On the use of graphene/GaAs templates for the epitaxy of freestanding III-V thin films

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ABSTRACT

Freestanding III-V epilayers are important building-blocks for different photovoltaic architectures under intensive research including ultrathin solar cells and III/V-Si tandem devices. To fabricate these structures, epitaxial III-V materials are released from their substrate using epitaxial lift-off techniques. Remote epitaxy using a monolayer graphene interlayer is a recently discovered phenomena[1] that could allow the growth of single-crystalline III-V layers where the adatoms follow the crystallographic registry of the underlying substrate. The films can be later mechanically exfoliated due to the weak Van der Waals bonding between the epilayer and the substrate, which can be potentially reused for subsequent growths without chemical-mechanical polishing. We report the fabrication of large-area graphene/GaAs heterostructures by a metal-assisted dry transfer approach as templates for remote-epitaxial growth. Structural characterization by Raman spectroscopy demonstrates no damage to the graphene lattice, negligible unintentional doping, and stress relaxation during the transfer process. X-ray photoelectron spectroscopy reveals a contamination-free surface and a very low level of interface oxidation compared to conventional wet-transferred graphene. We conducted a preliminary nucleation study of GaAs on the fabricated graphene/GaAs substrates using molecular beam epitaxy. We observe a Volmer-Weber growth mode, and partial epitaxial alignment of the islands with the underlying GaAs(001) substrate occurred at high growth temperatures (T_{growth}=620°C). At low temperature (T_{growth}=450°C), the GaAs islands are randomly oriented and the influence of the GaAs substrate on the nucleation was found to be negligible. These results together with the observed strong degradation of the graphene Raman spectrum at the growth conditions, and the weak remote interaction between the adatoms and the substrate below the graphene ($\ll K_B T_{growth}$), suggest that pinhole-seeded growth plays a major role as an alternative mechanism to remote epitaxy, as recently reported for graphene/GaSb[2]. The growth of a 330 nm GaAs layer resulted in a polycrystalline film that could be easily exfoliated from the substrate. Further investigation of the growth conditions to avoid random nucleation on the graphene and achieve large surface single-crystallinity is being carried out and will be discussed in the conference.

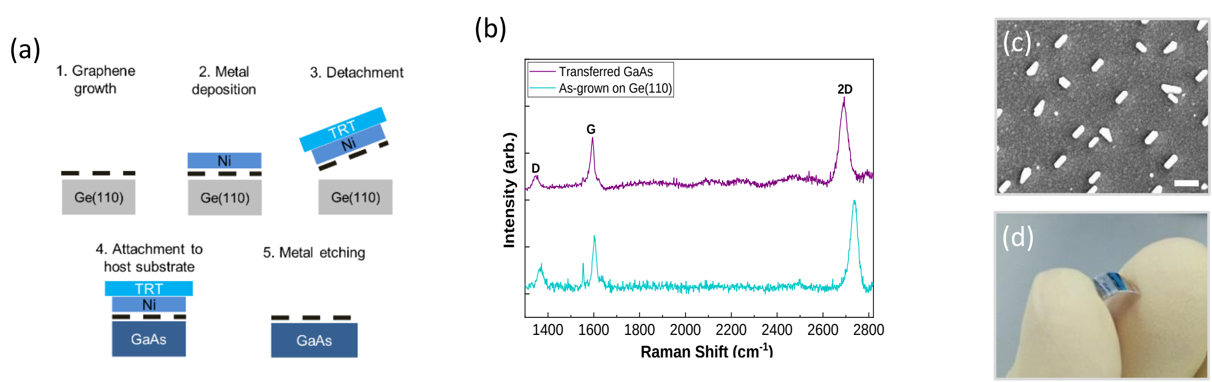

FIG 1: a) Schematic representation of the graphene transfer process. b) Raman spectrums of graphene before (blue) and after its transfer to GaAs (purple) showing no structural damage. c) Epitaxial GaAs islands grown on graphene/GaAs. 250 nm scalebar. c) Polycrystalline GaAs thin film grown on graphene/GaAs and transferred to a flexible substrate.

[1] Y. Kim et al. *Nature* 544, 340–343 (2017), [2] S. Manzo et al. *Nat Commun* 13, 4014 (2022).