L.8: Growth of InAs nanostructures on Ge(111)

We report on the role of self-catalyst (indium) and substrate surface in various growth mechanisms and crystalline structure of InAs nucleating layers on Ge (111) using Metal Organic Vapor Phase Epitaxy. This study opens up the possibility of direct integration of InAs with Ge (111) substrates for next generation optoelectronic and microelectronic device applications.

InAs/Ge(111) samples were grown by Metal Organic Vapor Phase Epitaxy (MOVPE) technique at Semiconductor Materials Lab, RRCAT using Trimethylindium (TMI) and Arsine sources in the growth temperature range of 400 - 540 °C. For self catalyst assisted growth, indium droplets were deposited before InAs growth by flowing TMI for 5 sec followed by a 30 sec soak. Different nucleation modes like droplet-epitaxy (DE), Volmer-Weber (VW), and Frank-Van der Marwe (FM) modes are observed in various growth windows. DE and FM are the dominating nucleation modes in the lower growth temperature range (400 - 470 °C) with the assistance of indium catalysts, while VW mode dominates at higher growth temperatures (470- 540 °C). Three dimensional faceted structures are formed with varying density in all over the growth temperature range of 400 - 540 °C, which is attributed to various factors like surface strain of indium adatom covered Ge (111) surface, indium surface diffusion and twin defect formation. Figure L.8.1 shows atomic force microscopy (AFM) image of the grown nanostructures imaged by a multimode scanning probe microscope (NT-MDT, SOLVER-PRO). High resolution x-ray diffraction identifies the twin formation at low temperature growth. Raman mapping reveals that InAs nano/microstructures grow with ZB-WZ polytypic crystal structure at higher growth temperature and under arsenic-rich condition.

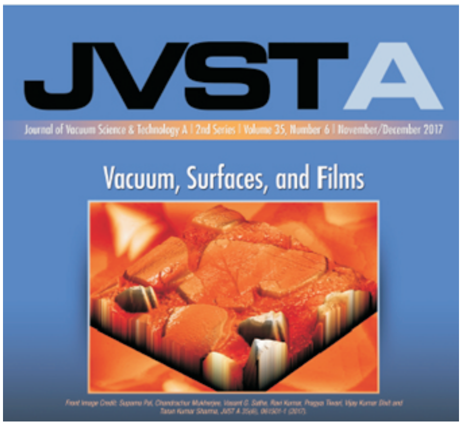

Fig. L.8.1: AFM images of MOVPE grown InAs nucleating layer, which also appeared on the cover page of J. Vac. Sci. Technol. A.

Raman data were recorded at CSR, Indore, using LABRAM HR-800 spectrometer in back scattering geometry at room temperature. Figure L.8.2 clearly shows E_2^H mode in the lower frequency wing of the TO phonon mode confirming presence of WZ phase. Figure L.8.2(b) is composed of both TO and E_2^H modes and hence represents regions with mixed ZB-WZ structure. On the other hand, Raman spectra shown in Figure L.8.2(a) and (c) represent ZB and WZ dominated regions, respectively, as TO and E_2^H modes are the major components in the corresponding spectrum. This observation shows that polytypism can be achieved in the crystalline structure of InAs/Ge (111) by engineering the growth conditions, which has potential application in designing advanced homostructure devices.

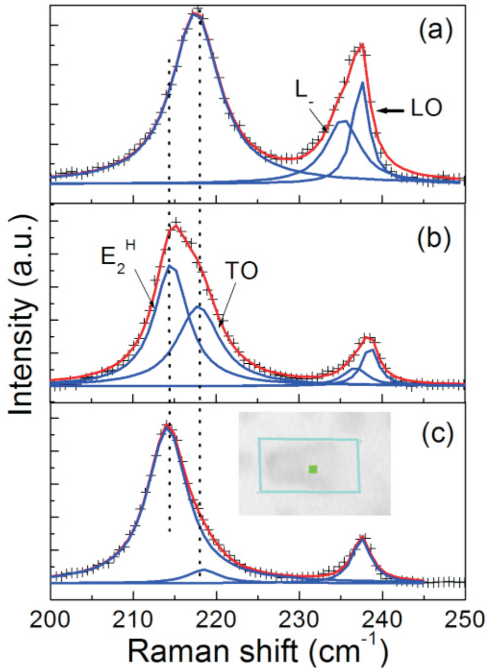

Fig. L.8.2: Raman spectra for polytypic sample recorded at different regions within a single InAs island as shown in the inset. (a) ZB dominated region (b) WZ/ZB polytypic region and (c) WZ dominated region.

A comparison is made about the growth modes, morphology and polytypism in InAs nanostructures, which are grown on Ge (111) and Si (111) substrates under identical conditions. Low surface diffusivity of indium on Ge substrate and InAs/Ge interface energy are proposed as the main factors for the inhibition of anisotropic axial growth of InAs on Ge via VLS mode, while it succeeds on Si substrate. For more details, please refer to Suparna Pal et al., J. Vac. Sci. Technol. A 35 (2017) 061501.

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