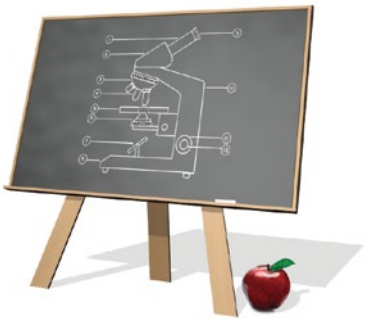
Design and Implementation of a Practical, Hands-On TEM Short Course



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Introduction

There has been a general increase in the use of Transmission Electron Microscopy (TEM) in nanotechnology areas by both industrial and academic laboratories. In many cases the scientist assigned to the new TEM has little or no prior TEM experience, and although a number of more advanced theoretical courses are offered, a survey of available short courses revealed the lack of a basic, practical TEM course.

In discussions with Mike Kersker from JEOL, it became clear that conventional training by installation engineers is not effective for very inexperienced users, and we decided to offer a basic course at the College of Microscopy with an emphasis on hands-on training. The College of Microscopy instructors have many years of experience teaching a similar Scanning Electron Microscopy course, and the new TEM course was modeled after that class.

We want the students to avoid the fear and frustration that a new TEM operator may experience. We show them how things are supposed to look in the TEM so that they can work with confidence. Every student gets several opportunities to practice alignment and learns how to set up the microscope to obtain good quality images, XEDS spectra, and electron diffraction patterns. We also emphasize good laboratory practices, how to monitor and maintain the instrument, and how to communicate effectively with service engineers. We also provide them with online and published resources to help them gain familiarity with the field of electron microscopy. Finally, we strive to share our enthusiasm with them and help them to enjoy using the TEM.

Figure 1: A laboratory session on the JEM-3010 using the large LCD panels.

Typical Training Scenarios

We started by looking at the ways in which microscopists typically learn how to use a TEM so that we could tailor the course to students from a variety of backgrounds. These may include:

- Being self-taught or taught by a colleague on the job.
- Receiving vendor training on-site by the installation engineer or off-site at the vendor premises by an applications scientist.
- Attending short courses such as those offered by Lehigh University and Arizona State University.
- Receiving university training included in undergraduate or graduate courses.

A variety of students have taken the College of Microscopy course. Some are users who have limited training and want to expand their capabilities because they are working with new equipment or applications. Others are technical staff with no formal training in TEM who are, or will be, looking after one or more TEMs. Then there are university faculty who are not microscopists but use TEM in their research. There are industrial users who are self-taught or had TEM training many years ago and need a refresher course in basic operations and new equipment developments. We have also had researchers who don't plan to operate a TEM themselves but have to understand TEM data provided by someone else.

COM250 Transmission Electron Microscopy Course

This course is aimed primarily at materials scientists, although it can also benefit biological scientists interested in basic TEM operations and use of digital cameras for imaging. These students can also gain awareness of the growing use of

	am		pm	
	Session 1	**Session 2**	**Session 3**	**Session 4**
Day 1	Introduction & What is a TEM	Types of TEM, Image Formation	TEM Alignment and Operation	TEM Alignment and Imaging - Demo
Day 2	Introduction to AEM; XEDS Analysis	TEM Alignment and Imaging - Hands-On	EELS & Diffraction	TEM Analytical Techniques - Demo
Day 3	Specimen Preparation Advanced Techniques (STEM, CBED etc)	TEM Analytical Techniques - Hands-On	TEM Analytical Techniques - Hands-On	TEM Students Choice - Demo
Key		Lecture		Lab Session

Figure 2: The schedule for the three-day course.

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advanced materials and nanomaterials in the medical field. Routine microscopy at intermediate magnifications can often be achieved with little understanding of the instrument, but analysis of nanomaterials requires pushing the operational limits of the microscope. To work at or near the instrument's resolution specification requires a better understanding of basic principles and practices, and this is what we try to provide.

The course is taught at the College of Microscopy [1], the newest branch of The McCrone Group in Westmont, Illinois. This is a state-of-the-art teaching facility for all forms of microscopy. The laboratory sessions utilize the JEOL JEM-3010 TEM in the McCrone Associates consulting laboratory adjacent to the College. This JEOL JEM-3010 is ideally configured to teach this course. It has a STEM unit, several different CCD imaging cameras, an Oxford XEDS system, and a Gatan Imaging Filter that can be used for EELS spectroscopy, as well as energy-filtered imaging. The standard monitors on the computers are replaced by large LCD panels to give everyone an unrestricted view of microscope operations. The class size is limited to no more than six students to ensure that everyone gets adequate hands-on time and to avoid crowding in the laboratory.

The course runs for three days with increasing amounts of hands-on time each day. Laboratory sessions are planned to provide practical experience in the topics covered in the preceding lectures. For example, in the "TEM Alignment and Operation" lecture, we cover enough electron optics (e.g., how alignment coils work, features of electromagnetic lenses, and stigmators) for the students to understand the principles of alignment and their impact on imaging. In the associated laboratory sessions, the students are shown and given experience with alignment so they know what to look for and what effect poor alignment has on imaging (Figure 3). We use the "combined test specimen" [2] for this lab because it allows alignment and atomic resolution imaging to be carried out on a single specimen that is readily available. Our biggest success—a student who was spending half a day aligning the microscope and was still not confident of his alignment—was aligning the 3010 within 10 minutes when he finished the course. Students are introduced to bright-field and dark-field imaging in the "image formation" and the "alignment and operation" modules and to electron diffraction in the "EELS and diffraction" module.

In the "Introduction to AEM: XEDS Analysis" lecture, we cover the theory and pitfalls of XEDS analysis, including X-ray generation, detector design, microscope evaluation using the NiOX test specimen, spectral artifacts, specimen thickness considerations, and why we should question auto-ID and semi-quantitative results. In the laboratory sessions, we show some of the pitfalls in setting up the microscope, such as specimen tilt, effect of apertures, and sources of uncollimated radiation. The "NiOX test specimen" [3] is used to show collection of X-rays, shadowing, hole count, and K-to-L ratio. This specimen is also used for the electron diffraction lab—the introduction of standard specimens for calibration and checking performance is stressed during the course. The student goes away with a better appreciation of the power of the TEM, how easy it can be to produce good quality results, and the value of practice and experience.

Student Feedback

We have run the course five times so far, and all students are required to fill in a survey before they are given their International Association for Continuing Education and Training (IACET) CEU certificate. Typically they believe that the course objectives were understood and met and that the course is applicable to their current and future work. They like how the material is organized and the fact that it is a practical,

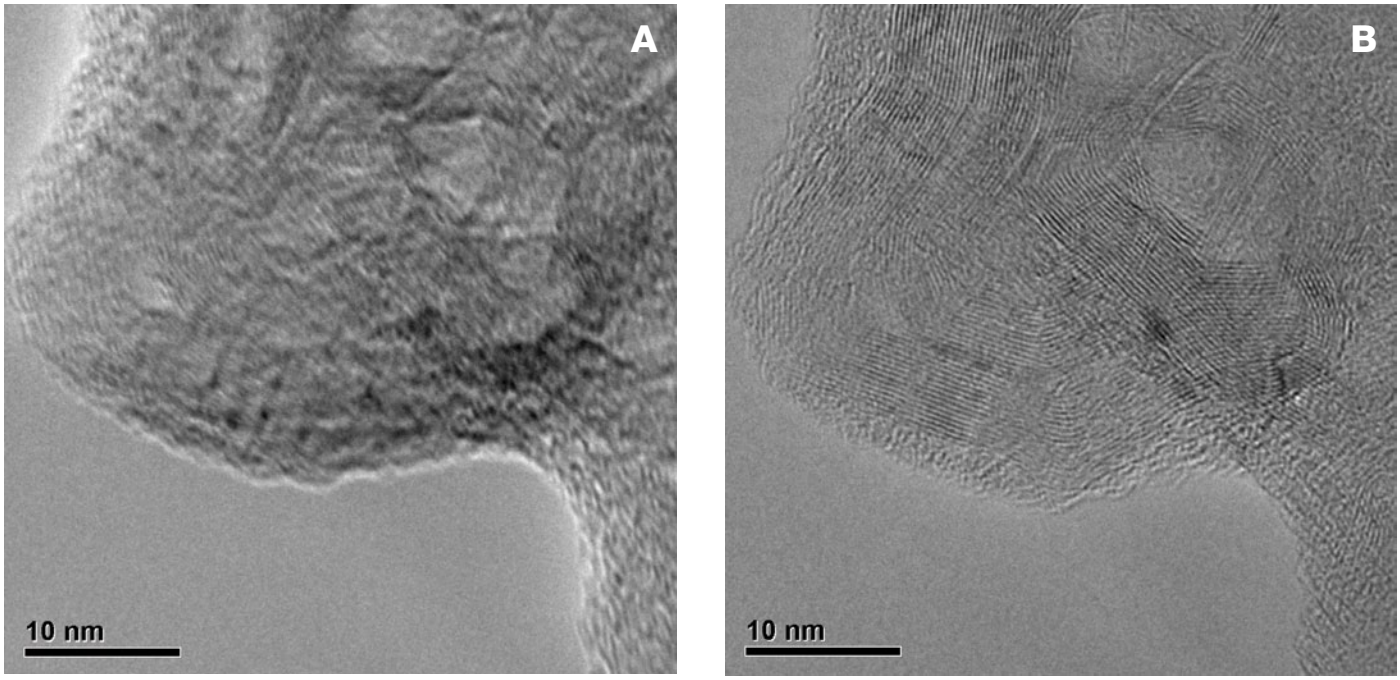

Figure 3: Examples of the effect of poor (A) and good (B) alignment on the quality of the best image obtained from graphite (JEOL JEM-3010, 300kV).

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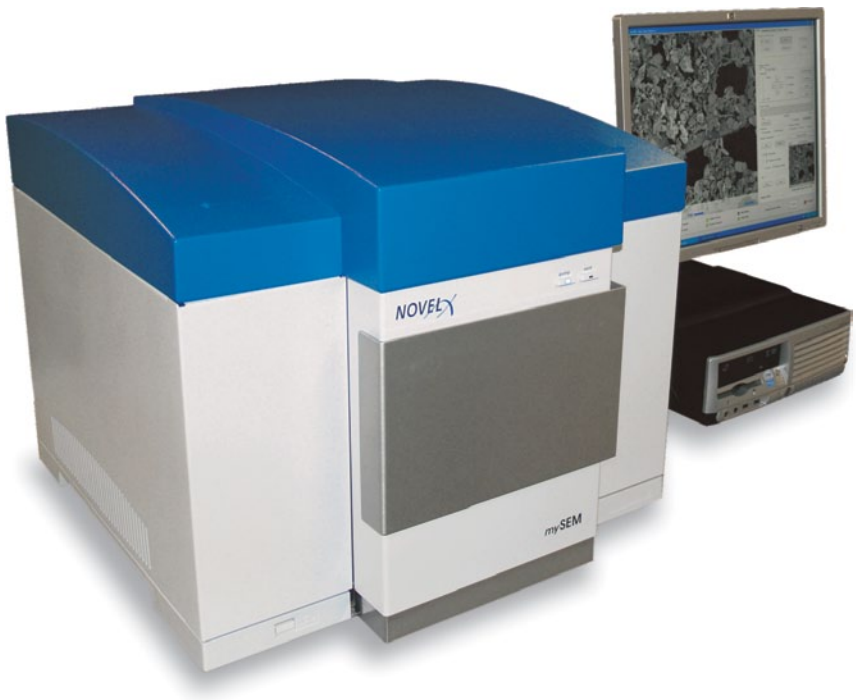

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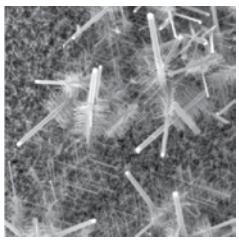

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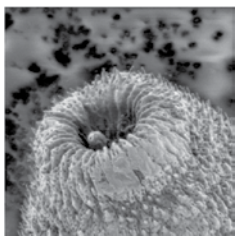

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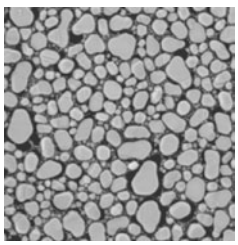

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hands-on course with a real TEM. They nearly always would prefer more hands-on time and have commented that fewer students and lunches on-site (planned for 2009) would meet this aim.

We have found that student backgrounds and experience levels vary, so it can be difficult to strike a balance. Depending on the student, either too much or not enough time was spent on basic operation versus advanced techniques. However, we believe that it is important to introduce the students to as wide a range of TEM-based techniques as possible so that they can be confident they are employing the correct technique to solve a problem and not just collecting data in the way that is most familiar to them.

Whereas most students felt that they lacked the knowledge and/or skills required coming into the course, all left feeling that they had learned valuable skills to take back to their own laboratories. We have watched every group of students learn from each other, and we have learned from them. The students consistently comment that they have enjoyed the experience. As instructors, we share that enjoyment and welcome the opportunity to teach future classes. MT

References

[1] College of Microscopy website:
http://www.collegeofmicroscopy.com
[2] The combined test specimen is available from any of the major microscopy supply companies, such as EMS, SPI, or Ted Pella.
[3] The NiOX test specimen is available from SPI:
http://www.2spi.com/catalog/standards/niox.shtml.

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Instruments to be used include FEI Tecnai, CM 200, Nova-200, Topcon 002B, JEOL 2010F, 4000EX, 2000FX, and LEO 912.

The registration form (available at http://le-csss.asu.edu /workshops/) and check for the course fee (in the amount of $950.00) payable to Arizona State University should be sent by November 2, 2009 to:

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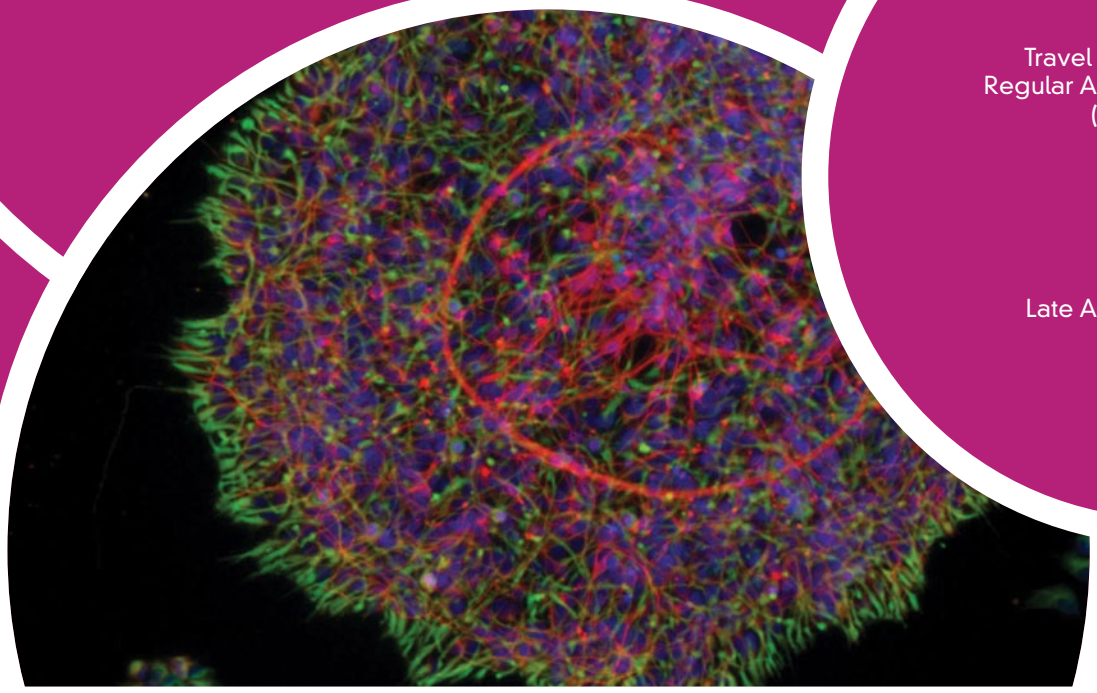

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SEPTEMBER 1
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OCTOBER 1
Early Registration

OCTOBER 15
Late Abstract Submission