Advances in the integration of graphene with Nitrides for high frequency electronics

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Group III Nitride semiconductors (III-N), i.e. GaN, AlN, InN and their alloys, are materials of choice for many applications in optoelectronics and high-power/high-frequency transistors (e.g. LEDs, diodes, HEMTs,..). Due to its electrical, optical and thermal properties, graphene (Gr) integration with III-N has been considered in the last years to address some issues of the state-of-the-art GaN technology, e.g. as transparent conductive electrode for GaN LEDs, or as a heat spreader for thermal management in high power AlGaN/GaN HEMTs [1]. More recently, Gr integration with III-N has been proposed to realize novel device concepts for ultra-high frequency applications. In this context, Gr/AlGaN/GaN heterostructures deserve particular interest, since they offer the possibility to exploit the properties of Gr and AlGaN/GaN 2DEGs in close proximity. As an example, such a system can represent a building block for a Gr-Base Hot Electron Transistor (GBHET), a vertical device where Gr plays the role of the ultrathin base and the AlGaN/GaN 2DEG of the emitter [1].

In our work, different approaches to fabricate Gr heterostructures with III-N have been explored, including the transfer of Gr grown by CVD on catalytic metals (Cu) [2], and the direct CVD growth of Gr on AlN templates on different substrates, such as Si [3], SiC and sapphire.

Several structural/chemical, morphological and electrical characterization techniques have been employed to investigate the heterostructures realized by these different approaches. Micro-Raman spectroscopy was used to evaluate the number of Gr layers and defects density, while AFM provided information on the surface roughness of the transferred/grown Gr, which is crucial for GBHETs. Local electrical analyses by CAFM [2] and electrical measurements on properly fabricated test patterns were used to investigate vertical current transport across the Gr/III-N heterostructures. The experimental results have been compared with ab-initio calculations of the Gr/III-N interface structure and electronic properties. Furthermore, kinetic Monte Carlo simulations were employed to describe the mechanisms of CVD Gr growth on III-N templates. Finally, some key processes for the fabrication of the GBHETs have been developed, such as isolation of Gr and AlGaN/GaN 2DEGs, Ohmic contacts formation, and the atomic layer deposition of ultra-thin dielectrics with high structural/electrical quality on Gr.

All these results represent important advances towards the assessment of a Gr/Nitrides hybrid technology for next generation high frequency electronics.

References

[1] F. Giannazzo, et al., Phys. Status Solidi A (2016) / DOI 10.1002/pssa.201600460.
[2] G. Fisichella, et al., Nanoscale 6 (2014) 8671.
[3] A. Michon, et al., Appl. Phys. Lett. 104 (2014) 071912.