Change of contrast in 2D-MoS_2 with Cc/Cs-corrected low-voltage HRTEM

ulm university universität ulm

Bachelor Thesis, Group of Electron Microscopy for Materials Science, Head: Prof. Dr. Ute Kaiser

Background

Spherical aberration correction has become inevitable for atomic resolution imaging in transmission electron microscopy (TEM) at accelerating voltages of 100-300 kV. However, there are classes of materials that require much lower accelerating voltages as their knock-on displacement threshold is far below 80 kV. Unfortunately, the resolution of spherical aberration-corrected transmission electron microscopes (TEM) at acceleration voltages below 80 kV with a conventional electron source is limited by chromatic aberration of the objective lens. There are two approaches to achieve atomic resolution at lower voltages: either develop a monochromated electron source with a particularly small energy width and reduced beam current [1] or develop an aberration corrector that corrects for both, the spherical and chromatic aberration of the objective lens [2, 3].

The Sub-Angström Low-Voltage Electron Microscope (SALVE) was developed with a Cc/Cs-corrector and works with accelerating voltages of 20-80 kV [4]. One advantage of going to low voltages is, that the contrast is increasing with decreasing voltage [5]. Even if the contrast is enhanced, the contrast transfer is dampened due to the Johnson-Nyquist noise. Especially for Cc/Cs- corrected TEMs are sensitive to the Johnson-Nyquist noise because the primary mechanisms of incoherence are eliminated. Furthermore, the beam path is increased due to the additional optics of the corrector which leads to a reinforced incoherence based on the Johnson-Nyquist noise [6].

Aim

The aim in this bachelor thesis is to prepare monolayers of MoS_2 which will be investigated together with the supervisor at the Cc/Cs-corrected Salve machine. High resolution TEM images will be acquired at voltages ranging from 80 kV down to 20 kV. It will be of great interest to compare the change of contrast at the different voltages and see how it fits to the scattering theory.

Workplan

- Fabrication of MoS_2 TEM samples with exfoliation
- Recording HRTEM images with the Cc/Cs-corrected Salve machine of the prepared 2D-MoS_2
- Evaluation of the voltage-dependent contrast and the comparison to the scattering theory

Requirements

- good physical and mathematical understanding
- high interest in laboratory work
- enjoying autonomous, scientific work in an international environment

[1] S. Morishita, M. Mukai, K. Suenaga, H. Sawada; Appl. Phys. Lett. 108, 013107 (2016)

[2] M. Haider, P. Hartel, H. Müller, S. Uhlemann, J. Zach, Microscopy and Microanalysis, 16 (04), 393-408 (2010)

[3] U. Kaiser, J. Biskupek, J. Mayer, J. Leschner, L. Lechner, H. Rose, M. Stöger-Pollach, A. Khlobystov, P. Hartel, H. Müller, M. Haider, S. Eyhusen, G. Benner; Ultramicroscopy, 111, 8, 1239-1246 (2011)

[4] M. Linck, P. Hartel, S. Uhlemann, F. Kahl, H. Müller, J. Zach, M. Haider, M. Niestadt, M. Bischoff, J. Biskupek, Z. Lee, T. Lehnert, F. Börrnert, H. Rose, U. Kaiser; Phys. Rev. Lett. 117, 076101 (2016)

[5] Z. Lee, J.C. Meyer, H. Rose, U. Kaiser; Ultramicroscopy 112 (2012) 39-46

[6] S. Uhlemann, H. Müller, P. Hartel, J. Zach, M Haider; Phys. Rev. Lett. 111, 046101 (2013)

Supervision: Tibor Lehnert (tibor.lehnert@uni-ulm.de)