Scalable Optoelectronic Devices Based on Two-Dimensional Transition Metal Dichalcogenides

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Two-dimensional (2D) transition metal dichalcogenides (TMDCs) exhibit efficient light absorption and light emission combined with sub-nm thickness and are thus attractive for optoelectronic devices on rigid, curved or flexible substrates. While first proof-of-concept devices relied on mechanically exfoliated 2D TMDCs, the transfer to real-world applications is currently in the focus of research activities requiring both scalable materials and scalable device architectures. Here, we report on our recent efforts on the development of scalable concepts for both, light emitting and light sensing devices based on 2D TMDCs.

Wafer-scale films of TMDC monolayers [1] and TMDC heterostructures [2] have been grown in an AIXTRON MOCVD reactor and were integrated into optoelectronic devices with different architectures. First, a vertical p-i-n architecture was chosen for fabricating light emitting devices. Hereby, WS_2 monolayers were embedded between inorganic and organic support layers at the cathode and anode side, respectively. Large-area electroluminescence has been achieved with turn-on voltages as low as 2.5 V on rigid [3] as well as flexible [4] substrates. This concept has been extended by replacing WS_2 with a directly grown type II WS_2-MoS_2 heterostructure to realize a self-powered p-i-n photodetector that exhibits an on-off ratio of 10^5 and an EQE of 17 %.

Second, a lateral device architecture with an interdigital contact mesh was developed for assembling large-area photosensors. The direct growth of a heterostructure comprising WS_2 and MoS_2 monolayers enables device fabrication without involving any transfer process. We demonstrate an enhancement of the responsivity by more than 5 orders of magnitude as compared to a single layer device, which we attribute to an efficient separation of optically generated electron-hole pairs at the WS_2-MoS_2 heterointerface [5]. In photosensors that combine a MOCVD-grown WS_2 monolayer as light sensitizer with CVD-grown graphene as a highly conductive channel, we have been able to shed light on the widely varying values of responsivity reported in literature for such devices. We demonstrate that adsorbate desorption can mask the intrinsic photoresponse in 2D heterostructure photodetectors. By using a multicolor optical pump – electrical probe technique, we disentangle both effects and extract the intrinsic photoresponse [6].

References

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