Graphene-based transparent conductive support layers for AlGaN deep-ultraviolet LEDs

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Graphene combines high electrical conductivity and easy Fermi level tuning with high optical transparency in the deep ultraviolet (UV-C) wavelength range. This makes graphene a very suitable candidate for a low absorbing support layer to increase device performance in UV-C LEDs. Hereby, graphene can either act as a current spreading layer in LEDs with standard geometry or as a contact interlayer between the Al mirror and the p-AlGaN layer in LEDs with flip-chip geometry. A challenge, however, is the realization of an industrially relevant process to incorporate graphene into UV-C LEDs.

Here we present a transfer-free approach for direct integration of graphene into functional AlGaN-based UV-C LEDs emitting at 275 nm. To avoid damage of the LED, we use a low temperature, plasma-assisted CVD process [2,3] for growing graphene directly on the UV-C LED wafer. Our nanocrystalline few layer graphene (I_D/I_G ratio of 1.6 and I_{2D}/I_G ratio of 1.4) shows a transparency of > 90 % in the UV-C range and a sheet resistance of < 3 kΩ/sq. Our graphene-enhanced UV-C LEDs show low threshold voltages of less than 6 V for both flip-chip geometry and standard geometry [4]. In the flip-chip geometry we achieved this by a combination of a graphene layer and a very thin NiO_x layer (Fig. 1). Most interesting, graphene acts as an efficient current spreading layer in standard geometry, enabling homogeneous top emission with areas of several hundred μm² (Fig. 2) [4].

References

[1] M. Kneissl et al., *Nature Photonics* **13**, 233 (2019)
[2] J. Mischke et al., *2D Materials* **7**, 035019 (2020)
[3] H. Zhang et al., *Materials* **15**(6), 2203 (2022)
[4] J. Meier et al., Adv. Mater. 2313037 (2024)

Figures

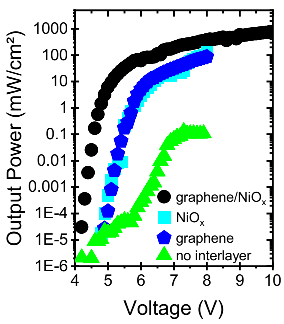
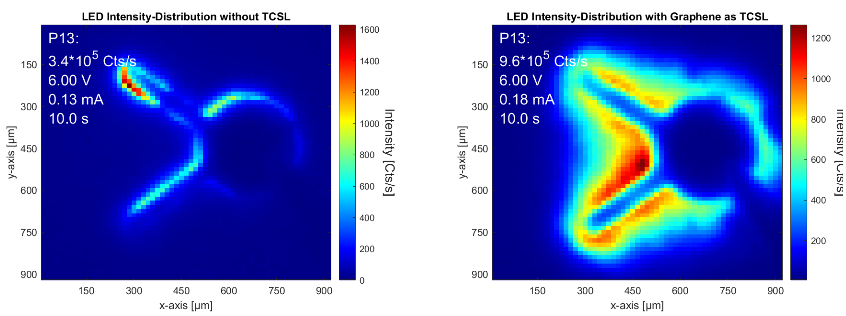


Figure 1: Optical output power vs. voltage for flip-chip devices with different graphene/metal oxide interlayers.



a) b)

Figure 2: Improved current spreading in UV-C LEDs with standard geometry a) without graphene and b) with graphene as a transparent conductive layer.