PhD thesis Project - 2024/2027

"Topological-superconductor group IV nanomaterials"

Context. Progress in quantum computing stems from major advances in materials science and engineering, and their integration into novel fabrication techniques to develop scalable solid-state qubits architectures. Over the last decade, a plethora of solid-state quantum devices have been developed by combining multiple materials with inherently different properties within the same device - *heterogeneous integration*. This is a significant challenge in materials science, where quantum device operation with high performance requires a very high purity of the interface between two different materials. Any structural defect and roughness at the interface could compromise the ability to detect and manipulate quantum states in solid-state devices.

Project. The goal of this thesis is to develop a scalable material platform where quantum properties can be engineered simply by tailoring the crystal structure of a single atomic element – *Tin (Sn)* – and achieve interfaces with the highest quality. Topological insulator/semimetal phases can be tailored in diamond cubic α-Sn by controlling strain,[1,2] while body-centered tetragonal β-Sn behaves as a superconductor at temperatures below 4 K.[3] Currently, a controlled switch between α/β-Sn phases is out of reach in a conventional thin film geometry. This thesis will establish the growth of defect-free one-dimensional (1D) Sn nanowires (NWs) on a Silicon wafer using a molecular beam epitaxy (MBE) system. In NWs a precise control over the growth of α/β-Sn phases (*i.e.* topological/superconductor phases) becomes possible, resulting in defect-free atomically-sharp interfaces with the highest structural quality. This will provide a truly *homogeneous integration* of multiple states of matter in solid-state quantum devices, paving the way to explore the fundamental processes in topological quantum computation,[4] spintronics,[5] and quantum photonics.[6]

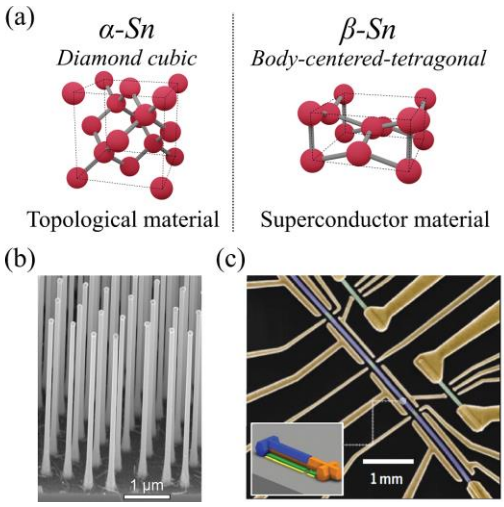

Figure: (a) Allotropes of Sn. (b) Vertical NW array. (c) Single NW quantum device.

Competences to be acquired.

(i) Epitaxial growth of Sn NW arrays using MBE and chemical vapor deposition (CVD) tools.

(ii) Structural characterization of the materials down to the atomic-level.

(iii) Fabrication of single NW devices in a cleanroom facility.

(iv) Magneto-transport measurements of the NW device at cryogenic temperatures (<1 K).

Required skills. Background in solid-state physics and materials science, interest in performing experiments in the lab, working in a collaborative team, and contributing to international collaborations.

Starting date. By the 1st October 2024.

Funding. The thesis was funded for its entire duration (3 years).

Supervisor. Dr. Simone Assali (CEA-IRIG/PHELIQS, Grenoble).

Further reading.

1. Elemental Topological Insulator with Tunable Fermi Level: Strained α-Sn on InSb(001).
2. Revisiting the physical origin and nature of surface states in inverted-band semiconductors.
3. Dramatic enhancement of superconductivity in single-crystalline nanowire arrays of β-Sn.
4. Topological Quantum Computation - From Basic Concepts to First Experiments.
5. Switching of a Magnet by Spin-Orbit Torque from a Topological Dirac Semimetal.
6. Josephson junction infrared single-photon detector.

APPLY NOW!

To apply for this position, send your application (CV, motivation letter, and transcripts) by e-mail to: simone.assali@cea.fr.

French Commission for Atomic Energy and Alternative Energies
Interdisciplinary Research Institute of Grenoble
Quantum Photonics, Electronics and Engineering Laboratory
17 av. des Martyrs – 38054 Grenoble cedex 9 – France