Transmission Electron Microscopy– Instruction Notes

Keywords: Electron beam, crystal structure, CCD, aberration, resolution

I. GOALS OF THE EXPERIMENT

Modern state-of-the-art microscopes are ideal instruments to obtain simultaneously local structural information of a material with a resolution below 10-10m and local spectroscopic information with an energy resolution below 1 eV. Thus, it is possible to directly relate structural properties to physical and chemical properties, respectively. This extremely high spatial resolution can be reached due to the use of novel correctors for lens aberrations of electro-magnetic lenses.

In this experiment you will learn basics of TEM by operating a historical instrument. The experiment consists of two parts. In the first part you will receive a light-optical introduction to microscopy. In the second part you will become familiar with basic operation modes of a TEM. You will investigate a sample by bright field and dark field imaging. You will use the diffraction mode in order to determine the lattice parameters of the material from a ring pattern.

II. LEARNING CONTENT

- Analogy between a light optical microscope and a transmission electron microscope, lens systems of microscopes
- Behaviour of an electron in a magnetic field, electro-magnetical lenses, lens aberrations, electron trajectory through the microscope (rotation of the image versus the diffraction pattern)
- Relationship between image and diffraction pattern, direct and reciprocal space, Fourier transform
- Comparison between the resolution of a light microscope and a TEM. (Distinction between resolution, accuracy and magnification)
- Different kinds of contrast: absorption contrast, Bragg contrast, amplitude and phase contrast, (contrast transfer function)
- Elastic and inelastic scattering, double diffraction, Kikuchi lines
- Crystal symmetry, extinction rules
- Crystal defects: dislocations, stacking faults

III. PROCEDURE

FIRST LAB SESSION

1) Light Optical Analog to the TEM

Build a microscope:

- Use the laser source, produce a defined beam.
- Use an objective lens and a projector lens to generate a focused image of the object on the screen.

You will receive the following objects for investigation:

- Adjustable single slit, various double slits, optical line grids
- Nylon tights
- Negatives of HRTEM images
- Further slides

The following principal sketches have to be drawn for every object:

- The image of the object before Fourier filtering
- The unfiltered and filtered diffraction pattern
- The image of the object after Fourier filtering

Problems and questions:

- Vary the width of the single slit. How does the diffraction pattern depend on the slit width?
- Compare the diffraction patterns of various double slits and explain the differences. Proceed in the same way for the optical line grids.
- Stretch the tights in different directions. What do you expect to happen to the diffraction pattern? Why?
- On the HRTEM negative you can see crystalline and amorphous parts. How do the diffraction patterns of the different areas look? And why?
- The crystalline area on the HRTEM negative shows a defect. Find and visualise the defect by Fourier filtering and discribe its shape. What type of defect do you see?
- Image the crystalline region and look at the unfiltered image. Try to block the primary beam. What does the image now look like and why?

SECOND LAB SESSION:

2) Work at the TEM

- Align the gun and the condensor system parallel to the optical axis in order to obtain a defined beam
- Produce an image of the sample and record it with the CCD camera. Describe the contrasts you see.
- Generate a bright field image and record it with the CCD. How does the contrast change?
- Generate a dark field image and record it with the CCD. Which parts are now visible and

which parts are invisible? Why?

- Obtain a selected area diffraction pattern of different parts of the sample. Always image the area from which you record the diffraction pattern.
- Evaluate the lattice parameter of the crystal from the diffraction pattern.

IV. REFERENCES:

(1) B. Fultz, J.M. Howe, *Transmission Electron Microscopy and Diffractometry of Materials*, Springer (2001).

(2) D. B.Williams, C. B. Carter, *Transmission Electron Microscopy*, Vol. I - IV, Springer (2009).

(3) L. Reimer, *Transmission Electron Microscopy - Physics of Image Formation and Microanalysis*, Springer (1984).

(4) E. Hecht, *Optik*, Oldenbourg Verlag (2001).

(5) Lipson, Lipson, Tannhauser, *Optical Physics*, Cambridge University Press (1995).

(6) H. Alexander, *Physikalische Grundlagen der Elektronenmikroskopie*, Teubner (1997).

(7) Will Kleber, Hans-Joachim Bautsch, Joachim Bohm, Detlef Klimm, *Einführung in die Kristallographie*, 19. Auflage, De Gruyter Oldenbourg (2010).

(8) Walter Borchardt-Ott, *Kristallographie: Eine Einführung für Naturwissenschaftler*, Springer (2008).