Realization of 2D Group-III Materials Through Thermal Evaporation-Based Intercalation

[1]Natalie Briggs, [1]Brian Bersch, [1]Ana De La Fuente, [1,2]Carlos Lopez Pernia, [3]Ke Wang, [1]Joshua Robinson

[1]Department of Materials Science & Engineering, Center for 2-Dimensional and Layered Materials, 2D Crystal Consortium, Pennsylvania State University, University Park, PA 16802, USA

[2]Department of Materials Engineering, Technical University of Madrid, Madrid 28040, Spain

[3]Materials Characterization Laboratory, Pennsylvania State University, University Park, PA 16802, USA

Recent years have seen continued developments in the synthesis of 2D materials, and along with improved deposition techniques have come new strategies and approaches to realizing 2D compounds. One such strategy utilizes intercalation of metal atoms as a pathway to forming graphene-encapsulated 2D materials. This approach has allowed for the realization of a 2D form of gallium nitride (GaN) by annealing intercalated metal atoms in ammonia, as a result, expanding the pallet of materials that may be realized in 2D forms [1]. However, initial studies of 2D GaN synthesized from intercalation have relied on involved metal organic chemical vapor deposition techniques, and the resulting materials have suffered small domain sizes. We report a method of intercalating group-III (GIII) metal atoms gallium and indium through simple vaporization of metallic precursors in the presence of graphene layers. Through this method, micron-scale intercalation is possible. Following the intercalation of GIII metals, graphene-encapsulated gallium and indium layers are selenized and nitridated through exposure to selenium and ammonia at high temperatures. Ongoing work aims to elucidate the requirements of forming encapsulated 2D materials, as well as the resulting structures, and electronic and optical properties.

[1] Balushi, Z. Y. Al *et al.* Two-dimensional gallium nitride realized via graphene encapsulation. *Nat. Mater.* **15,** 1166–1171 (2016)

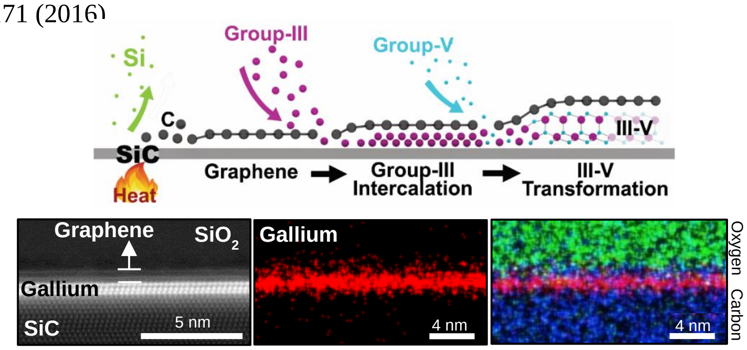

Figure 1: Top: Schematic of GIII material formation, bottom: scanning tunneling electron microscopy of intercalated gallium between graphene and silicon carbide (SiC) (left), energy dispersive spectroscopy (EDS) showing gallium (middle), and EDS showing gallium, carbon, and oxygen (right).

Supplementary Page

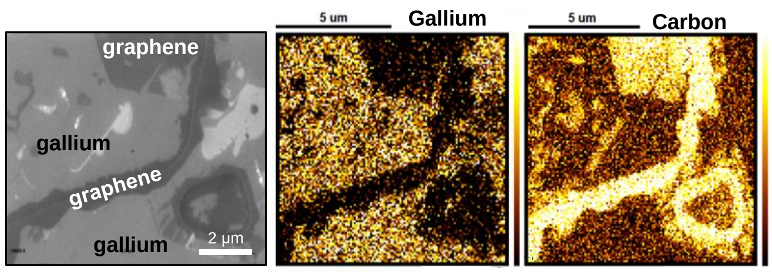

Figure 2: Scanning electron microscopy (left) and Auger electron spectroscopy maps showing gallium and carbon on the surface of gallium-intercalated, epitaxial graphene samples.

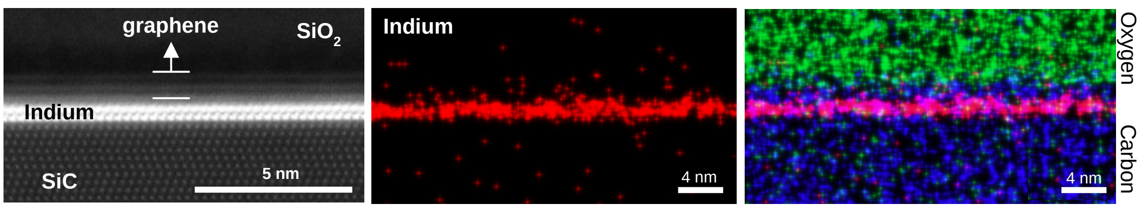

Figure 3: Cross-sectional transmission electron microscope image showing intercalated indium beneath epitaxial graphene (left), energy dispersive spectroscopy (EDS) showing indium (middle), and EDS showing indium, carbon, and oxygen (right).