MMPS20 "Hybrid superconductor-semiconductor nanostructures"

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Lien avec GDR ou autres structures : GDR Pulse (croissance épitaxiale), réseau Nanofils (anciennement GDR Nanofils), GDR Physique Quantique Mésoscopique, NSF-ANR PIRE HYBRID

Résumé : Very recently, the National Science Foundation in the United States has funded a 25M$ Quantum Foundry, a center for development of materials for quantum information-based technologies [0], while the European Union has launched a “Quantum Flagship”. These efforts, which are echoed by major investments from Google, IBM, Intel, Microsoft [1] and other industry giants, set as their goal the realization of a quantum computer which would unlock revolutionary computing powers based on the principles of quantum superposition and entanglement. However, any computer is only as good as the materials it is built from: for instance, the success of classical computers is due to the remarkable materials properties of silicon which forms the foundation of CMOS technology. Due to the inherent fragility of quantum information, the materials requirements for quantum computers are more stringent than for classical computers [2]. Furthermore, new physical phenomena may need to be discovered and mastered before a practical quantum computer can be built [3]. The motivation of this mini colloquium is to gather the community of researcher developing new hybrid materials and searching for emergent phenomena that can only be realized at hybrid interfaces. Hybrid materials are those which combine layers of dissimilar material classes, such as superconductors and semiconductors [4]. This interdisciplinary colloquium focuses on a diverse universe of hybrid materials including nanowires [5], van der Waals heterostructures [6] and two-dimensional epitaxial interfaces (Figure 1). The different research areas that cover the colloquium will extend from in-situ observation of crystal growth to low temperature measurements of quantum devices based on these materials, guided by first-principles and mesoscopic theory studies.

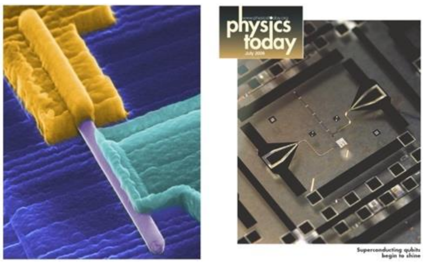

Figure 1. Left: device used to experimentally study Majorana bound states [7]. Semiconductor nanowire (purple) is covered by a superconductor (cyan). Right: superconducting qubit device [8].

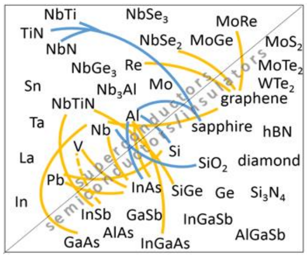

Figure 2: **The super-semi materials universe:** Materials to be considered for superconducting (blue lines) and topological qubits (orange lines).

The actors involved in the development of hybrid materials and in the study of quantum devices belong to different geographical areas in France: LAAS in Toulouse develops topological nanostructures based on BiSb, Néel and CEA in Grenoble develops epitaxial superconducting layers on nanowires, in-situ TEM and have a strong expertise in low temperature electronic properties of these hybrid S/N nanostructures. CEA and LPS at Paris-Saclay have also been very much involved in the exploration of new states of matter provided by superconducting hybrids. Theory of the mesoscopic aspects of hybrid systems is developed both in Grenoble, Saclay, Bordeaux. In addition, the French community has strong collaborations with the US, Microsoft Sation Q in Copenhaguen. Scuola Normale Pisa, etc… We aim at gathering between 30 and 40 people during the colloquium.

Références : [1] A Quantum Leap https://www.news.ucsb.edu/2019/019626/quantum-leap [2] Markoff, J. “**Microsoft Spends Big to Build a Computer Straight Out of Science Fiction**” *The New York Times* Nov 21, (2016): B4. [3] Eckstein, J. N. and Levy, J. “**Materials Issues for Quantum Computation**” *Mrs Bulletin* 38, no. 10 (2013): 783–789. doi:10.1557/mrs.2013.210. [4] Stern, A. “**Non-Abelian States of Matter**” *Nature* 464, no. 7286 (2010): 187–193. doi:Doi 10.1038/Nature08915. [5] Franceschi, S. De, Kouwenhoven, L., Schönenberger, C., and Wernsdorfer, W. “**Hybrid Superconductor–quantum Dot Devices**” *Nature Publishing Group* 5, (2010): doi:10.1038/nnano.2010.173. [6] Bakkers, E. P. A. M., Borgstrom, M. T., and Verheijen, M. A. “**Epitaxial Growth of III-V Nanowires on Group IV Substrates**” *Mrs Bulletin* 32, no. 2 (2007): 117–122. [7] Geim, A. K. and Grigorieva, I. V. “**Van Der Waals Heterostructures**” *Nature* 499, no. 7459 (2013): 419–425. doi:10.1038/nature12385. [8] Mourik, V., Zuo, K., Frolov, S. M., Plissard, S. R., Bakkers, E. P. A. M., and Kouwenhoven, L. P. “**Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices**” *Science* 336, no. 6084 (2012): 1003–1007. doi:DOI 10.1126/science.1222360. [9] “**Superconducting Qubit Systems Come of Age**” *Physics Today* 62, no. 7 (2009): 14–16. doi:10.1063/1.3177215