Improved Epitaxy of AlN Film for Deep-ultraviolet Light-emitting Diodes Enabled by Graphene

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Abstract

The growth of single-crystal III-nitride films with a low stress and dislocation density is crucial for the semiconductor industry. In particular, AlN-derived deep-ultraviolet lightemitting diodes (DUV-LEDs) have important applications in microelectronic technologies and environmental sciences but are still limited by large lattice and thermal mismatches between the epilayer and substrate. Thus, we directly grow graphene on sapphire to obtain a new epitaxial substrate, called graphene sapphire substrate. Based on this, we present the quasi-van der Waals epitaxial (QvdWE) growth of high-quality AlN films on graphene/sapphire substrates and have demonstrated their application in high-performance DUV-LEDs.[1] Guided by density functional theory calculations, we find that pyrrolic nitrogen in graphene introduced by a plasma treatment greatly facilitates the AlN nucleation and enables fast growth of a mirror-smooth single crystal film in the very short time of approximately 0.5 h (an ~50% decrease compared with the conventional process), thus leading to a largely reduced cost. Additionally, graphene effectively releases the biaxial stress (0.11 GPa) and reduces the dislocation density (1.96×10^8 cm^{-2}) in the epilayer. The as-fabricated DUV-LED shows a low turn-on voltage, good reliability and high output power.

References

[1] Z. L. Chen, Z. F. Liu *et al.*, *Adv. Mater.* (2019, DOI: 10.1002/adma.201807345)

Figures

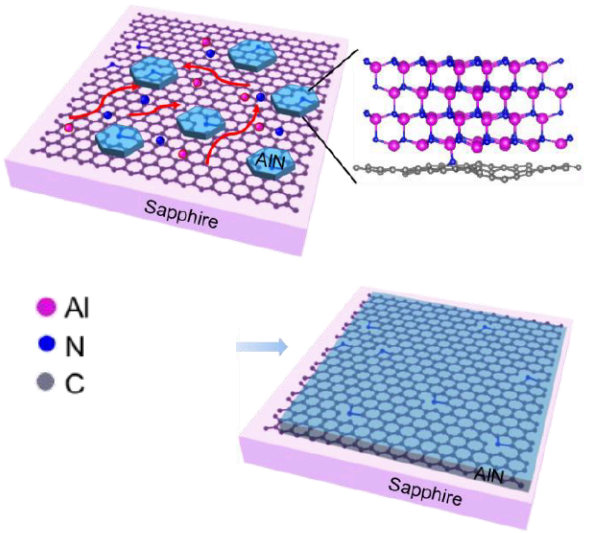

Figure 1: Schematic diagram of the nucleation and film growth of AlN on N_2 plasma treated-graphene/sapphire substrate.
1) Enhanced AlN nucleation on plasma treated-graphene/sapphire substrate through Al-N bonding. 2) Then, the fast 2D lateral growth of the AlN islands to form a continuous film due to the reduced diffusion barrier of adatoms on the ideal graphene.

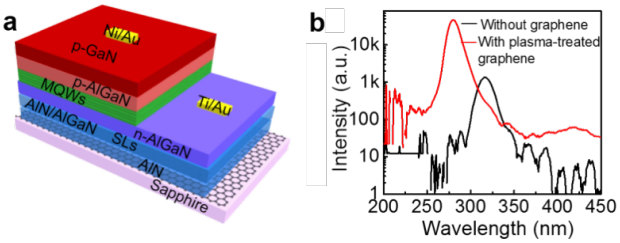

Figure 2: The structure and electroluminescence of as-fabricated DUV-LEDs. a) Schematic illustration of the DUV-LED structure. b) Electroluminescence (EL) spectra of the DUV-LEDs with and without graphene interlayer.