HIGH QUALITY GALLIUM NITRIDE HETEROSTRUCTURES GROWN ON GRAPHENE

András Kovács [1] – Béla Pécz [2] – Martial Duchamp [2] – Rositza Yakimova [3] – Péter L. Neumann [2] – Hannes Behmenburg [4] – Bartosz Foltynski [4] – Cristoph Giesen [4] – Michael Heuken [4] – Rafal E. Dunin-Borkowski [2]

[1] Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, Germany, e-mail: a.kovacs@fz-juelich.de
[2] Institute for Technical Physics and Materials Science, Centre for Energy Research, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Hungary
[3] Department of Physics, Chemistry and Biology, Linköping University, 581 83 Linköping, Sweden
[4] AIXTRON SE, Kaiserstrasse 98, 52134 Herzogenrath, Germany

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The incorporation of graphene layers in GaN heterostructures can be used to overcome self-heating problems in nitride-based high-power electronic and light-emitting optoelectronic devices. However, the lack of chemical reactivity between GaN and graphene leads to imperfect polycrystalline growth, resulting in undesired defects in the GaN and a possible rough surface, making the integration of graphene into nitride thin film heterostructures very challenging. Here, we present a transmission electron microscopy (TEM) study of high quality GaN heterostructure growth on patterned graphene layers on 6H-SiC [1].

Graphene layers were prepared on the Si-terminated face of an 0001-oriented 6H-SiC single crystal 2-inch wafer by a high temperature sublimation process. A periodic pattern of graphene layers (Fig. 1) was fabricated on 6H-SiC by using poly-methyl methacrylate (PMMA) deposition and electron beam lithography, followed by etching in an Ar/O_2 gas atmosphere. Prior to GaN growth, an AlN buffer layer and an $Al_{0.2}Ga_{0.8}N$ transition layer were deposited using metalorganic chemical vapour deposition. Samples for TEM studies were prepared in cross-sectional geometry using focused ion beam milling. Ion-beam-induced surface damage was reduced by using low energy Ar ion milling at 500 eV. Above the continuous graphene layers, polycrystalline defective GaN was rapidly overgrown by higher quality single crystalline GaN from the etched regions, as shown in Fig. 2. Lateral overgrowth of GaN results in the presence of a low density of dislocations (~10^9 cm^{-2}) and inversion domains, as well as the formation of a smooth GaN surface. An AlN/GaN superlattice (not shown) formed in the $Al_{0.2}Ga_{0.8}N$ transition layers, perhaps as a result of the presence of a small amount of C contamination originating from the graphene layers. The nucleation and growth of the heterostructure were studied using aberration-corrected scanning TEM (STEM) combined with electron energy-loss spectroscopy and energy dispersive X-ray spectroscopy (EDXS), as shown in Fig. 3.

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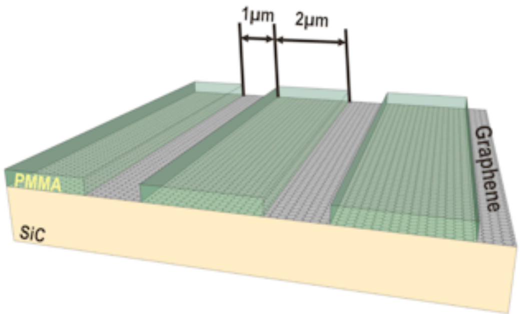

Figure 1. Schematic illustration of graphene layers patterned using PMMA.

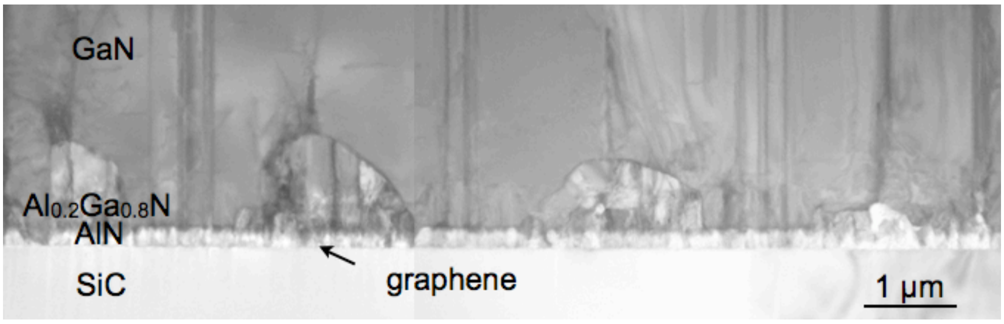

Figure 2. Low magnification bright-field TEM image of a cross-sectional specimen of the nitride heterostructure.

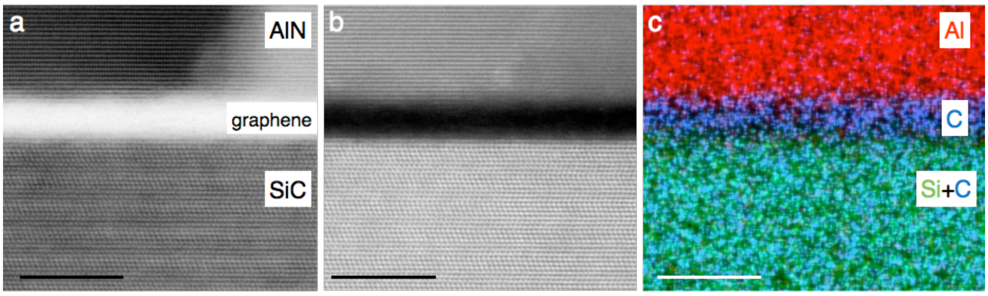

Figure 3. (a) Aberration-corrected bright-field STEM and (b) high-angle annular dark-field STEM images of the graphene layers between the SiC substrate and the AlN buffer layer. The inner ADF detector semi-angle used was 69 mrad. (c) Elemental map of Al, C and Si recorded using STEM EDXS spectrum imaging. The scale bar in each image is 5 nm.

References

1. A. Kovács et al. "Graphoepitaxy of High-Quality GaN Layers on Graphene/6H-SiC" Advanced Materials Interfaces 2, p. 1400230, 2015