Atomic order, energetics and femtosecond electron dynamics of MOCVD-prepared III-V semiconductor surfaces

T. Hannappel, L. Töben, L. Gundlach, R. Eichberger, S. Ramakrishna, A. Knorr, F. Willig

Hahn-Meitner-Institute, SE4, Glienicker Str.100, D-14109 Berlin, Germany

Abstract

Information about the properties and the electron dynamics of III-V semiconductor surfaces can be of decisive importance for the preparation of thin film devices like solar cells, high speed devices, surface emitting lasers, and LED's. Well-reconstructed (100) surfaces and interfaces of the III-V-semiconductors InP, GaP, and GaSb, were prepared with metal organic chemical vapor deposition (MOCVD) and in-situ monitored with reflectance difference spectroscopy (RDS). STM, UPS, XPS, LEED, FT-IR, RDS at low temperature, and femtosecond (fs)-resolved two photon photoelectron spectroscopy (2PPE) was performed after contamination-free and atomic order preserving sample transfer to UHV. Well-ordered P-terminated and In-terminated InP (100) surfaces were investigated in detail since recent theoretical and experimental findings suggest that the chemical composition of the MOCVD prepared and the MBE prepared P-rich InP(100) surface is different and differently reconstructed.

Empty surface states on the reconstructed surfaces of atomically clean semiconductors can be populated with hot electrons, either via a direct optical transition or via electron scattering from bulk-like states. The C_1 surface resonance of the In-rich surface of InP(100) was populated directly with a femtosecond laser pulse as well as indirectly via scattering from isoenergetic bulk states after generation of hot electrons in the conduction band above the energetic position of C_1 (2PPE spectra in fig. 1). The two time constants observed for the energy relaxation to bulk states isoenergetic to C_1 were attributed to fast scattering caused by redistribution of the initial hot electron distribution due to effective electron-electron scattering with a time constant of 35fs followed by slower electron-phonon scattering (250fs). The scattering time between surface and bulk states was found to be shorter than 40fs. Similar scenarios have been discussed in the literature before but to our knowledge these are the first time-resolved experimental data.

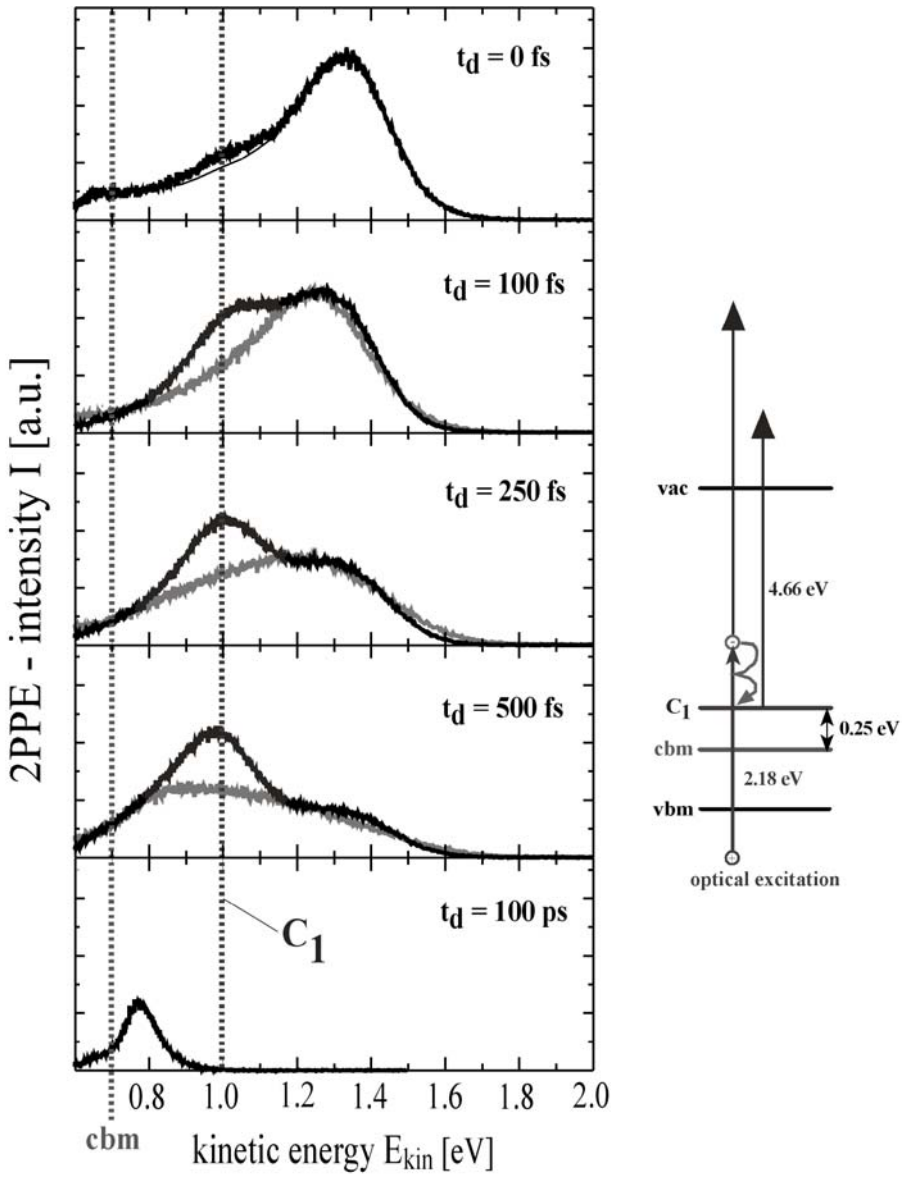

Fig.1 2PPE-spectra measured at different delay times between pump (2.18eV photons) and probe laser pulse (values given as insets at the right). The position of the C_1 surface resonance and the conduction band minimum are marked by vertical dotted lines. From the difference of the 2PPE signal of the In-rich surface (black curves) and the P-rich surface (grey curves) at the energetic position of C_1 the time-dependent population in the surface resonance can be derived.The conduction band minimum corresponds to about 0.7 eV kinetic energy.