Direct integration of PECVD-grown graphene electrodes into $Al_xGa_{1-x}N$-based UV-LEDs

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In anticipation of their promising applications in the deep-UV spectral range, e. g., for water disinfection or UV curing, $Al_xGa_{1-x}N$ LEDs have experienced a lot of attention over the last decade [1]. One challenge on the route to efficient devices is the poor conductivity of the p-$Al_xGa_{1-x}N$ top layer, and thus the limited lateral current spreading. While for blue GaN-based LEDs this issue is addressed by transparent conductive layers (TCL) of, e.g., ITO, this approach is not suitable for deep-UV LEDs due to the poor transparency of ITO in this spectral range.

Here, we present an attempt for using graphene as a TCL in UV $Al_xGa_{1-x}N$ LEDs, expanding our recent work on graphene TCL in blue GaN-based LEDs [2]. Hereby, graphene has been directly grown on p-doped $Al_xGa_{1-x}N$ via a PECVD process at low growth temperatures of around 670 °C to avoid surface degradation of the device. Using a N_2-flux of 200 sccm instead of the commonly used H_2, a CH_4 flux of 5 sccm and a growth time of 1 h, we routinely obtain few-layer graphene with a ratio of I_D/I_G between 1.1 and 2.7 and a ratio of I_{2D}/I_G between 0.3 and 0.95 on 2" wafers, with a maximum value of I_{2D}/I_G = 1.3 (Fig. 1). The graphene layers exhibit a transparency higher than 90 % in the UV range and a sheet resistance of less than 5 kΩ/sq. After integrating this graphene TCL directly into an $Al_xGa_{1-x}N$ LED, an I/V characteristic with a diode-like behaviour is obtained. The corresponding electroluminescence spectrum (Fig. 2) reveals a distinct UV emission with a peak wavelength at 273 nm, with some contribution in the VIS spectral range. Remarkably, UV emission starts already at about 4 V, indicating excellent current injection on both, the n- and the p-side of the device.

References

[1] M. Kneissl, Nature Photonics **13** (2019) 233
[2] J. Mischke et al., 2D Materials **7** (2020) 035019

Figures

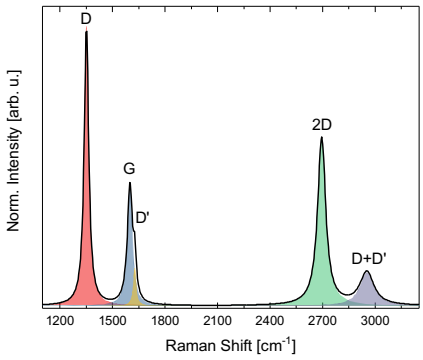

Figure 1: Raman spectrum of graphene directly grown on an $Al_xGa_{1-x}N$ LED.

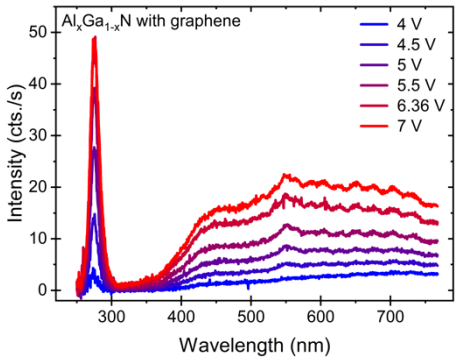

Figure 2: Electroluminescence spectra of an $Al_xGa_{1-x}N$ LED with graphene TCL for various voltages.

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