Using graphene as epitaxial substrate and transparent electrode for semiconductor devices

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In 2012 we reported on a generic atomic model, which describes the epitaxial growth of semiconductors on graphene applicable to all semiconductor materials.[1] The epitaxial growth of semiconductors on graphene is very appealing for device applications since graphene can function not only as a replacement of the semiconductor substrate but in addition as a transparent and flexible electrode for e.g. solar cells and LEDs. The epitaxial model was first verified by cross-sectional transmission electron microscopy studies of self-catalyzed GaAs nanowires that grew vertically on graphene.[1,2] After that we also demonstrated the vertical growth of random GaN nanowires as well as positioned GaN nanopyramids on graphene grown by selective area epitaxy using a hole mask.[3]

For deep ultraviolet AlGaN-based light emitting diodes (LEDs), in need for various disinfection and sterilization purposes, the concept offers a real advantage over present thin film-based technology. Deep UV LEDs are today very expensive and inefficient due to the lack of a good transparent electrode (ITO is absorbing in deep UV), the high dislocation density in the active thin film layers, low light extraction efficiency, and the use of very expensive AlN substrates or AlN buffer layers on sapphire substrates.

A first proof-of-principle flip-chip UV LED was recently demonstrated using double-layer graphene, where GaN/AlGaN nanowires were grown as the light-emitting structure using plasma-assisted molecular beam epitaxy (Figure 1). Although the sheet resistance was increased after nanowire growth, the experiments showed that the double-layer graphene functions adequately as an electrode. The GaN/AlGaN nanowires are found to exhibit a high crystal quality with no observable defects or stacking faults. Room-temperature electroluminescence measurements show a GaN related near bandgap emission peak at 365 nm and no defect-related yellow emission.

Our spin-off company CrayoNano are now developing a commercial platform (using MOCVD) for deep UV LEDs based on this technology as will be further discussed in my talk.

References

[1] A.M. Munshi, et al., Nano Letters **12**, 4570 (2012).
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[3] A.M. Munshi, et al., Appl.Phys Lett. **113**, 263102 (2018).
[5] I.M. Hoiaas et al., Nano Letters **19**, 1649 (2019).

Figure

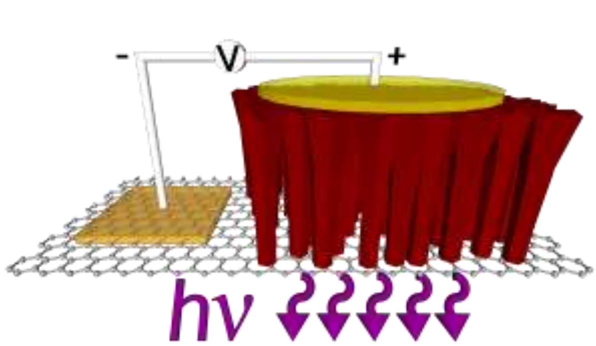

Figure 1: Schematic of an AlGaN nanowire flip-chip UV LED device using graphene as both substrate and transparent electrode.