# Quantitative measurement of mean inner potential and specimen thickness from high-resolution off-axis electron holograms of ultra-thin layered WSe2

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Off-axis electron holography is a powerful tool to measure electrostatic and magnetic fields at the nanoscale inside a transmission electron microscope. The electron wave that has passed through a thin specimen can be recovered from an electron hologram and the phase can be related to the specimen thickness or the electrostatic potential in and around the specimen. However, dynamical diffraction may cause a deviation from the expected linear relationship between phase and specimen thickness, which emphasizes the need for comparisons with corresponding computer simulations.

Here, we study few-layer-thick two-dimensional $WSe_2$ flakes by off-axis electron holography. Voronoi tessellation is used to spatially average the phase and amplitude of the electron wavefunction within regions of unit-cell size (see Fig. 1). A determination of specimen thickness of the $WSe_2$ is not possible from either the phase or the amplitude alone. Instead, we show that the combined analysis of phase and amplitude from experimental measurements and simulations allows an accurate determination of the local specimen thickness. Extremely thin specimens that are tilted slightly away from the [001] zone axis show an approximately linear relationship between phase and projected potential. If the specimen thickness is known, the electrostatic potential can be determined from the measured phase.

We used this combined approach to determine a value for the mean inner potential of 18.9 ± 0.8 V for $WSe_2$, which is approximately 10% lower than the value calculated from neutral atom scattering factors. In this way, a comparison of high-resolution electron holography data with simulations has been achieved on a quantitative level, enabling an assessment of the experimental conditions under which electrostatic potentials can be extracted directly from the phases of measured wavefunctions.

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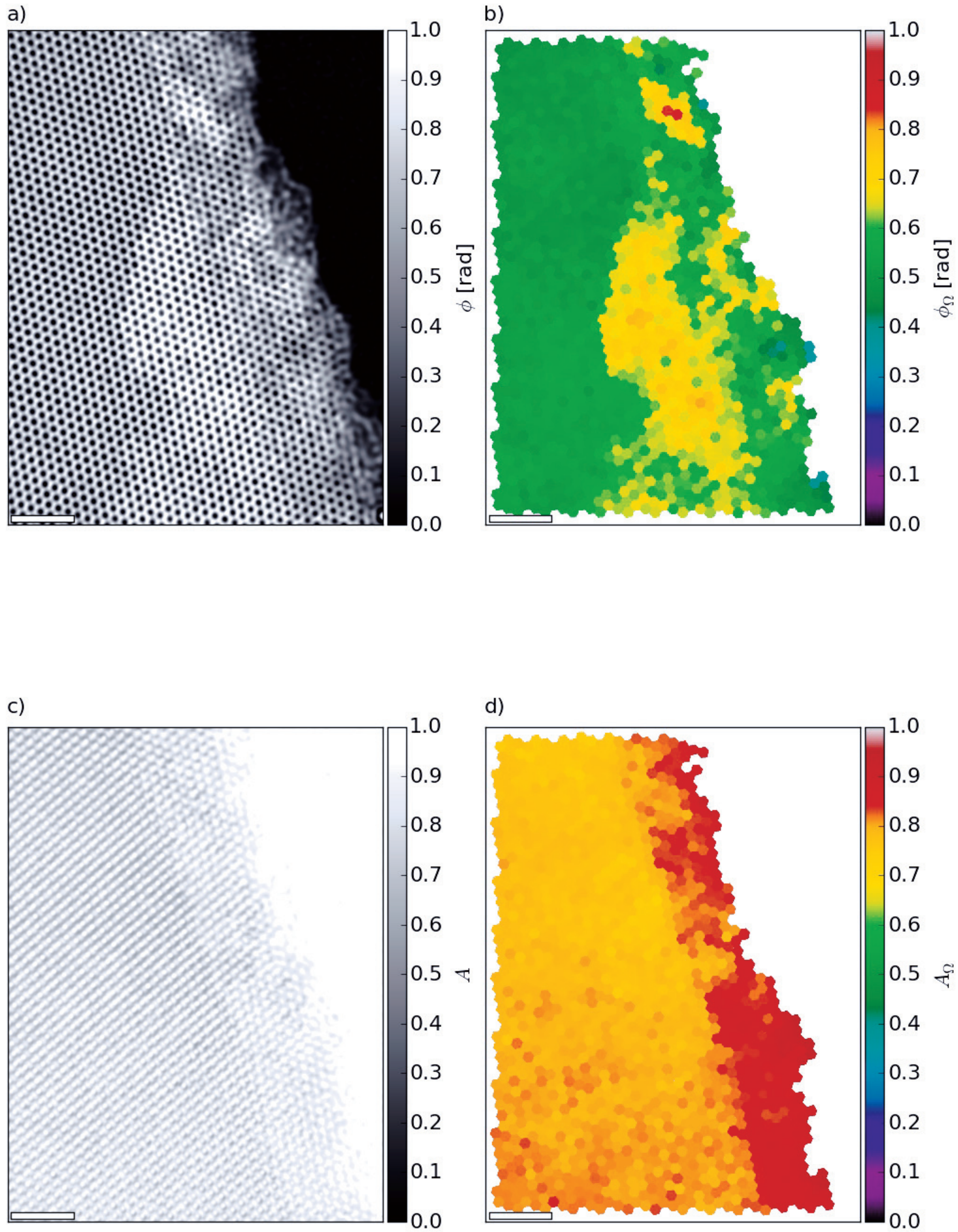


a) Phase $\Phi$ and b) amplitude A images of a few-layer-thick WSe2 flake with a vacuum area at the right side and a thinner, but also contaminated region close to the edge of the specimen. c) $\Phi$ and d) A after averaging within the area of each Voronoi cell $\Omega$ constructed from the phase image in a). The scale bars are 2 nm.