Growth of III-V Semiconductors on Graphene

N. Nateghi [1]*, S. Mukherjee* [1]*, D. Cardinal* [2]*, R. Jacobberger* [3]*, A. Way* [3]*, P. L. Levesque* [2]*, M.S. Arnold* [3]*, P. Desjardins* [1]*, R. Martel* [2]*, R.A. Masut* [1]*, and O. Moutanabbir* [1]

[1]*Departement de Genie Physique, Polytechnique Montréal, C.P. 6079, succ. Centre-Ville, Montreal (Quebec), Canada H3C 3A7*

[2]*Departement de Chimie, Universite de Montreal, C.P. 6128, succ. Centre-Ville, Montreal, (Quebec), Canada H3C 3J7*

[3] *Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, Wisconsin 53706, United States*

Corresponding author. E-mail address: Seyyed-nima.nateghi@polymtl.ca

Heteroepitaxial growth of III-V on group IV semiconductors has been an attractive paradigm to implement hybrid systems with novel or enhanced functionalities, combining the advantages of these two families of semiconductors within the same platform. The obvious challenges limiting this heterointegration of III-V and group IV semiconductors are related to lattice and thermal mismatches. Herein, to overcome these challenges, we exploit van der Waals epitaxy using graphene interlayer to grow monocrystalline III-V on SiO_2/Si and Ge substrates.

We demonstrate the low-pressure metal-organic vapour phase deposition of InAs, GaAs, InP, and GaP islands on single layer graphene sheets transferred on SiO_2/Si(100) and grown on Ge (100), (110), and (111) substrates. The crystalline nature of the islands has been confirmed by X-ray diffraction and micro-Raman spectroscopy. Plan-view and cross-sectional scanning electron microscopy (SEM), as well as atomic force microscopy revealed the formation of flat surface and faceted surface crystals on all the samples. The dimensions of the crystalline islands range from ~20 nm to ~1.5 μm (lateral) and ~40 nm to ~2 μm (height), depending on the growth temperature and time. Two-step growth (nucleation at low temperature and growth at high temperature) led to formation of few microns wide and few tens of microns long films with smooth surface (roughness < 1nm) on graphene/Ge substrates, while in the same growth run, negligible coalescence was observed on graphene/SiO_2/Si. This may correspond to the shorter diffusion length of the adatoms on rough and defected graphene surface transferred on SiO_2/Si.

The ability to grow these crystalline structures with variable morphologies provides valuable opportunities to expand the fundamental understanding of the basic properties of III-V/Graphene/IV heterostructures and explore their use in innovative devices.

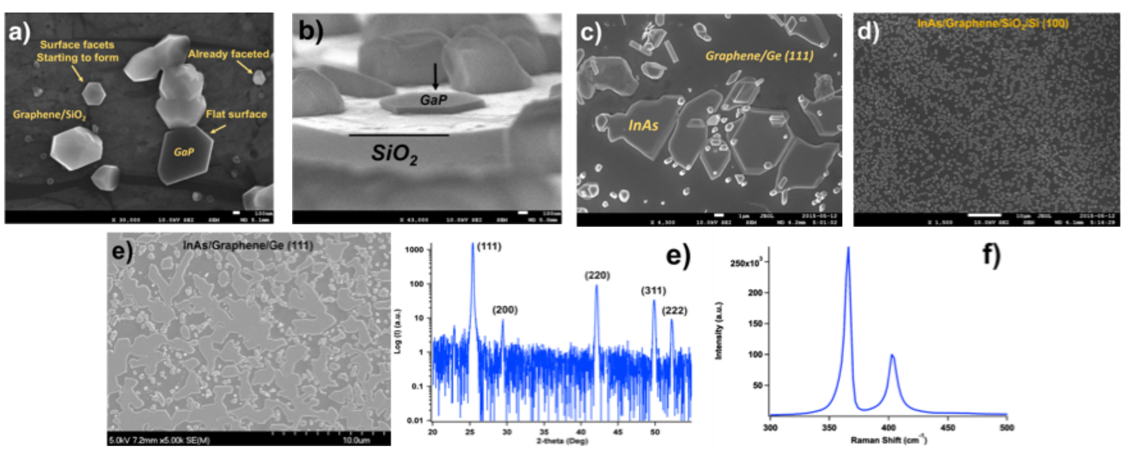

FIG 1. (a) Plan-view and (b) cross sectional SEM images showing the formation of faceted and flat surface GaP crystals on graphene/SiO_2/Si, (c) few microns large InAs island formation on graphene/Ge (111). Two-step growth (nucleation at 450 °C and growth at 600 °C) of InAs on (d) graphene/SiO_2/Si and (e) graphene/Ge (111) resulting in smooth island coalescence on Ge (111), (e) X-Ray diffraction spectrum of InAs grown on graphene/SiO_2/Si showing a polycrystalline texture, and (f) Micro-Raman spectrum of a GaP island grown on graphene/SiO_2/Si, confirming the crystalline nature of GaP.