Precise control over III-V compound semiconductor nanowires (NWs) growth is crucial for the fabrication of advanced nanoscale electronic and optoelectronic devices. Core-shell GaAs/AlGaAs NWs were grown on Si (111) by plasma assisted molecular beam epitaxy (PAMBE). Initially, the NWs were grown via the vapor-liquid-solid mechanism, using Ga droplets as catalyst, for 20 min. Subsequently, the Ga droplets were removed by exposing the NWs to As flux and growth continued for another 40 min, varying the fluxes of the Al, Ga, and As, in order to form an AlGaAs shell around the GaAs initial core.

The structural features of the NWs were characterized by transmission electron microscopy (TEM) methods. TEM observations and selected area diffraction analysis showed that NWs are zinc-blende (ZB) single crystals grown epitaxially along the [111] direction normal to the Si substrate, despite the presence of a 1-3 nm thick amorphous SiO2 layer on the Si surface. Simultaneously, an interfacial GaAs layer is formed between the NWs, comprising large epitaxial and {111} twin related crystals [Fig. 1(a)]. The emanation point of the NWs is located on small heavily twinned GaAs crystals [Fig 1(b)], which evolve into NWs and finally, through the growth process usually merge with the GaAs crystals of the interfacial layer. In addition, “parasitic” NWs emerging from either the interface, or the original NWs were observed along the inclined <111> and/or the <100> directions. Mirror twins normal to the [111] growth direction can be observed throughout the length of the NWs [Fig. 1(c)]. In fact, NWs grow for several micrometers under a continuous succession of mirror twins. No wurtzite structure was observed.

The weak absorption contrast of high-resolution TEM (HRTEM) in conjunction with the minimal difference of the AlGaAs and GaAs lattice parameters turn HRTEM images unsuitable for visualizing the core-shell structure. Hence, the chemically sensitive 200 reflection for mass contrast TEM imaging [Fig. 1(d)], in addition to annular dark-field (ADF) scanning TEM (STEM) imaging [Fig. 1(e)], were used. These revealed the core-shell configuration of the NWs, where the AlGaAs shell spans from one half to 2/3 of the projected diameter of the NWs ranging from 80 nm to 180 nm. Furthermore, energy dispersive X-ray (EDX) analysis confirmed the core-shell morphology of the NWs and was used to estimate the NW shell composition.

Acknowledgement: Research co-financed by the European Union (European Social Fund-ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Research Frame (NSRF)-Research Funding Program: ARISTEIA II, project “NILES”.
Fig. 1: (a) TEM image, taken off the [1-10] zone axis, showing the NWs morphology. (b) A NW emerging from a small defected GaAs crystal. (c) HRTEM image, along the [1-10] direction, where mirror twins are depicted by arrows. The amorphous shell is attributed to oxidation. (d) & (e) TEM and ADF STEM images revealing the GaAs/AlGaAs core-shell structure.