doi: 10.1017/S1431927609095531
Microsc Microanal 15(Suppl 2), 2009
Copyright 2009 Microscopy Society of America

The Use of Transmission Electron Microscopy – What are the Real Capabilities and When can I use it?

J. Ringnalda and G.Scholes

FEI Company, Hillsboro, OR 97124

Transmission Electron Microscopy, and therefore, microscopes, have enjoyed a significant increase in attention level in an era when the focus is concentrated on NanoTechnology in many countries around the world. Since electron microscopy is an essential component to investigate and explain most things 'nano', more interest means more money available, enhancing the developments of new technologies. In the case of electron microscopy, both scanning and transmission techniques have been equipped with corrector technology, which appeared as an apparent magic trick to beat the laws of physics a number of years ago; but since have been refined to production additions to a commercially available microscope and by now most people now know they did not 'cheat' the laws of Physics, but instead obey the laws of physics. In looking at the boundary conditions of the law: "A ROUND lens has positive spherical aberration [1]" it would seem we are stuck with positive Cs. However these correctors employ lenses which are simply not round, and can therefore be tuned to have negative spherical aberration. Add the two, and you can generate any value of spherical aberration you want, including 0. Utilizing this 'non-round' technology, newer generation of correctors, such as Dodecapole correctors for the probe and Cc correctors for even further improvement of the imaging resolution is being developed [3].

Utilizing this type of technology, the optical resolution of the instrument has already been improved to levels previously unheard of; 0.5 Angstrom at 300kV [3]. First and foremost, it has to be established that the microscope column itself, which is the support structure for the corrector technology, is up to the job to allow the correctors to function to their designed level. However what needs to be remembered also, is that there are other effects and characteristics which need to be thought about when performing experiments on this type of instrumentation. One of the fundamental questions that should always be asked is: "Does what I am looking at still represent the bulk that it came from" and "Is this sample going to allow the results that I need to be obtained, furthermore was it prepared in a manner consistent with the resolutions I will be deducing from the data?"

We have now also entered an era where SEM resolution at 30kV is below 1nm. While TEM systems have been at that resolution level for a long time. For analytical performance 1nm is a key capability for most research into high spatial resolution analysis for materials analysis. Clearly the sample needs to be thin, otherwise this 'entry' resolution of the probe is meaningless; even at lower kV's. Fortunately there are methods to make samples thin readily available such as dualbeam[tm] instruments, which have a focused ion beam as well as a focused electron beam concentrated on the same part of the sample.

This is the essence of the capabilities of electron microscopy. What we typically see is that the sample is usually the limiting factor, not the microscope. The depth of focus on corrected systems is down to a few nanometers, beyond that range the sample image is blurry; certainly contrast is not enhanced. On a non-corrected system it is not unusual to be a micron or so away from focus to get a

https://doi.org/10.1017/S1431927609095531 Published online by Cambridge University Press

good image. For 'soft' materials, the Cs provides the contrast, so when the Cs is reduced or taken away, the perceived contrast in the image is certainly reduced. We are about to be entering an era where we can take away one of the other remaining aberrations; Cc, what will that do for our contrast?

So if the sample has been prepared in such a way that the surface modifications (amorphization etc) is negligible compared to the material to be imaged or analyzed (a tough thing to do just by itself), the sample is clean (especially free of hydrocarbons) and the sample material is resilient to the energy of the electrons that are about to interact with it, we have stage one of our experiment ready. Stage two of the experiment is the preparation of our microscope, to ensure the system is tuned and ready for the experiment. Thankfully because of automation of tuning and alignments, this job is now much easier than it used to be, however it is still not trivial and it needs to be done correctly and with care. Stage three is the successful combination of the perfect sample with the perfect microscope, and we a continually trying to get that particular project stage perfected. There have been some significant improvements in automation and improvement for stage one and stage two, however the final stage of a successful experiment is still largely down to the operator; orienting the sample for imaging, orienting the sample for analysis, ensuring that the correct area of the sample is indeed thin enough to allow the experiment to be valid, etc.

All three stages need to be completed to a high standard before high spatial resolution analysis can be called a success. A comforting thought is this: At this moment in time, anybody that states that atomic resolution analysis is easy, has not done it. If anybody says it is easy and also say they have done it; they have not done it correctly…

The main focus of this tutorial will be on the preparation and the usefulness of electron microscopy techniques. There are many answers that can be provided on a 120kV system for specific research fields; the use of a monochromated, double corrected 300kV column is not always required. Keeping the operation of the system as straightforward as possible, and allowing the best results to be obtained from the most applicable system to do the work is the key of the planning stages of any experiment.

This tutorial will have some state of the art results to illustrate what is possible with modern systems, both S/TEM and SEM. Also some of the pitfalls in setup and preparation will be discussed.

The authors thank the employees of CEOS GmbH for their contributions to making the new generations of corrector technology on Titan microscopes a success. We would also like to acknowledge stimulating discussions with Mike Scheinfein, FEI Company.

References

[1] O. Scherzer, Z. Physik 101 (1936) 593.
[2] M. Haider, G. Braunhausen, and E. Schwan, Optik 99 (1995) 167.
[3] C. Kisielowski, R. Erni, B. Freitag, Microscopy and Microanalysis 14 Suppl. 2 (2008) 78-79.

https://doi.org/10.1017/S1431927609095531 Published online by Cambridge University Press