WS_2 monolayer based light emitting devices in a p-i-n architecture

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2D semiconductors represent an attractive material for ultrathin optoelectronic devices. WS_2 monolayers are promising candidates for light emitters due to their direct band gap and high luminescence intensities up to room temperature. Several concepts for light emitting devices have been presented, including lateral contact designs [1] or complex stacking layouts [2] – where, however, up-scaling might be challenging. In our contribution, we embed WS_2 monolayers into a vertical p-i-n layout using organic p- and inorganic n-supporting layers.

ITO coated glass substrates were spin coated with PEDOT:PSS and poly-TPD, serving as hole injection and transport layer, respectively. Monolayer WS_2 flakes were exfoliated and placed via a PDMS stamp onto the organic layer stack. For the cathode side, two concepts are studied: On the one hand, ZnO nanocrystals (NCs) are used, following recent QLED designs [3]. On the other hand, naturally n-doped few-layer MoS_2 is included on the cathode side, pursuing a 2D material approach. Aluminium contacts are defined by laser lithography in alignment to the monolayer flakes, ensuring a vertical current path to the active WS_2 monolayer and preventing current leakage. Electroluminescence is mapped using a confocal setup from the transparent substrate side.

The diodic nature of the devices, stemming from the p-i-n architecture, becomes obvious from the rectifying current-voltage curve (Fig. 1). Both device architectures exhibit clear electroluminescence (EL) from the WS_2 monolayers (inset in Fig. 1), located at the contacted areas defined by laser lithography (Fig. 2, left). EL starts at an operation voltage V_d of 4 V for MoS_2 injection layers on the cathode side. Using ZnO-NCs as electron supporting layer, in contrast, EL arises at a slightly higher voltage of 6 V, but the EL intensity exceeds the one obtained with MoS_2-based transport layers by a factor of 5, reaching a luminance of 50 cd/m² (see Fig. 2, right). We attribute the better performance to a more effective hole blocking due to the ZnO layer.

Figures

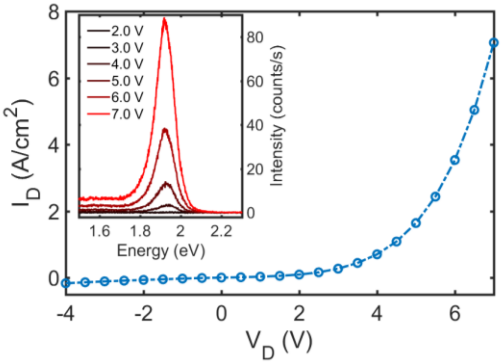

Figure 1: EL spectra (inset) and current-voltage curve from a WS_2 based LED using MoS_2 as supporting layer.

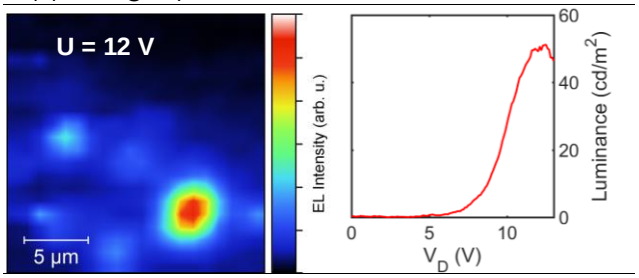

Figure 2: EL map and luminance of a WS_2 based LED using ZnO NCs as electron supporting layer.

References

[1] Cheng et al., Nano Letters **14** (2014), 5590
[2] Withers et al., Nat. Mater. **14** (2015), 301
[3] Wepfer et al., ACS Appl. Mater. Interfaces **9** (2017), 11224