Using the TEM Condenser Lens to Switch between Image and Diffraction Modes

Lydia Rivaud
GLOBALFOUNDRIES, 400 Stone Break Road Extension, Malta, NY 12020
lydia.rivaud@globalfoundries.com

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Introduction

Central to the operation of the transmission electron microscope (TEM) (when used with crystalline samples) is the ability to go back and forth between an image and a diffraction pattern [1]. Although it is quite simple to go from the image to a convergent-beam diffraction pattern or from an image to a selected-area diffraction pattern (and back), I have found it useful to be able to go between image and diffraction pattern even more quickly. In the method described, once the microscope is set up, it is possible to go from image to diffraction pattern and back by *turning just one knob*. This makes many operations on the microscope much more convenient. It should be made clear that, in this method, neither the image nor the diffraction pattern is "ideal" (details below), but both are good enough for many necessary procedures.

Basics of the Method

At the core of this technique is the operation of the microscope such that the objective lens is not focused at the plane of the specimen. If the objective lens is focused on a plane some way away from the sample—some microns away turns out to be suitable—what is seen on the screen (or on the camera, as the case may be) is either a diffraction pattern or an image, depending on whether the illumination is focused or spread. Hence turning the C2 control (generally called "brightness" or "illumination" depending on the manufacturer) takes you from image to diffraction pattern and back. When the illumination is widely spread ("parallel"), the image on the screen will be an image of the sample. This image will be out of focus, of course, because the lens is focused far from the sample. However it is sharp enough for many purposes. When the illumination is focused in the plane you are viewing (where the objective lens is focused), what appears on the screen is a diffraction pattern from the part of the sample that is illuminated. This diffraction pattern looks like a selected-area diffraction pattern. It consists of an array of spots (see Figure 1). Generally the Kikuchi lines will not be clearly visible, and the camera length is not known.

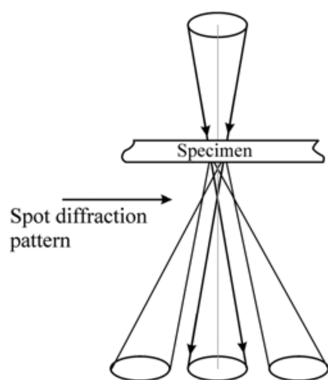

Figure 1: When the illumination is focused below the sample, the electrons that are Bragg-reflected are brought to focused spots in the same plane as the direct beam. In this way a spot diffraction pattern (similar in appearance to a selected-area pattern) is formed. It does not matter if the illumination is focused above or below the sample. If the illumination is focused above the sample, rather than below, the pattern seen on the screen or camera is the same, but adjacent to the specimen the spot pattern is virtual rather than real. Image courtesy of Alwyn Eades.

Details of the Method

This work was performed on an FEI Tecnai T30 TEM. This microscope has a motorized sample height control with a digital height read out. Under these conditions it has proved convenient to use a change of sample height to move the sample away from the focus plane. On other instruments it might prove easier to leave the sample at the eucentric height and use the objective lens control ("focus") to focus away from the sample plane.

Here is the procedure:

Step 1: Start in the normal way. Have the sample at the eucentric height and in focus.

Step 2: Take out the objective aperture.

Step 3: Focus the illumination to a small spot.

Step 4: Go out of focus by changing the height of the sample. The small spot will change to a diffraction pattern. Change the height of the sample until the diffraction pattern has a convenient camera length. (Remember you are still in image mode, so the camera length is not given by the read-out of the microscope.)

Step 5: Use the C2 control (brightness or illumination) to spread the illumination to obtain an image. Now, to go back and forth from image to diffraction pattern, just change C2.

When this mode has served its purpose, you can go back to normal operation by bringing the sample back to its eucentric height (and using the objective aperture in image mode).

Conclusion

When the requirements of microscopy involve going back and forth between images and diffraction patterns repeatedly, it is convenient to use the method described here (not previously reported as far as Alwyn Eades, reviewer and contributor to this article, is aware). If the sample is far from focus, a change of the condenser lens setting is all that is needed to go from an image to a diffraction pattern and back.

Additional Note from Alwyn Eades

When I received an early version of this note from Lydia Rivaud, I was skeptical because I imagined that the image obtained would be too blurred to be useful. I was wrong; the method works very well, and the image is surprisingly clear. When I tried it over a range of magnifications from 5k to 60k, I found that I could clearly see dislocations and other defects, including the fringes in images of grain boundaries. The explanation, I think, for the unexpectedly good images has its origin in the fact that the electrons are mostly in the diffracted beams so that there are just bright- and dark-field images. If the microscope is very far out of focus, the bright- and dark-field images are superimposed on each other but are so far displaced from registry with each other that instead of a blurred image a relatively sharp bright-field image is seen with unrelated dark-field images superimposed on it; but these do not, for the most part, prevent seeing clearly the features of the bright-field image. On the microscope that I used, which does not have digitally controlled sample height, I found it easier to go out of focus by changing the objective lens setting rather than by changing the sample height. This method has the disadvantage that the setup requires one more step to get started (the spot diffraction pattern has to be refocused at step 4), but it has the advantage that the sample stays at the eucentric height. Altogether, this is a novel and productive way to operate the microscope—give it a try.

Reference

[1] DB Williams and CB Carter, *Transmission Electron Microscopy*, Second Edition, Springer, New York, 2009.

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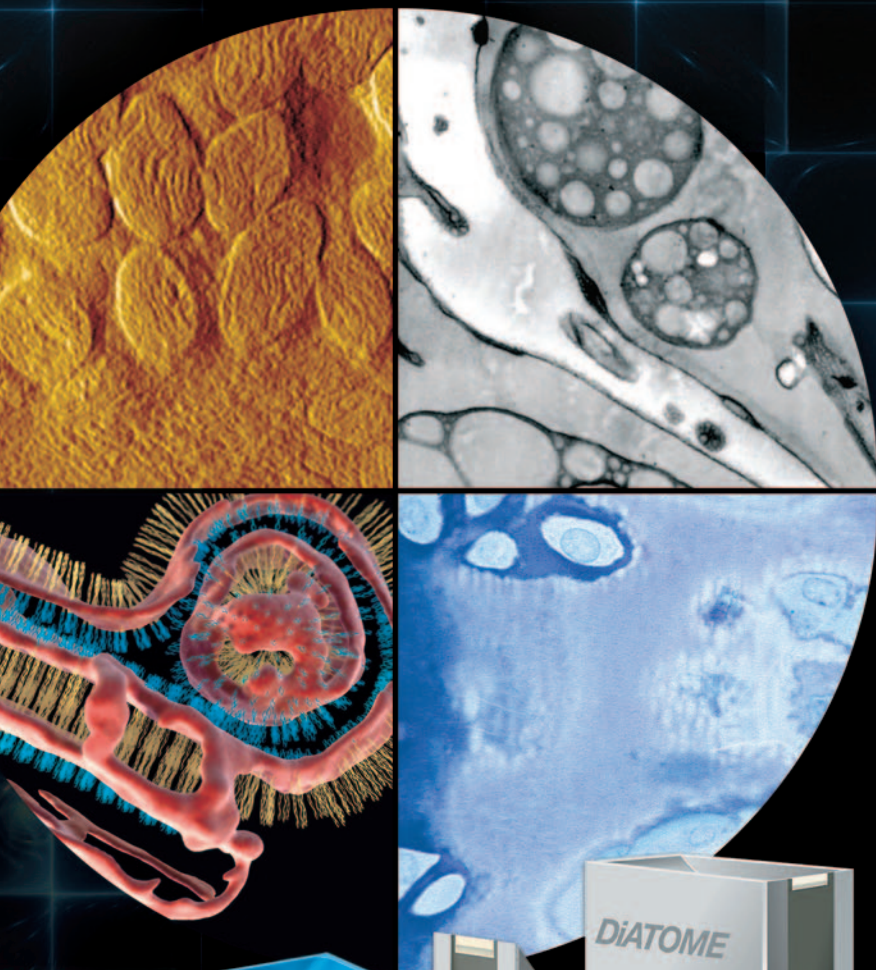

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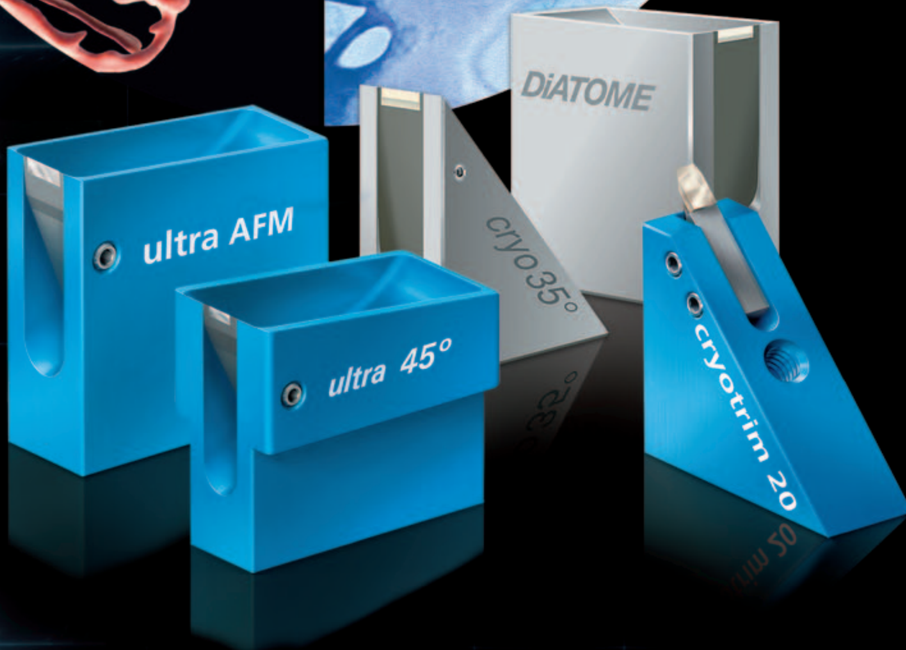

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