Poster-2-15

k-space imaging of chemically gated 2D electron and hole gases in nitride heterostructures

E. Della Valle,[1,2] T.-S. Nguyen,[3] Z. Zhang,[3] Z. He,[3] N. Pieczulewski,[3] P. Constantinou,[1] C. Chang,[3] H. G. Xing,[3] D. A. Muller,[3] G. Khalsa,[3] D. Jena,[3] and V. N. Strocov[1]

[1] *Swiss Light Source, Paul Scherrer Institute, 5232 Villigen-PSI, Switzerland*
[2] *Department of Physics, ETH Zürich, 8093 Zürich, Switzerland*
[3] *Cornell University, 14853 Ithaca NY, USA*

Interfacing GaN to the metal- and N-terminated surfaces of AlN builds up high-density 2D electron and hole gases, respectively, located in the undoped GaN quantum wells [1]. Created by internal polarization fields and favorable band offsets, these interfacial electron and hole states form the core of nitride-based high-power and high-frequency devices, including complementary n- and p-channel field-effect transistors for telecom applications. Yet, ARPES investigations of the band structure of these states (in particular under applied bias) with resolution in electron momentum (**k**) remain rare [2] due to two challenges: (i) surface sensitivity of conventional vacuum-ultraviolet ARPES hinders probing of deeply buried states, and (ii) the difficulty of implementing electrostatic gating in semiconductor heterostructures due to leakage currents. Here, we use soft X-ray ARPES to overcome the first challenge and directly access the quantized electron and hole states several nanometers below the surface of GaN/AlN heterostructures. We determine their subband dispersions, effective masses and Fermi surface, and directly relate them to transport characteristics. Furthermore, analysis of Ga 3d core-level spectra as a function of photon energy allows reconstruction of the interfacial potential profile. As a precursor to gated ARPES, we employ controlled alkali-metal and oxygen adsorption to chemically tune the interfacial potential and track the resulting bands-structure evolution. This approach opens a pathway toward fully gate-tunable **k**-resolved studies of buried states in wide-bandgap semiconductor devices.

[1] V. Nguyen *et al.*, Visualizing electrostatic gating effects in two-dimensional heterostructures. Nature **572** (2019) 220.

[2] L. L. Lev *et al.*, **k**-space imaging of anisotropic 2D electron gas in GaN/GaAlN high-electron-mobility transistor heterostructures. Nature Communications **9** (2018) 2653.