Analysis of beam-induced damage in high-resolution TEM of 2D hexagonal boron nitride (hBN) at different acceleration voltages

Bachelor thesis, Electron Microscopy Group of Materials Science, Prof. Dr. Ute Kaiser

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Background

In high-resolution transmission electron microscopy (HRTEM), two-dimensional materials such as graphene, transition metal dichalcogenides (TMDs), and hexagonal boron nitride (hBN) are typically investigated at acceleration voltages of ≤80 kV. Using such low acceleration voltages prevents the (elastic) knock-on displacement of atoms, for which a certain energy transfer is required. While the reduced knock-on makes the highly conductive graphene very stable, the semiconducting TMDs and hBN suffer strongly from additional *inelastic* damage. Especially hBN can degrade very quickly under the electron beam, forming large triangular holes. [1–5]

Aim

The aim of the proposed bachelor thesis is to describe the typical electron-beam-induced damage in hBN at different acceleration voltages available at the TEMs in Ulm (SALVE and Titan microscopes, 20–120 kV). For this purpose, high-resolution TEM images at selected acceleration voltages have to be systematically analyzed. The findings should be explained by the knock-on displacement of atoms and inelastic beam damage. Eventually, the bachelor thesis should recommend (i) optimum voltages for the least amount of beam damage and (ii) methods for the quantification of beam damage in hBN.

Workplan

- Preparation of TEM samples by mechanical exfoliation
- TEM experiments at different acceleration voltages (20–120 kV)
- Evaluation of HRTEM data with image processing software (e.g., ImageJ, [6]) and comparison of electron-beam-induced damage at the different acceleration voltages

Requirements

- Good understanding of the fundamentals of optics and solid-state physics
- Interest in laboratory work
- Basic programming skills (Python, MATLAB, or other)

Supervisor: Dr. Michael Mohn

Literature

[1] O. Cretu, Y.-C. Lin, and K. Suenaga, Micron **72**, 21 (2015).
[2] T. Susi, J. C. Meyer, and J. Kotakoski, Nat. Rev. Phys. **1**, 397 (2019).
[3] J. C. Meyer *et al.*, Nano Lett. **9**, 2683 (2009).
[4] J. Kotakoski *et al.*, Phys. Rev. B **82**, 113404 (2010).
[5] O. Cretu *et al.*, ACS Nano **8**, 11950 (2014).
[6] W. Rasband, *ImageJ* (NIH, Bethesda, Maryland, U.S., 2021).