Scalable light emitting diodes based on WS_2 monolayers grown by MOCVD

Tilmar Kümmell[1], Dominik Andrzejewski[1], Henrik Myja[1], Michael Heuken[2,3], Annika Grundmann[3] , Holger Kalisch[3], Andrei Vescan[3], Gerd Bacher[1]

[1]*Werkstoffe der Elektrotechnik & CENIDE, Universität Duisburg-Essen, 47057 Duisburg, Germany*
[2]*AIXTRON SE, 52134 Herzogenrath, Germany*
[3]*Compound Semiconductor Technology, RWTH Aachen University, 52074 Aachen, Germany*

tilmar.kuemmell@uni-due.de

2D semiconductors represent a highly attractive material class for ultrathin electronic devices. Transition metal dichalcogenides (TMDC) monolayers are promising candidates for light emitters due to their direct band gap and high luminescence intensities up to room temperature. A number of approaches towards light emitting devices, e.g. based on exfoliated or chemical vapor deposited (CVD) TMDC monolayers have been reported. However, high complexity in the contact design [1] or the stacking layout [2] is currently limiting the scalability and reproducibility, which are essential for industrial fabrication. In our contribution, we demonstrate a light emitting device in a scalable approach by embedding metal organic (MO-)CVD WS_2 monolayers into a vertical p-i-n device architecture using organic and inorganic injection layers.

ITO-coated glass substrates represent the anode side of the devices and are spin coated with PEDOT:PSS and poly-TPD for hole injection and transport, respectively. The active material is a three atom (0.7 nm) thick fully coalesced WS_2 monolayer grown by MOCVD on 2" sapphire (0001) wafers using tungsten hexacarbonyl (WCO) and di-tert-butyl sulphide (DTBS) [3], transferred on top of the hole supporting layers. On the cathode side ZnO nanocrystals form an electron supporting layer and 6 mm² aluminium contact pads are realized by electron beam evaporation with shadow masks.

The diode characteristics of the devices, stemming from their p-i-n architecture, becomes obvious from a rectifying current-voltage curve. By applying a voltage in forward direction, electroluminescence (EL) from the WS_2 monolayer is detected already at an operation voltage of 3 V (Fig. 1 left), reaching a luminance of almost 1 cd/m² at 7 V. A photograph of a 6 mm² device is shown in Fig. 1 (right), indicating large-area emission. Our results pave the way to 2D light emitting devices which are easily processable and scalable for future lighting concepts.

Figures

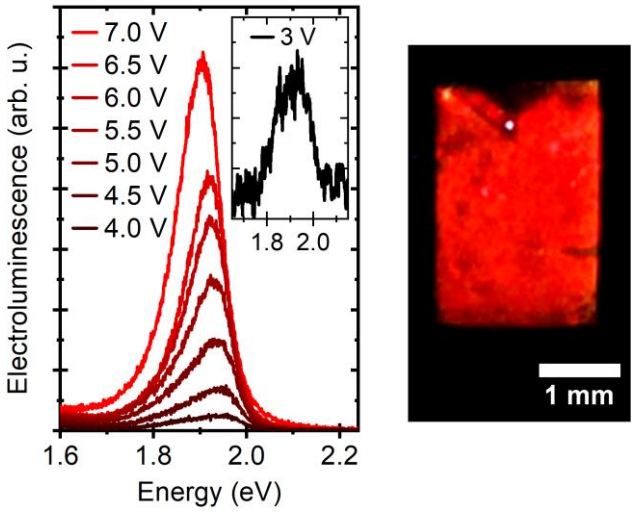

Figure 1: (Left) EL spectra of a light emitting device with a WS_2 monolayer as active material for different operation voltages. (Right) Photograph of a 6 mm² light emitting diode driven at 7 V.

References

[1] Lien et al., Nat Comm. **9** (2018), 1229.
[2] Withers et al., Nat. Mater. **14** (2015), 301.
[3] Grundmann et al., MRS Adv. **3** (2019), 1.