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# III-V Nanowires grown by MOCVD for Optoelectronics Applications

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Nanowire (NW) research is a new and emerging field growing at a fast pace. The excitement in this field is due to the unique electronic and optical properties of the nanowires. Novel nanowire-based electronic and photonic devices with superior performance over existing devices are expected to revolutionise our technological world in the way of new devices and components. The unique properties stem from their large surface to volume ratio, very high aspect ratio, and carrier and photon confinement in two dimensions. One particular class of nanowires is the epitaxial III-V compound semiconductor nanowires, typically grown by Metal Organic Chemical Vapour Deposition (MOCVD) or Molecular Beam Epitaxy (MBE).

In this talk, I will present an overview of the III-V nanowire work carried out at the The Australian National University using the Au-catalysed MOCVD growth. Our work can broadly be classified into five areas:

(i) Growth on GaAs-related NWs
(ii) Growth of InP-related NWs
(iii) Growth of GaSb-related NWs
(iv) Growth of branched, axial and radial NW heterostructures
(v) Growth of III-V NWs on Si substrates

GaAs NWs grown on (111) GaAs substrates usually have zincblende structure but with stacking faults along the axis of the NWs and also some tapering effect. By using the two-temperature growth method, not only we are able to suppress the formation of these stacking faults but also reduce the tapering significantly. Fig. 1 shows the effect of single temperature growth in comparison with the two-temperature growth. Additionally, the optical properties (luminescence) of the nanowires by two-temperature growth are enhanced substantially due to the suppression of the stacking faults which act as non-radiative recombination centres.

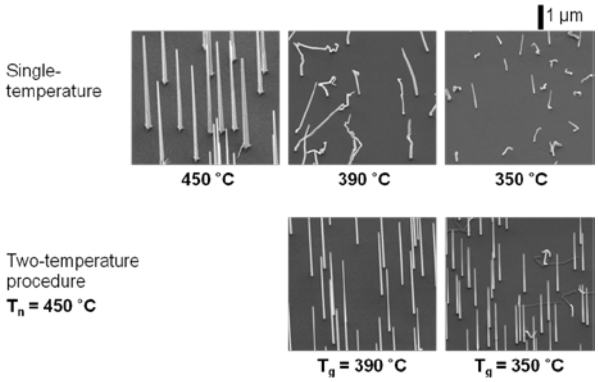


Fig. 1 SEM micrograph showing GaAs NWs grown using single temperature (top) and two-temperature growth (bottom). For the two-temperature growth, initial nucleation temperature, $T_n$, was 450°C.

InP NWs grown on (111) InP substrate on the other hand tend to be in a polytypic phase (mixed zincblende and wurtzite structure). However, by controlling the growth conditions (mainly V/III ratio, growth temperature and growth rate), we are able to control the formation of either wurtzite or zincblende structure, as illustrated by the photoluminescence spectra in Fig. 2 shows that for three different V/III ratios. Since the bandgap of wurtzite and zincblende InP are different, this is an interesting phenomena because it would allow us to engineer wurtzite-zincblende superlattice-type structures which may have unique optical properties.

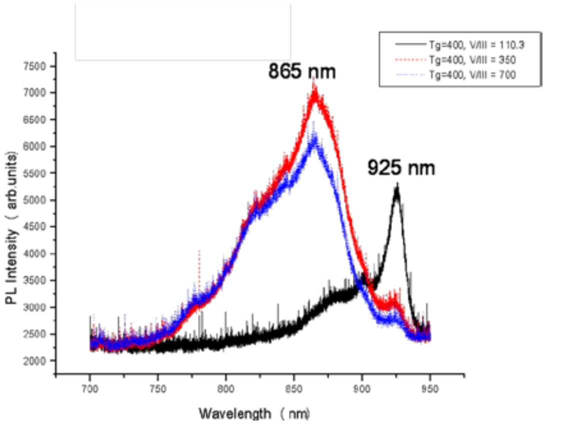


Fig. 2 Room temperature photoluminescence spectra for InP NWs grown at 400°C for three different V/III ratios. The two highest V/III ratios resulted in NWs having a wurtzite structure (λ=865nm) and zincblende for the lowest V/III ratio ((λ=925nm).

The growth of InAs NWs on GaAs substrates follows an interesting route, where branching of the InAs NWs is observed. Detailed studies of this mechanism have led us to propose the slipping of the Au particle during growth due to differences in the wettability of Au with InAs and GaAs. This effect is illustrated in Fig. 3, where the progressive growth of the InAs NW is captured. Initially the Au particle slips down the GaAs NW with the growth of InAs as the Au particle prefers to wet the GaAs surface. With further deposition of InAs and due to some radial growth, the GaAs NW is eventually covered with InAs. From this point on, the Au particle is forced to wet the InAs and hence branching occurs.

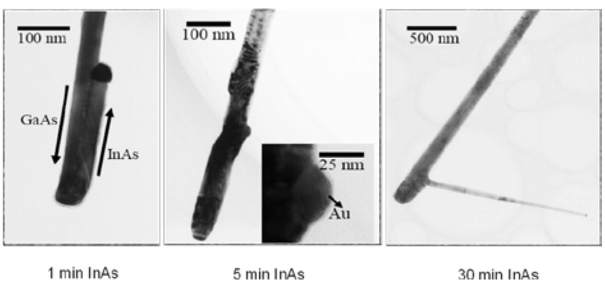


Fig. 3 Growth of InAs NW on GaAs NW as a function of growth time for the InAs.

It is interesting to note that despite the large lattice mismatch difference between GaSb and GaAs (~7.8%), we are able to grow GaSb NWs on GaAs NWs with perfect crystallinity. Fig. 4 is a high resolution TEM image showing the interface of the GaSb-GaAs without any defects or dislocations. We also note that the growth of GaSb NW is extremely slow compared to that of GaAs NW. Due to the slow growth rate, it is postulated that the growth of GaSb is reaching the thermodynamic equilibrium and hence the lattice of the GaSb is able to gradually relax to accommodate the strain at the interface.

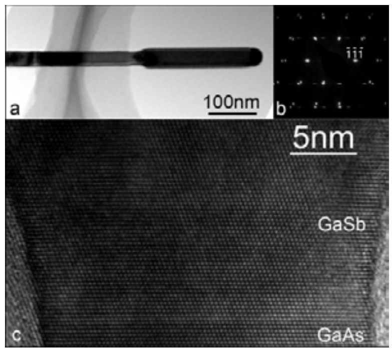


Fig. 4 High resolution TEM image showing the high crystalline interface between GaSb and GaAs NW.

There has been a significant amount of work in the last 20 years or so on growing III-V semiconductors on Si substrates. Although there has been mixed success of the epitaxy of III-Vs (GaAs) on Si, this technology has not materialised to a commercial level. There are several difficulties which limit the success of growing III-V semiconductors on Si, such as large lattice mismatch (4.1%), polar and non-polar nature of the materials and differences in thermal expansion coefficients. To minimise or suppress these problems, our III-V NWs are grown on a thin layer of III-V buffer material. By optimising the growth condition of the buffer layer, we are able to obtain surface with good morphology on (111) Si substrates. Indeed, the morphology, density and quality of the GaAs NWs grown with a buffer on Si substrate is similar to those grown directly on GaAs substrates.