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Semiconductors analyzed by Scanning Probe Methods

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Scanning Probe Methods (SPM) have evolved as versatile tools for inspecting semiconductor surfaces and interfaces probing topography and electronic energy levels at a high resolution. Historically, scanning tunneling microscopy (STM) operated in the spectroscopy mode (STS) helped solving a variety of fundamental questions, i.e. identifying surface states and local oxidation processes. Nevertheless, STM/STS inherently operates under tunneling transport conditions, and thus is restricted to relatively good conductors. Scanning force microscopy (SFM) circumvents some of these drawbacks allowing for ground state probing of organic and inorganic semiconductors through a variety of SFM techniques such as spreading resistance and Kelvin Probe Force Microscopy (KPFM) [1]. The latter proved to be of enormous benefit specifically when operated non-invasively in the non-contact mode. KPFM firstly is able to identify correct and quantitative local workfunctions and contact potentials [2] of doped areas. Secondly, KPFM can easily be combined with light assisted spectroscopy modes in order to probe the so-called surface photovoltage (SPV), as it is important to quantify local trap levels in any semiconductor device. Local SPV will be shown for a variety of semiconductor materials such as p- and n-doped Si nanostructures [3], wide bandgap materials [4] and molecular systems.

In addition, also the nano-optical access to probe semiconductor surfaces and interfaces by SPM will be sketched. Modern type principles of scanning near-field optical probing (SNOM) will be outlined. Optical excitation in the visible and IR wavelength range allows to inspect quite different optical properties such as the local fluorescence and absorption [5], but equally IR active and Raman [6] bands. As one such result, IR-SNOM allows to quantitatively deducing the local doping levels [7] solely by optical means. Tuned optical excitation in semiconductors also may be used to probe the local dielectric or conductive properties. To this, I will show two examples of light induced effects, (a) the domain wall conductivity in multiferroic systems, and (b) the optical tuneability of dielectric functions in semiconductor sandwiches for metamaterial applications [8].

References:

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