Charge dynamics at semiconductor surfaces investigated by time resolved Scanning Tunneling Microscopy

The combination of Scanning Tunneling Microscopy (STM) and optical excitation merges two successful experimental techniques in solid-state physics. The combination of optical pump-probe techniques with Scanning Tunneling Microscopy (STM) enables us to get atomic resolution of an STM with time resolution on the ns time scale, i.e. well beyond the bandwidth of the current amplifier. This approach provides the prospect to resolve surface dynamics on the atomic scale. More specifically, optical excitation and Scanning Tunneling Microscopy (STM) is discussed to study the carrier dynamics at the GaAs(110) surface. By illuminating the tunnel contact between a tip and an n-doped GaAs crystal, we generate electron-hole pairs, which will be separated in the tip-induced space charge region (SCR). A detailed spectroscopic analysis shows that photo-excited charge carriers, trapped in a local region beneath the STM tip, contribute to the tunneling current. By adjusting the current in a controlled manner we are able to actively access different screening conditions of the electric potential at the surface. Studying the time evolution of the photo-induced tunnel current gives access to the charge dynamics. We discuss different processes determining the relaxation characteristic of the excited system. By using the lateral resolution of the STM, the influence of single dopants on the relaxation dynamics of the system is investigated. We discuss the impact of these defects in terms of their depth dependent binding energy of the donors.

Transport in epitaxial graphene on the nanoscale

The transport properties of epitaxial graphene have been subject of intense theoretical and experimental investigations since its invention. Besides electron-electron and electron-phonon scattering, the charge transport is determined by structural defects such as impurities, substrate steps or monolayer/bilayer junctions. The latter are leading to a spatially varying potential landscape as well as an inhomogeneous current density. Scanning Tunneling Microscopy combined with a potentiometric extension, called Scanning Tunneling Potentiometry (STP), has opened a way to study these transport properties down to the nanometer scale. Using an STP setup based on a home-built low-temperature STM operating down to 6 K and applicable magnetic field of up to 6T, we have investigated the sheet resistance of graphene focusing on charge transport across different localized defects on a sub-nanometer scale. We find that the voltage drop at a monolayer-bilayer boundary in graphene clearly extends spatially up to a few nanometers into the bilayer and hence is not located strictly at the structural defect. We explain this behavior by the weak coupling between the two bilayer sheets. From magneto-transport STP measurements mapping the local electrochemical potential as a function of the applied magnetic field, we have extracted the local charge carrier concentration by the emerging Hall field. Additionally, we show that the defect resistance at local defects such as steps, wrinkles and ML/BL-junctions remains constant for all magnetic fields applied here. To determine local resistances quantitatively, the local driving field as well as the local current density are needed. While STP is measuring the local chemical potential with high precision, the local current density is a priory unknown. In all STP studies up to now, the local current density is replaced by an averaged value, e.g. given by the total current and the geometry of the sample. Graphene grown on 6H-silicon carbide (0001) prepared by polymer assisted sublimation growth (PASG) are characterized by a high degree of a spatial homogeneity. This allows analyzing transport properties quantitatively on the nanometer scale. We demonstrate this new possibility by determining the sheet resistance as a function of the stacking sequence of 6H-SiC. At 8 Kelvin, highly resolved STP measurements show a significant variation of up to 240% demonstrating the strong influenced of the underlying substrate on a local scale.