in some cases makes the interpretation of the results more difficult for the operator.
- Due to the requirement for transmitted electrons, TEM samples must be very thin, generally below 150 nm, and in cases that high-resolution imaging is required, even below 30 nm, whereas for SEM imaging there is no such specific requirement.

# Which electron microscopy technique is best for your analysis?

- This reveals one more major difference between the two techniques; sample preparation. SEM samples require little or no effort for sample preparation and can be directly imaged by mounting them on an aluminum stub.
- In contrast, TEM sample preparation is a quite complex and tedious procedure that only trained and experienced users can follow successfully. The samples need to be very thin, as flat as possible, and the preparation technique should not induce any artefacts (such as precipitates or amorphization) to the sample. Many methods have been developed, including electropolishing, mechanical polishing and focused ion beam milling. Dedicated grids and holders are used to mount the TEM samples.

# SEM vs TEM: differences in operation

- The two EM systems also differ in the way they are operated. SEMs usually use acceleration voltages up to 30 kV, while TEM users can set it in the range of 60 – 300kV
- The magnifications that TEMs offer are also much higher compared to SEMs: TEM users can magnify their samples by more than 50 million times, while for the SEM this is limited up to 1-2 million times.
- However, the maximum Field of View (FOV) that SEMs can achieve is far larger than TEMs, which users can only use to image a very small part of their sample. Similarly, the depth of field of SEM systems are much higher than in TEM systems.



*Figure 1: Electron microscopy images of silicon. a) SEM image with SED offers information on the morphology of the surface, while b) TEM image reveals structural information about the inner sample*

