(MO)CVD Grown 2D Materials for Light Emitting and Light Sensing Devices

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Two-dimensional (2D) materials represent a material class with unique electronic and optical properties. Graphene as the first 2D material reported combines high electrical conductivity and high transparency, whereas transition metal dichalcogenides (TMDCs) exhibit efficient light absorption and emission. Although a wide variety of optoelectronic devices based on 2D materials are reported, most of them lack scalability from both a material as well as a device architecture point of view. In this contribution we report on wafer-scale 2D materials grown by (MO-)CVD and their implementation in scalable optoelectronic devices.

Graphene has been grown by CVD in an AIXTRON Black Magic reactor by a plasma-enhanced (PE) growth procedure. The PECVD growth was first developed for Cu foils [1], and then adapted to metal-free substrates like Ge [2] and GaN [3] to avoid complex transfer processes during device implementation. As a proof-of-concept, we demonstrate integration of directly grown graphene as a transparent electrode in GaInN/GaN light emitting devices. To impede surface degradation during growth, N_2 instead of H_2 was used as a process gas. Strong lateral current spreading, and a reduced turn-on voltage indicate the suitability of our concept [3].

Using a horizontal multiwafer AIXTRON MOCVD reactor, high quality films of both, MoS_2 as well as WS_2 monolayers have been realized [4]. 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 [5] as well as flexible substrates [6]. In a further step, 2D materials heterostructures were directly grown on a sapphire substrate to enable the fabrication of photodetectors without involving any transfer process. We demonstrate an enhancement of the responsivity by more than 5 orders of magnitude in a WS_2-MoS_2 heterostructure device as compared to a single layer reference, which we attribute to an efficient separation of optical generated electron-hole pairs at the heterointerface [7].

References

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