Ref. Ares(2020)1861952 - 31/03/2020

AndQC

Report on InSb nanowires with controlled morphology and crystalline structure

Author	Affiliation	Email
Lucia Sorba	CNR	Lucia.sorba@nano.cnr.it
Project Number	Project Start Date	Duration
828948	01.04.2019	48 Months
Classification		
	PU	
File Name		
WP No	Work Package Name	
WP1	Materials development	
Deliverable No	Deliverable Name	
1.1	InSb nanowires with controlled morphology and crystalline structure	
	Approved by	
	Steering Committee of the action	

 This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 828948.

DOCUMENT REVISION HISTORY

Revision	Date	Description	Author
1.0	31.03.2020		Lucia Sorba

Table of Contents

1. Introduction

The aim of the WP1 is to implement the growth of the superconductor-semiconductor heterostructures that will form the basis of further investigations in the framework of the project. The optimized materials require that two key properties be fulfilled by the semiconductor-superconductor heterostructures. Firstly, the induced superconductivity in the semiconductor has to exhibit a so-called hard superconducting gap with an amplitude of Δ, which, crucially, lacks a continuum of subgap electron states. Secondly, the semiconductor channel has to exhibit ballistic electronic transport, with transmission probabilities very close to $T = 1$.

In this WP we have started to investigate two leading ballistic semiconductor platforms: semiconductor nanowires and planar two-dimensional electron gas (2DEG) semiconductor heterostructures. The materials developed throughout the first year of the project are fully characterized, and we have started to provide samples to the consortium partners.

2. InSb Nanowires

InSb nanowires (NWs) were grown on InAs (111)B substrates by chemical beam epitaxy (CBE) by Au-assisted growth [1,2]. The precursors used for the NW growth are trimethylindium (TMIn), tertiarybutylarsine (TBA), and tert-dimethylaminoantimony (TDMASb).

Au nanoparticles were realised by thermal dewetting of nominally 0.5 nm thick gold films. The gold films were deposited onto InAs wafers by thermal evaporation in a separate chamber, and then transferred to the CBE system. In the CBE chamber, they were heated under TBA flow for 20 min at 450 °C in order to remove the surface oxide and to dewet the Au film into nanoparticles.

Since it is difficult to nucleate InSb NWs directly on a dissimilar substrate, they are often grown on InAs NW stems [2]. We have opted for the same procedure. The InAs stems were grown for 60 min at a temperature of 370 °C, with precursor line pressures of 0.3 Torr and 0.22 Torr for TMIn and TBA, respectively. For the following InSb growth, the TMIn and TDMASb line pressures were switched to 0.45 Torr and 0.75 Torr, respectively, while the substrate temperature was decreased to 350°C. The InSb NWs were grown for 2 hours. In order to reduce the radial growth, the substrate temperature was then increased by 30 °C within 20 mins, and the InSb segment was grown for 70 more minutes. To terminate the growth, the samples were cooled down under TDMASb flux.

InSb/InAs heterostructure NWs were characterized by scanning electron microscopy (SEM) with an accelerating voltage of 5 kV and with the substrate tilted by 45° (see Fig.1). The resulting average length and diameter of the InSb segments are 2300±50nm, and 125±10nm, respectively.

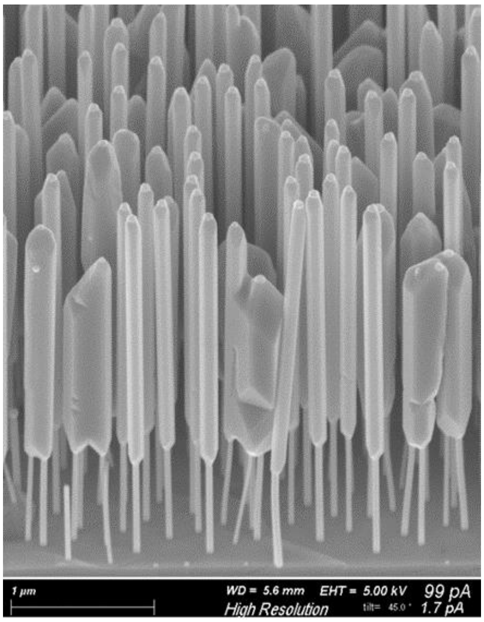

Fig. 1: Scanning electron micrograph of InSb/InAs heterostructured NWs, measured under 45 °.

The crystal structure of the InSb/InAs heterostructured NWs was measured by transmission electron microscopy (TEM) using a JEOL JEM-2200FS microscope operated at 200 keV, equipped with an in-column Ω filter. Imaging was performed in high resolution (HR) TEM mode combined with zero-loss energy filtering. For TEM characterization, the NWs were mechanically transferred to carbon-coated copper grids. Figure 2 shows a HR-TEM image of a representative NW at the InAs/InSb interface. The power spectra obtained by Fast Fourier Transform of the selected regions show zincblende structure for InSb (oriented in <110> zone axis) and wurtzite structure for InAs (oriented in <11-20> zone axis). Furthermore, the crystallographic study shows defect-free InSb along the whole NW segment. A TEM image of a representative InSb segment is shown in Fig. 3.

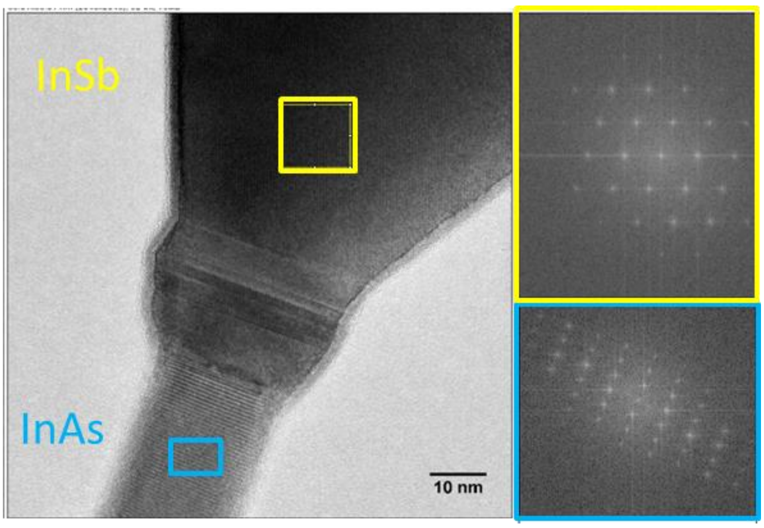

Fig. 2: High-resolution TEM image and the corresponding FFT of selected portions of the InSb/InAs heterostructured nanowire.

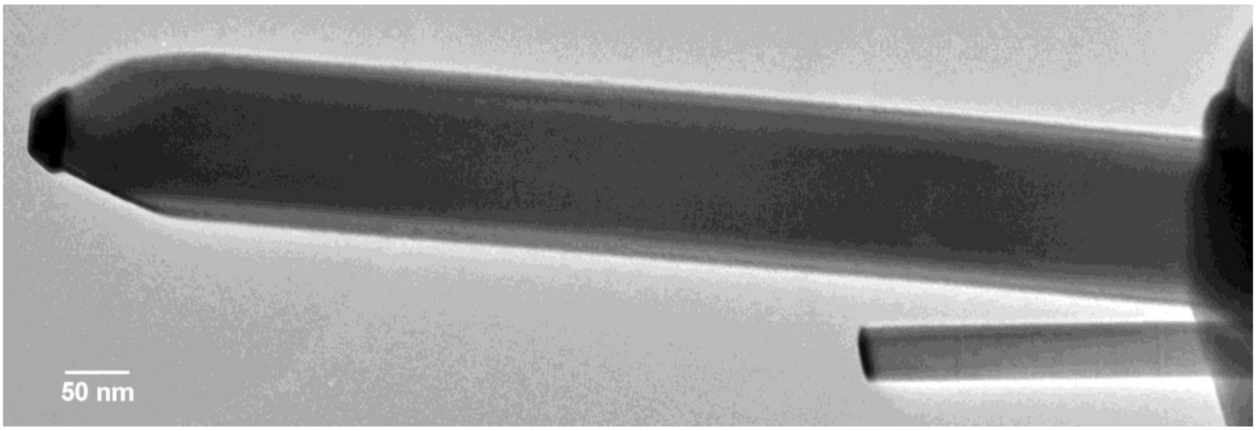

Fig. 3: TEM image of the InSb segment of a representative NW oriented in the <110> zone axis.

3. Conclusions

In the first year, the deliverable D1.1 of the WP1 “Materials Developments” was fully reached. Samples were fully characterised. Optimised samples were provided to the Chalmers partner for device fabrication and transport measurements.

4. References

[1] U. P. Gomes, D. Ercolani, V. Zannier, F. Beltram, and L. Sorba, Controlling the diameter distribution and density of InAs nanowires grown by Au-assisted methods, Semicond Sci Tech 30, 010301 (2015).
[2] D. Ercolani, F. Rossi, A. Li, S. Roddaro, V. Grillo, G. Salviati, F. Beltram, L. Sorba, InAs/InSb nanowire heterostructures grown by chemical beam epitaxy, Nanotechnology 16, 505605 (2009).