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Using graphene as an epitaxial substrate and transparent electrode for GaN/AlGaN UV LEDs

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Abstract

In my talk I will review our recent research activities on the epitaxial growth of semiconductor nanostructures on graphene substrates. I will address the challenges for the growth and highlight some potential device applications of the NW/graphene hybrid system.

In 2012 we described a generic atomic model, which describes the epitaxial growth of semiconductor nanostructures on graphene that is applicable to all conventional semiconductor materials [1]. The epitaxial growth of semiconductor nanostructures 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]. Recently we have also shown the vertical growth of random (catalyst-free) GaN nanowires as well as positioned GaN nanopyramids on graphene. A very high nucleation yield is achieved on untreated CVD graphene using nanometer-sized AlGaN nucleation islands [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. NTNU (using nitrogen plasma-assisted molecular beam epitaxy (PA-MBE)) and CrayoNano (using metal-organic vapour phase epitaxy (MOVPE)) are now developing UV LEDs based on AlGaN nanostructures on graphene/silica glass substrates, which potentially can overcome these problems.

As a first proof-of-concept I will show the use of graphene as a growth substrate and transparent conductive electrode for an UV LED in a flip-chip configuration (Fig. 1). The GaN/AlGaN nanocolumns were grown as the light emitting structure using PA-MBE [4]. The results show that the graphene preserves many of its qualities during nanocolumn growth, although the conductivity is reduced compared with pristine graphene. The GaN/AlGaN nanocolumns are found to exhibit a high crystal quality with no defects nor stacking faults. Electroluminescence measurements show a distinct GaN bandgap related emission peak at 365 nm at room temperature with no defect-related yellow emission.

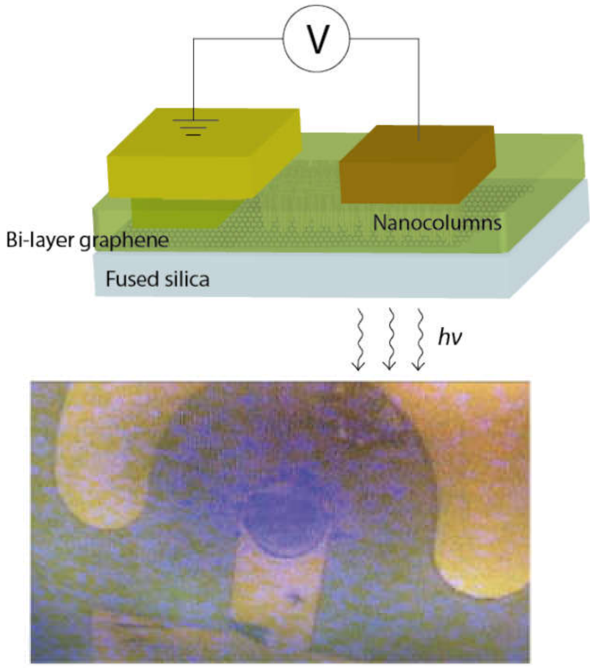

Fig. 1 GaN/AlGaN nanocolumns grown by MBE on bi-layer graphene/fused silica (amorphous glass) and processed into a flip-chip UV LED. Violet emitted light (365 nm) from a 75 µm aperture LED is observed in the picture at the bottom [4].

References

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