NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2021-2022

Tailoring superconductivity in two-shells superconductor-semiconductor nanowires

General Scope : Controlling and manipulating topological superconductivity[1] can lead to the creation of a new generation of quantum bits, called topological quantum bits, that are more robust to decoherence than traditional quantum bits. One solution to create topological superconductivity is to combine a superconductor with a one-dimensional semiconductor having a large spin-orbit coupling. Superconductivity in the semiconductor appears via the proximity effect and so far, the most studied systems have been Al/InAs and Al/InSb core-shell nanowires. Yet, magnetic fields are necessary to create topological quantum bits and because of its low critical field, Al is not a good choice. New combinations of materials[2] are currently emerging including Sn and Pb. Yet, induced superconductivity in the semiconductor can be too strong with Sn and Pb. In order to mitigate this effect, high quality tunnel barriers are envisaged, preferentially lattice matched with the semiconductor nanowire.

Research topic and facilities available : The objective of the internship is to explore the properties of two-shells superconductor-semiconductor nanowires using the InAs-ZnTe(CdSe)-superconductor system. Two-shells nanowires are very novel, as previously only one-shell nanowires were explored. This will be realized through (1) the preparation of InAs nanowires wrapped with ZnTe(CdSe) shells using a molecular beam epitaxy reactor and (2) the fabrication and transport characterization of two-shells nanowire devices in a low temperature setup. The work consisting in growing the nanowires will take place at CEA-IRIG where molecular beam epitaxy reactors are available within the joint CEA/CNRS NPSC team. Fabrication of the devices will take place at Institut Néel at the Epitaxy platform and the Nanofab cleanroom facility. Transport measurements in a dilution fridge will take place in collaboration with the QNES team at Institut Néel.

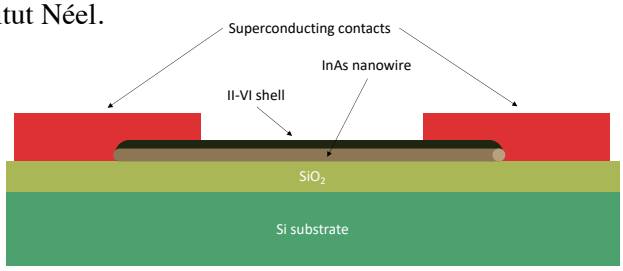

Figure1. Example of a two-shells nanowire device designed for the study of topological superconductivity

[1]S.M. Frolov, M.J. Manfra, J.D. Sau *Topological superconductivity in hybrid devices* Nat. Phys. 16, 718–724 (2020)
[2]M. Pendharkar, B. Zhang, H. Wu, A. Zarassi, P. Zhang, C. P. Dempsey, J. S. Lee, S. D. Harrington, G. Badawy, M. Rossi, R. op het Veld, S. Gazibegovic, J. Jung, A. -H. Chen, M. A. Verheijen, M. Hocevar, E. P. A. M. Bakkers, C. J. Palmstrøm, S. M. Frolov. *Parity-preserving and magnetic field resilient superconductivity in indium antimonide nanowires with tin shells* Science 372 508 (2021)

Possible collaboration and networking : Collaboration with USA (University of Pittsburgh, Carnegie Mellon University, UCSB) and The Netherlands (TU/Eindhoven) via the NSF/ANR HYBRID project. The intern will work closely with the PhD students of the international collaboration through his/her participation in regular meetings and discussions.

Possible extension as a PhD : Yes

Required skills: Interest in performing experiments in the lab (materials growth, fabrication of devices and measurement), background in solid-state physics and nanotechnologies.
Starting date : Beginning of 2022

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