MM 14: Topical Session TEM IV

Time: Tuesday 11:00–13:00 Location: IFW A

Topical Talk MM 14.1 Tue 11:00 IFW A

Transmission Electron Microscopy at 20 kV for Imaging and Spectroscopy - Current Status and Future Prospects — •U. Kaiser[1], J. Biskupek[1], J.C. Meyer[1], J. Leschner[1], L. Lechner[1], Z. Lee[1], S. Kurasch[1], U. Golla-Schindler[1], M. Kinyanjui[1], H. Rose[1], M. Stöger-Pollach[2], A.N. Khlobystov[3], M. Haider[4], P. Hartel[4], H. Müller[4], S. Eyhusen[5], and G. Benner[5] — [1]Central Facility of Electron Microscopy, Ulm University, Germany — [2]USTEM, Vienna University of Technology, Austria — [3]University of Nottingham, United Kingdom — [4]CEOS GmbH, Heidelberg, Germany — [5]Carl Zeiss NTS GmbH, Germany

We demonstrate the feasibility of a transmission electron microscope for direct spatial imaging and spectroscopy using electrons with energy in the range between 20 and 80keV. The highly stable instrument is equipped with an electrostatic monochromator, an imaging energy filter and a CS-corrector. High image contrast is obtained at 20 kV. Using this voltage, we have shown the transfer of the 213 pm lattice structure of single-layer graphene and of the 200 reflections (271.5 pm) of 4 nm thick Si layers. Moreover, radiation-sensitive fullerenes (C60) within a carbon nanotube container withstand at 20kV an about two orders of magnitude higher electron dose than at 80 kV. In spectroscopy mode we show that the quasi-monochromatic low-energy electron beam enables the acquisition of EELS spectra with exceptionally low background noise.

Topical Talk MM 14.2 Tue 11:30 IFW A

Quantification of instrumental properties in high-resolution transmission electron microscopy — •Juri Barthel and Andreas Thust — Institute for Solid State Research and Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

The precise characterization of the instrumental imaging properties in the form of aberration parameters constitutes an almost universal necessity in quantitative high-resolution transmission electron microscopy, and is underlying most hardware and software techniques established in this field. An effective and reproducible aberration control depends on two crucial aspects: First, an adequate aberration measurement technique is required, which must achieve a sufficient precision depending on the instrumental information limit. Second, an accordingly high optical stability of the microscope is needed, because the relevance of an aberration measurement ends with the lifetime of the measured optical state.

Both prerequisites, measurement precision and instrumental stability, are investigated in a quantitative way with respect to their achievable limits. Numerical procedures are presented for the automatic extraction of the two lower-order aberrations, defocus and 2-fold astigmatism, from single diffractograms of amorphous material [1]. The novel procedures achieve a precision of a nearly 1 Angstrom, which is sufficient to control the optical state and to assess its stability for successful sub- Angstrom microscopy.

[1] J. Barthel, A. Thust, Ultramicroscopy 111 (2010) 27 - 46.

MM 14.3 Tue 12:00 IFW A

Quantitative High-Resolution Transmission Electron Microscopy of Single PlatinumAtoms — •Björn Gamm[1], Radian Popescu[1], Holger Blank[1], Reinhard Schneider[1], Dagmar Gerthsen[1], André Beyer[2], and Armin Gölzhäuser[2] — [1]Laboratorium für Elektronenmikroskopie, Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]Physik Supramolekularer Systeme, Universität Bielefeld, 33501 Bielefeld, Germany

Single atoms can be considered as the most basic objects to be imaged in an electron microscope and can therefore be used to test the image contrast model which comprises the electron-atom interaction and image formation in the microscope. In this work a quantitative comparison of simulated and experimental high-resolution transmission electron microscopy (HRTEM) images of single Pt-atoms is performed to test the basic image contrast model. Single Pt-atoms were deposited on a self-assembled monolayer substrate and imaged by HRTEM using an aberration-corrected microscope. The negligible contrast of the substrate allows the quantification of single-atom contrast. Image simulations are performed on the basis of Weickenmeier-Kohl and Doyle-Turner scattering factors. Objective-lens aberrations as well as the effects of partial coherence and MTF of the CCD camera are considered. The contrast from the simulations is compared with the experimentally measured contrast. Peak intensity and full width at half maximum are determined. For these properties full agreement on an absolute intensity scale is found within the error limits for WK scattering factors.

MM 14.4 Tue 12:15 IFW A

Applications of CS-corrected TEM in metal nitride hard coating materials — •Zaoli Zhang[1], Boriana Roshkava[1], Rostislav Daniel[2], Christian Mitterer[2], Gerhard Dehm[1,2], Petr Lazar[3], Josef Redinger[3], and Raimund Podloucky[4] — [1]Erich Schmid Institute of Materials Science, Austrian Academy of Sciences — [2]Department Materials Physics, University of Leoben, Leoben, Austria — [3]Institute of General Physics, Vienna University of Technology, Vienna, Austria — [4]Department of Physical Chemistry, University of Vienna, Vienna, Austria

Using CS-corrected HRTEM), electron energy loss spectroscopy (EELS), and ab-initio density functional theory (DFT) the interface microstructures of VN (CrN)/MgO (001) are closely examined. By HRTEM, we show an atomic resolution structure of epitaxially grown VN film on MgO (CrN/MgO, CrN/Cr/Si) with a clearly resolved oxygen and nitrogen sub-lattice across the interface. As revealed by DFT calculation, the (002) interplanar spacing oscillates in the first several VN layers across the interface. Interfacial chemistry determined by EELS shows the preponderance of O and V atom at the interface of VN/MgO, and V-L2,3 at the interface show a small detectable core-level shift. A clear energy shift of Cr-L2,3 at CrN/Cr/Si interface is observed, Cs-corrected HRTEM images reveal the presence of one interlayer(Cr2N), which leads to the chemical shift of Cr-L2,3.

MM 14.5 Tue 12:30 IFW A

Optimum TEM imaging conditions for graphene at low and medium voltages — •Zhongbo Lee[1], Ute Kaiser[1], Jannik Meyer[2], and Harald Rose[1] — [1]Central Facility of Electron Microscopy, Group of Materials Science Electron Microscopy, University of Ulm, 89069 Ulm, Germany — [2]University of Vienna, Department of Physics, 1090 Vienna, Austria

In standard electron microscopy graphene is usually considered as a weak phase object (WPO) for which the contribution of the non-linear terms to the image contrast is negligibly small. Here we investigate whether this argument holds true for low voltages by means of calculating optimum positive and negative image contrast for an aberration-corrected TEM operating at acceleration voltages of 80kV and 20kV, respectively. The results in the case of achromatic imaging conditions show that graphene cannot be treated as a WPO for low voltages. Even at 80kV the difference between optimum positive and negative contrast is significant. At 20kV this difference becomes very large for the same imaging conditions demonstrating that in this case graphene acts as a strong phase object. In the presence of chromatic aberration, however, the finite energy width of the electron beam largely nullifies this difference. This behavior is shown by the calculations and verified by the experiment for 80kV. Moreover, for chromatic imaging conditions at 80kV the contrast can be increased significantly by means of a monochromator which reduces the energy width to about 0.1eV. In the case of 20kV, however, a significant improvement of contrast can only be achieved by the additional correction of chromatic aberration.

MM 14.6 Tue 12:45 IFW A

Quantitative scanning transmission electron microscopy at low energies — •Erich Müller, Marina Pfaff, Holger Blank, Tobias Volkenandt, Felix Bleimund, and Dagmar Gerthsen — Laboratorium für Elektronenmikroskopie, Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany

Sensitive material (Z-)contrast is obtained by high-angle annular dark-field (HAADF) scanning transmission electron microscopy (STEM) at low electron energies ($<$ 30 keV). Even for small atom-number differences, quantitative analysis of composition is possible (e.g. in ternary semiconductors) and the TEM sample thickness can be determined. Moreover, knock-on damage is negligible at low electron energies, which is favorable for the examination of radiation-sensitive materials like semiconductors, organics or biological samples. The electron transmission is measured with a standard annular semiconductor detector in a state-of-art scanning electron microscope. This allows rapid change of instrumental alignments and parameters like electron energy or collection angles, which is essential for the determination of the characteristic dependence of the image intensity on these parameters. In combination with a focused-ion-beam system, samples with defined geometry and thickness can be prepared from materials with known composition which is essential to test the procedure for the extraction of quantitative image information. The presented method is based on HAADF STEM images and the comparison of the measured intensities with semi-empirical calculations or Monte-Carlo simulations. Examples of radiation-sensitive materials are shown to illustrate the method.