L.13: MOVPE growth and electronic band alignment of GaP/Ge(111) nanostructures

Epitaxial structures of group III-V and III-V-N semiconductors on Silicon (Si) and Germanium (Ge) opens up a path way for the development of high efficiency multijunction solar cells, wide range of detectors, advanced lasers and spin-photonic devices. In fact very recently high-coherence semiconductor lasers, based on integral high-Q resonators in hybrid III-V/Si platforms, have also been proposed. However, the integration of device quality III-V structures on Si and Ge substrates is not trivial due to the incompatibility between respective material properties. Further, the epitaxial growth of GaP on Ge(111) substrates has several advantages because tensile strain based heterostructures offers a promising route for the synthesis of epitaxial nanostructures without creating dislocations. This is because combination of tensile strain and (111) surface prohibits the glide of 90 partial dislocations. Thus there exists a possibility that GaP nanostructure (~10nm) free from anti phase domain (APD) and dislocations can be integrated on Ge (111) substrates for several photonic applications. We, at RRCAT, have grown GaP epitaxial nanostructures on Ge(111) substrates using metal organic vapour phase epitaxy (MOVPE) and their crystalline properties are investigated by using high resolution x-ray diffraction (HRXRD). It was confirmed by HRXRD results that the layer was highly crystalline and oriented with the coexistence of two domains, i.e., GaP(111)A and GaP(111)B, with an angle of 60° between them due to the formation of a wurtzite monolayer at the interface as shown below in Fig. L.13.1.

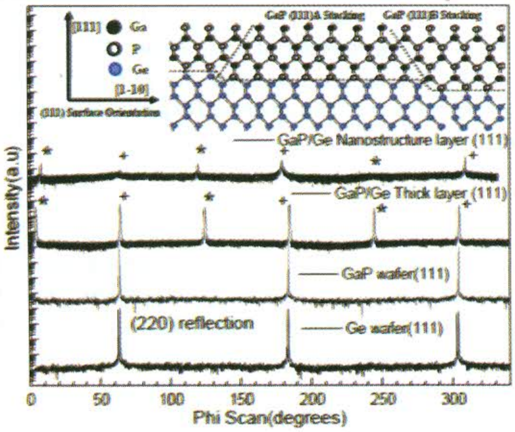

Fig. L.13.1: XRD patterns of φ scan over 360° azimuths and schematic of APD on GaP/Ge

Ultraviolet photoelectron spectroscopy (UPS) measurements are carried out with an angle integrated photoelectron spectroscopy (PES) beam line at Indus-I synchrotron radiation source with photon energies of 100 and 180eV. Fig. L.13.2(a) shows the PES spectra of GaP/Ge nanostructure. The PES spectrum of GaP/Ge is arising from the valence band (VB) and core levels of (1) GaO_x, (2) GaP, (3) GaO_x/GaP, (4) native oxide (GeOx) layer left after 5 minutes Ar^+ ion sputtering, (5) buried surface of Ge substrate under the native oxide layer, and (6) from the interface between GeO_x/Ge, as shown by the schematic diagram in the inset of Fig. L.13.2(a). It is further noted that the three onsets observed in the PES spectrum of GaP/Ge shown in L.13.2(b) at ~0.5±0.1,~1.2±0.1, and ~3.0±0.1eV are related to Ge substrate, top GaP layer and GeO_x layer, respectively. Thus, the value of valence band offset (ΔE_V) between GaP nanostructure and Ge substrates, extracted from the difference between the valence band onsets, is ~0.7±0.1eV. The value of ΔE_V is also calculated by using Kraut's et al. formula $\Delta E_V = \Delta E_{CL} + [E_{Ge3d} - E_{VBM}]^{Ge} - [E_{Ge3d} - E_{VBM}]^{Gap}$, where ΔE_{CL} denotes the core level energy difference between Ge 3d and Ga 3d that is measured on a GaP/Ge. $[E_{Ge3d} - E_{VBM}]^{Ge}$ and $[E_{Ge3d} - E_{VBM}]^{Gap}$ are the core level energies corresponding to Ge 3d and Ga 3d peaks with respect to the VBM of Ge substrate and GaP layer, respectively. Thus, the value of valence band onsets, is ~0.7±0.1eV obtained from these two methods and a band diagram of GaP/Ge/GeOx is constructed showing type-I band alignment as shown in inset of Fig L.13.2(a).

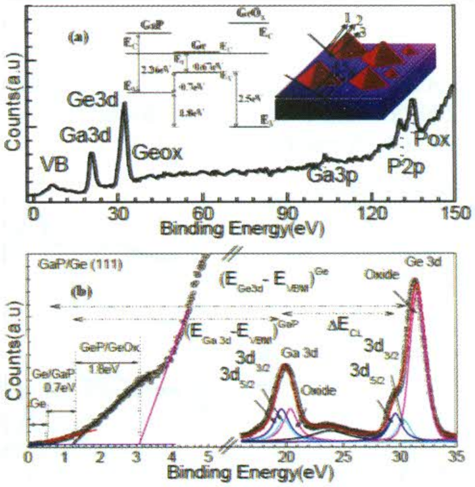

Fig.L.13.2: Valence band, core level spectra and a band alignment diagram of GaP/Ge

The knowledge of crystalline and electronic band alignment properties of GaP/Ge nanostructure can play a pivotal role in the design of high efficiency solar cells, optoelectronic and spin photonic circuits under monolithic integration. For details please see Dixit et al. Appl. Phys. Lett. 104, 092101 (2014).

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