Integration of (MO)CVD Grown 2D Materials into Optoelectronic Devices

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Atomically thin layers represent an exciting class of two-dimensional (2D) materials with unique properties, like e.g. high electrical conductivity combined with high transparency in case of graphene, or efficient light absorption and emission in case of transition metal dichalcogenides (TMDCs). Originally prepared by mechanical exfoliation for more basic scientific studies, developments in large area CVD growth techniques paved the path towards practical applications. In this contribution some of our recent efforts on scalable 2D materials grown by (MO-)CVD and their implementation in optoelectronic devices will be presented, which includes both graphene as well as TMDC layers.

Graphene has been grown by CVD in an AIXTRON Black Magic Pro reactor on both, metallic and semiconducting substrates. In order to avoid decomposition and/or melting of the substrate, we reduce the process temperature by implementing a plasma-enhanced growth procedure first developed for Cu foils [1], and then adapted to both Ge and GaN substrates. As a proof-of-concept, we demonstrate integration of directly grown graphene as a transparent electrode in GaInN/GaN light emitting devices. Our approach thus avoids contamination and process issues typical for transfer techniques. Strong lateral current spreading and a reduced turn-on voltage indicate the suitability of our concept [2].

Using a horizontal multiwafer AIXTRON MOCVD reactor, high quality films of both, MoS_2 as well as WS_2 monolayers have been realized [3]. The potential of these ultrathin semiconductors for light emitting devices in the red spectral range is demonstrated by embedding MOCVD grown WS_2 monolayers in a vertical device design, where inorganic and organic injection layers are used for electron and hole injection, respectively. Large area red electroluminescence stemming from the TMDC layer with a turn-on voltage as low as 2.5 V has been achieved for both, rigid [4] as well as flexible substrates. The direct growth of a heterostructure comprising WS_2 and MoS_2 monolayers enables the fabrication of a photodetector 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 optical generated electron-hole pairs at the WS_2-MoS_2 heterointerface.

References

[1] B. Bekdüz et al., Nanotechnology 29 (2018), 455603
[2] J. Mischke et al., 2D Materials 7 (2020) 035019
[3] D. Andrzejewski et al., Nanotechnology 29 (2018) 295704
[4] D. Andrzejewski et al., ACS Photonics 6 (2019) 1832