Fs-dynamics and energetics of III-V (100) interfaces with atomic scale preparation

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Extended abstract

Information on the electronic and atomic properties of bulk semiconductor systems has been a topic of intense studies for many years. In recent years experimental femtosecond (fs) techniques have been increasingly utilized for the study of hot electron dynamics. Equally important to the understanding of bulk properties is the knowledge of the electronic and atomic properties of (100) interfaces. The latter are of crucial importance for preparing well-defined device components, e. g. abrupt hetero-interfaces, in thin film devices like solar cells, high speed switches, surface emitting lasers (VCSEL's), and LED's. Hot carrier dynamics at interfaces are of critical importance for the performance of such devices. The investigation of surface science is the first step towards understanding interface physics clearly. Understanding the atomic and electronic structure and the dynamics of hot electrons at (100) semiconductor surfaces must precede the investigation of similar phenomena at (100) interfaces.

Metal organic chemical vapor deposition (MOCVD) is the preferred method for growing many thin film devices, e. g. solar cells. Control over the preparation and formation of a (100) semiconductor surface/interface in an MOCVD reactor needs in-situ monitoring of the surface structure. The latter is usually achieved via optical spectroscopy, i. e. reflectance difference (anisotropy) spectroscopy (RDS/RAS).

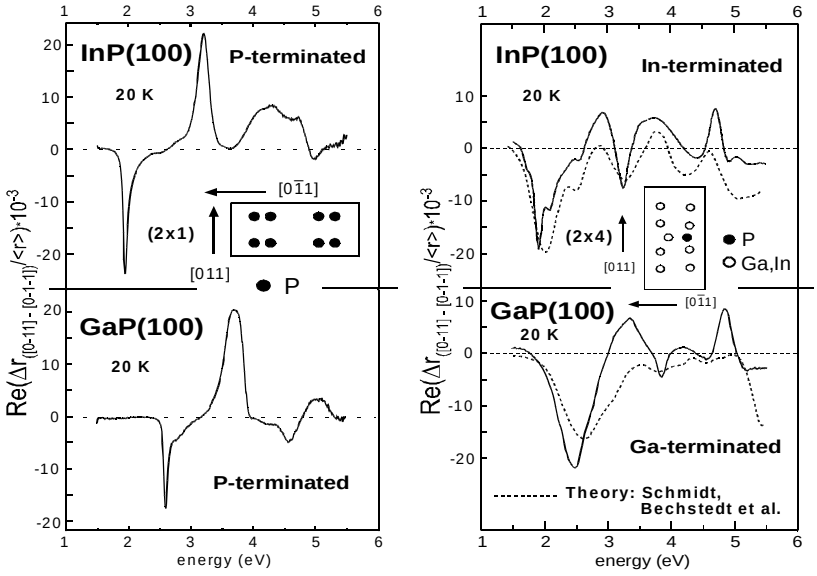

Fig.1 *Experimental 20 K UHV RD spectra (solid) of well-ordered (100) surfaces. Left column: P-terminated surfaces. Right column: cation-terminated surfaces and calculated RD spectra (dashed) according to the mixed-dimer model (Schmidt, Bechstedt et al.)*

MOCVD-preparation of well defined (100) surfaces were studied in-situ with reflectance difference spectroscopy (RDS). After contamination-free transfer of the samples to UHV RDS measurements were performed at 20 K. Specific RD spectra measured with the highest peaks and specific fine structures indicate highly ordered P-terminated and cation-terminated surface reconstructions, respectively (Fig.1). RD spectra of ordered P-terminated, (2x1)-like reconstructed and cation-terminated, (2x4)-reconstructed (100) interfaces were correlated with ultraviolet and x-ray photoelectron spectroscopy (UPS/XPS), low energy electron diffraction (LEED), and scanning tunneling microscopy (STM) measurements. Dangling bonds at the ordered P-terminated surface are saturated with hydrogen. The thus characterized in-situ signals were used as bench marks for preparing well-ordered surfaces in the MOCVD reactor.

Electronic structure and hot electron dynamics at (100) InP surfaces were studied with femtosecond (fs)-two-photon-photoemission (2PPE). 2PPE spectra of the In-terminated surface revealed two surface resonances at 0.25eV and 0.8eV above the conduction band minimum, respectively, and one occupied surface state 0.1eV below the valence band maximum. These experimental data are in excellent agreement with theoretical predictions of Schmidt et al. [1]. In striking contrast, the ordered P-rich surface did not show any significant peak due to surface resonances. At this surface there is a distinct final state 0.1eV above the vacuum level. Electron relaxation was measured with 30 fs resolution at different photon energies between the conduction band minimum and 3eV into the conduction band. The relaxation of hot electrons slowed down when approaching the conduction band minimum.

[1] W. G. Schmidt, N. Esser, A. M. Frisch, P. Vogt, J. Bernholc, F. Bechstedt, M. Zorn, T. Hannappel, S. Visbeck, F. Willig, and W. Richter; Phys. Rev. B, **61** (24), R16335, 2000