Hybrid nanowire based quantum networks at atomic scale: From growth mechanisms to properties

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Nanotechnology allows modifying the structure of nanoobjects down to the atomic scale. Low dimensional quantum heterostructures can be created in a nanowire system in order to modify its properties at will, e.g.: hybrid semiconductorsuperconductor nanowire based quantum networks. The aim of these new hybrid systems is to take advantage of Majorana pairs as the building blocks for the generation of qubits, which are the fundamental units of information in quantum computation. The configuration that would suit this application the most is the interface between a semiconductor and a superconductor, and an appropriate way to build them is to arrange them in a nanowire, which creates the so-called concept of proximitized nanowires. The selected semiconductors are usually InAs or InSb, while Al is mainly used as the superconductor, due to its theoretical transition to topological phase under certain chemical potential and external applied magnetic field conditions. In fact, reaching the material's topological phase is a fundamental requirement to achieve the Majorana Zero Modes (MZMs), and for them to materialize it is mandatory to create thoroughly ordered and epitaxial heterojunctions, as well as perfectly grown materials (as well as specific requirements for each of the materials implied), that avoid the disorderbased scattering that can prevent the transition or even the failure of the topological regime. Incredible efforts are being made to avoid the so unwanted decoherence of the electrons and to directly apply the signatures of MZMs (basically conductance peaks) into real devices for quantum computing, as up to date, the total number and stability of the created qubits is not enough for a functional quantum processor. These qubits are based on binary gates that control the interaction between the Majorana pairs, and it is actually this interaction what can produce the quantum phenomenon based on the superposition of states. Indeed, in order to achieve in the future a direct observation of the theoretical properties of the MZMs, defect free, relaxed and perfectly epitaxial heterostructures are needed. In order to fulfill the above approach, several growth methodologies have been used: (1) vapour– liquid–solid (VLS) vertical nanowire growth and the posterior nanowire nanopositioning and contacting into the selected circuits, (2) VLS nanowire networks grown by using trenches on etched substrates, (3) guided-growth nanowires or (4) the newly developed selected area grown nanowire networks directly epitaxed on top of the substrates.These newly developed hybrid quantum devices benefit from the new advances in growth methodologies, as mentioned above. However, in order to obtain the most outstanding conditions to achieve the MZMs we will need to assure perfect growth conditions. In the present work, we will present how an accurate knowledge on the atomic positions, down to single atom detection, may help to deeply understand the improved properties of our complex nanowire heterostructures. We will show how from scanning transmission electron microscopy (STEM) and related spectroscopies, it is possible to obtain precise 3D atomic models of our hybrid systems and understand the growth mechanisms in detail. Atomic scale strain studies will allow to observe the different relaxation mechanisms based on plastic and elastic deformations and visualize the defects induced to the nanowire structures that might be detrimental of their quantum properties. Special attention will be put on the superconductor-semiconductor heterointerface.

Biography:

Prof. Jordi Arbiol graduated in Physics at Universitat de Barcelona (UB) in 1997, where he also obtained his PhD (European Doctorate and PhD Extraordinary Award) in 2001 in the field of transmission electron microscopy (TEM) applied to nanostructured materials. He was Assistant Professor at UB. From 2009 to 2015 he was Group Leader at Institut de Ciència de Materials de Barcelona, ICMAB-CSIC. Since 2017 he is President of the Spanish Microscopy Society (SME), was Vice-President from 2013 to 2017 and since 2009 he is Member of its Executive Board. In 2018 he was elected as Member of the Executive Board of the International Federation of Societies for Microscopy (IFSM) (2019- 2026). Since 2015 he is the leader of the Group of Advanced Electron Nanoscopy at Institut Català de Nanociència i Nanotecnologia (ICN2), CSIC and BIST. He has been awarded with the 2014 EMS Outstanding Paper Award, the EU40 Materials Prize 2014 (E-MRS), listed in the Top 40 under 40 Power List (2014) by The Analytical Scientist and the PhD Extraordinary Award in 2001 (UB). He has published more than 315 papers, cited more than 11971 WoS (15525 GoS) and h-index: 62 WoK (71 GoS).

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