Adsorbate-sensitive Photoresponse in MOCVD MoS_2-Graphene Heterostructure Photodetectors

Yannick Beckmann[1]
Leon Daniel[1], Annika Grundmann[2], Mohamed Abdelbaky[1], Michael Heuken[2,3], Wolfgang Mertin[1], Tilmar Kümmell[1], Holger Kalisch[2], Andrei Vescan[2], Gerd Bacher[1]
[1]*Werkstoffe der Elektrotechnik and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany*
[2]*Compound Semiconductor Technology, RWTH Aachen University, 52074 Aachen, Germany*
[3]*AIXTRON SE, 52134 Herzogenrath, Germany*
yannick.beckmann@uni-due.de

A promising route to photodetectors based on 2D materials is the combination of photoactive transition metal dichalcogenides (TMDCs) such as MoS_2 with graphene. The response of such devices to light irradiation, however, is quite complex: Light can trigger both fast processes like photocurrent generation and much slower chemical processes on surfaces like adsorbate desorption. In our approach, we fabricate TMDC-graphene heterostructures by a transfer-free metal-organic chemical vapor deposition (MOCVD) synthesis and realize photodetectors on the mm^2 scale using interdigital contact meshes. To separate direct photocurrent generation in the heterostructure from surface effects after optical excitation, we establish an optical pump – electrical probe experiment. UV light is used to remove adsorbates from the surface. VIS light pulses generate electron-hole-pairs in the TMDC-graphene heterostructure leading to a photocurrent which is being detected.
Fig. 1 illustrates the experimental results. UV irradiation at t = 0 s yields a fast initial decrease of the photocurrent, followed by an increase on a time scale of seconds. We attribute the change in current to the UV-triggered removal of adsorbates: Electrons within the 2D heterostructure initially bound to adsorbates become free, leading to a transition of the graphene from p- to n-type. This assumption is confirmed by probing the device with red light pulses to generate photo-excited charge carriers in the MoS_2 without affecting the adsorbate density. Interestingly, the sign of the photocurrent generated by these pulses will reverse if the adsorbate density is reduced by UV light. This supports the idea that the current-transporting graphene layer switches from the hole to the electron regime upon adsorbate removal. These findings are not only shedding new light on the very diverse mechanisms of photoresponse found in literature for 2D heterostructure devices, but in addition open interesting perspectives for photodetectors that are sensitive to the environment.

Figures

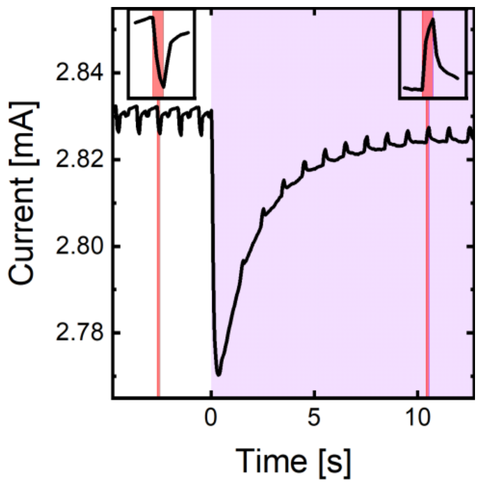

Figure 1: Current in a MoS_2-graphene photodetector under ambient conditions. Photocurrent is generated by probe pulses at 632 nm (red bar). After UV irradiation (starting at t = 0 s), the photocurrent switches from negative to positive values.