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Does the Scanning Electron Microscope Have an Objective Lens?

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No, Virginia, there is no objective lens in the Scanning Electron Microscope.

There is much confusion about the lenses in a scanning electron microscope (SEM). All of the lenses in a SEM are condenser lenses. The fact that some scanning electron microscope manufacturers have labelled the controls for the final condenser "objective lens" is misleading and this may have contributed to the confusion.

To get some perspective on this matter, observe your compound light microscope. Starting with the light source, the first lens encountered is the condenser lens (the lens that handles the light before it interacts with the specimen). Next the light interacts with the specimen on a microscope slide. Then the light enters the objective lens (the first lens the light enters after interacting with the specimen) and finally the light travels through the ocular lens and then it enters your eye.

In the SEM the electrons emitted by the cathode travel through two to three condenser lenses before interacting with the specimen on a specimen stub. When the electron beam hits the specimen, the specimen is excited and gives off Auger electrons, secondary electrons, and X-rays. In addition, electrons from the primary beam may bounce back in the direction of the final condenser lens. These are called back scattered electrons.

The lens that is sometimes incorrectly designated the objective lens is the final condenser lens, the last lens that the electrons travel through before they interact with the specimen. Now, you may ask, so what's the big deal? Who cares what name is used for that final lens? We electron microscopists and all scientists should be concerned about naming things correctly and using the correct name. In addition, the use of the incorrect designation has led some persons to think that the Abbe equation can be used to calculate resolution in the scanning electron microsocpe. Remember the Abbe equation: Limit of resolution = $0.612\lambda/(n \sin \alpha_0)$. Part of that equation is "$\sin \alpha_o$" or the sine of the half angle of the objective lens. Since there is no objective lens in the SEM, the ABBE equation is not applicable to the SEM. Yet statements are made that imply that the resolution of any system that uses lenses is limited to half the wavelength used. That "half the wavelength" concept refers to the top part of the Abbe equation (0.612λ). For example H. K. Wickramasinghe states "more than 100 years ago, after all, the German physicist and lens maker Ernst Abbe described a fundamental limitation of any microscope that relies on lenses to focus light or other radiation: diffraction obscures details smaller than about one half the wavelength of the radiation." I presume that Wickramasinghe includes scanning electron microscopes in this statement since he uses the phrase "any microscope that relies on lenses to focus light or other radiation." Certainly the SEM uses lenses to focus the electron beam on the specimen, but wavelength or accelerating voltage is not involved in resolution in the SEM. Instead, the spot size of the primary beam as it scans the specimen and the nature of the the specimen are critical to resolution.

Let's explore some of reasoning that is behind the tendency to call the final condenser lens an objective lens. One argument might be that it is the lens closest to the specimen.

Another argument might be that it is the lens that you manipulate to focus the image of the specimen. After all, in the compound microscope, what lens do you adjust in order to get the image in focus? The objective lens! Similarly in the TEM, one adjusts the objective lens to get the image in focus! So what are you doing when you focus the SEM? You are adjusting the final condenser which means you are adjusting the spot size of the primary beam so that you get no overlap or gaps as the bream traverses across the specimen!

To emphasize the point of this paper: The SEM has no objective lens. The Abbe equation is not usable in calculating resolution in the SEM. Instead, resolution in the SEM is related to spot size (the diameter of the electron beam when it interacts with the specimen), that is, the smaller the spot size the higher the

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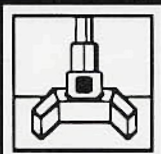

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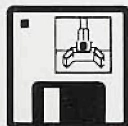

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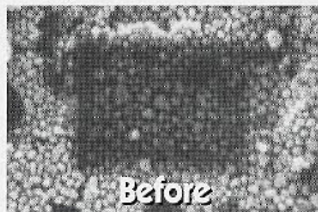

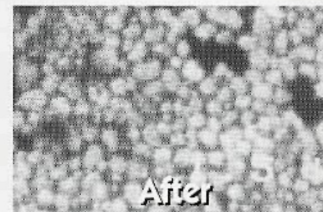

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resolution. Resolution is also related to the stability of the spot size, that is a variable spot diameter will limit resolution. Resolution is also related to the nature of the specimen, that is how the beam spreads when it interacts with the specimen.

To illustrate the relation of spot size to resolution to my students, I step up to the blackboard and draw an outline of my hand with fingers outstratched. Then I demonstrate how this hand would be imaged as a mitten with large spots and how the fingers could be resolved by using small spots for imaging.

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Isolation of Single Crystals from Liquid Drops

Walter C. McCrone, McCrone Research Institute

Microscopists often recrystallize or precipitate compounds for purposes of identification. Almost as often, a few crystals form that are irresistibly beautiful and demand isolating for single-crystal x-ray diffraction, spindle stage, polarized IR absorption, or remounting in a crystal-rolling medium like Aroclor® 1260.

The isolation of one such crystal among hundreds from the center of a drop is not as difficult as it sounds. It is done at 50-100X under a stereomicroscope using a fine, usually a tungsten, needle. The needle may (rarely) need to be surface-treated by rubbing with a water-insoluble wax (then tissue-wiped "clean") to prevent creeping of the solution up the needle and causing solution (and crystal) movement.

The needle is used to clear a path for the desired crystal by pushing the edge crust and other intervening crystals to one side. Complete clearance is not necessary. The desired crystal is then pushed with the needle along the slide to the edge and then well outside of the drop. A few smaller crystals and much solution may accompany it. An isthmus of solution is usually left back to the drop. The extraneous crystals are needed back into the drop and a small square of filter paper is used to cut the isthmus and leave the crystal in a small droplet of solution. The needle is then repeatedly touched to the remaining solution and small drops are thereby removed to a safe distance. This renders the crystal nearly dry but is is then pushed along the clean slide surface until it has left all of its surface liquid behind. It must be pushed until completely dry (10 seconds +/-). It is then ready for remounting.

The same procedure is adaptable to other solvents if precautions are taken to prevent spreading of low surface tension solvents. This is essentially impossible for low boiling solvents but can be done for DMF, diethylene glycol, alcohols above C_2 and higher boiling liquids like nitrobenzene, tricresyl phosphate, benzyl alcohol, and monobromonaphthalene.

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