L.12: Catalyst-free growth of InAs NWs on Si(001)

III-V nanowires (NWs) have a potential role in the advanced technologies like high performance field effect transistors, photodetectors, chemical / biosensors and thermo electric devices. In particular, InAs NWs are promising because of their narrow bandgap with small electron effective mass, high electron mobility, strong quantum confinement effect and possible application in infrared photodetectors and high-speed electronics. NWs of InAs have been grown successfully on Si(111) surface. However, although the preferred substrate for industrial applications would be Si(001), the growth of InAs NWs on this surface has not been explored widely and remains a challenging task. At SCLS, we have carried out growth of InAs NWs on Si(001) using Metal Organic Vapor Phase Epitaxy under various growth conditions such as, catalyst assisted and catalyst free growth, growth on native oxide covered and oxide-cleaned Si, grooved Si-surfaces and also varying V/III ratio and growth temperature (Semicond. Sci. Technol. 28 (2013) 015025). Low (10^4 cm^{-2}) and high (10^8 cm^{-2}) density NWs were grown on Si(001) at growth temperature ~ 425°C and 550°C, respectively. Three types of NWs were formed depending on the growth condition. i) On oxide-cleaned Si-wafer NWs were formed at 550 °C. Under this growth condition 0.5-1 µm long NWs of 40-80 nm diameters were formed as observed from Fig.L.12.1(a). The height of the NWs varied between 70 - 160 nm as measured by atomic force microscopy (AFM) [Fig.L.12.1(b)]. At this growth temperature, the dimensions of the NW are very dependent on the V/III ratio.

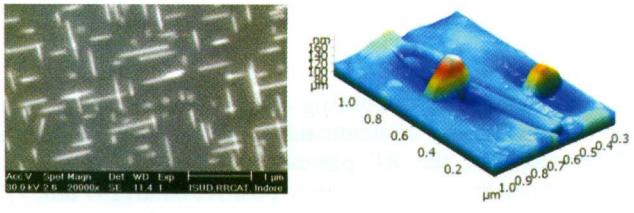

Fig.L.12.1: SEM image of (a) NW on oxide-cleaned Si(001) (b) 3D AFM image of a single NW along with two nanohillocks.

Furthermore, XRD shows (Fig.L.12.2) two peaks at 29.45° and 61.16° identified as due to (002) and (004) reflections of InAs. This confirms that the grown InAs nanostructures are oriented with Si(001). The FWHM of the InAs (002) reflection is 0.2°. Growth of hillock and wire like structures are observed under same growth condition. XRD, high resolution transmission electron microscopy and AFM analyses confirm that the hillocks are grown along <001> direction whereas the wires are grown along [110] directions in the plane of Si(001). ii) Native oxide covered Si(001) wafers were annealed first at 625 °C under H_2 flow for 5 min. and were cooled down to the growth temperature (~ 425 °C). This growth condition led to formation of long (50 - 80 µm), tapered (tapering factor of 0.02) NWs on oxide covered surface as shown by the SEM micrographs in Fig.L.12.3(a). iii) The grooved surface on oxide covered Si(001) wafer was formed using a mechanical scriber. Subsequently the growth of InAs NWs was carried out on these grooved surfaces under the above optimized condition [same as (i)].

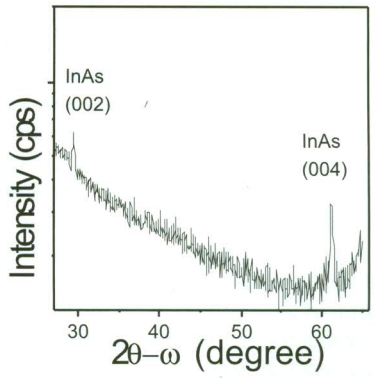

Fig.L.12.2: An out-of-plane double axis ω–2θ scan of the oriented zinc blende InAs shown in Fig.1(a).

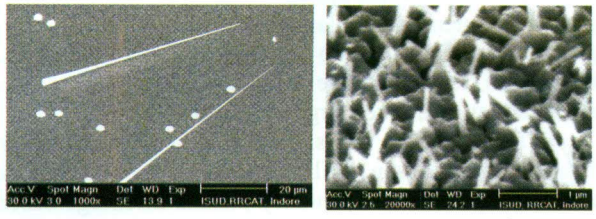

Fig.L.12.3: (a) NW on native oxide-covered Si (b) NW grown on grooved Si(001).

We observed from SEM images that under this growth condition, non-tapered InAs NWs were grown on the grooved surface in a upright fashion [Fig.L.xx.3(b)]. Normally it is difficult to grow standing NWs on (001) substrates without assistance of any catalyst. Therefore (111) substrates are natural choice for vertical growth of NWs. However, in our study we observe that standing NWs can be formed on (001) substrates even without catalyst by simple surface modification e.g. making v-grooves on the (001) surface. SAED and HRTEM suggest that the growth direction is along the [111] direction. This study suggests that both horizontal and standing NWs of different dimensions can be grown on Si(001) surface by varying the substrate surface and the growth conditions. This study can be used for the controlled integration of III-V NW technology on Si substrate.

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