# Surface calibrated electron holography: Anomalous strain relaxation and minimization of polarization changes at III-nitride hetero-interfaces

**M. Schnedler[1+], Y. Wang[1],·Q. Lan[1], F. Zheng[1], L. Freter[1], Y. Lu[1], U. Breuer[2], H. Eisele[3], J.-F. Carlin[4], R. Butté[4], N. Grandjean[4], R. E. Dunin-Borkowski[1], Ph. Ebert[1]**

*[1]Ernst Ruska Centrum, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany*
*[2]Zentralinstitut für Engineering, Elektronik und Analytik (ZEA-3), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany*
*[3]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany*
*[4]Institute of Physics, EPFL, 1015 Lausanne, Switzerland*

Polarization and electron affinity changes at $Al_{0.06}Ga_{0.94}N$/GaN and $In_{0.05}Ga_{0.95}N$/$Al_{0.06}Ga_{0.94}N$ interfaces are quantified by off-axis electron holography (EH) in transmission electron microscopy (TEM), in conjunction with scanning tunneling microscopy and spectroscopy, as well as self-consistent simulations of the electrostatic potential and electron phase maps. The central problem of quantitative EH is that at the surfaces of the thin TEM lamellae a defect-induced pinning occurs, which alters the phase contrast. Therefore, we calibrated the electron optical phase maps using a δ-doped layer at the GaN buffer/substrate interface by determining the energy of the pinning level at the surface to 0.69 eV above the VBM (consistent with pinning by nitrogen vacancies). The such calibrated EH provides quantification of the key interface properties: The biaxially relaxed $In_{0.05}Ga_{0.95}N$/$Al_{0.06}Ga_{0.94}N$ interface exhibits polarization and electron affinity changes as theoretically expected. However, at the $Al_{0.06}Ga_{0.94}N$/GaN interface anomalous lattice relaxations and vanishing polarization and electron affinity changes occur, whose underlying physical origin is anticipated to be total energy minimization by the minimization of Coulomb interactions between the polarization-induced interface charges. [1]

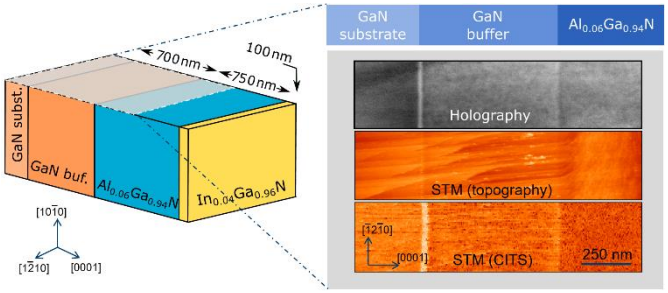


Figure 2 Sample structure (left) and electron optical phase change obtained by off-axis electron holography, as well as topography and current map measured by scanning tunneling microscopy (right).

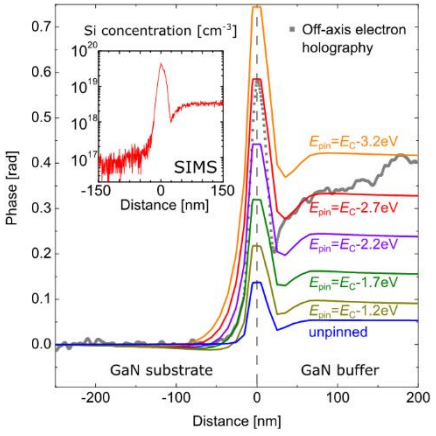


Figure 1 Phase profiles (measured and simulated, shown as symbols and lines, respectively) across the GaN buffer/substrate interface.

[1] Y. Wang *et al.*, Phys. Rev. B **102**, 245304 (2020)
[+] Author for correspondence: m.schnedler@fz-juelich.de