Topic Thesis 2015

November 2014

CEA Grenoble (France) – thèse au CEA-LETI
Duration : 3 years

"Spintronics on silicon : conception, realization and characterization of devices for the quantum computation"

The sudent should have good knowledge in quantum mechanics, mesoscopic transport, solid-state physics and physics of semiconductor.

The LETI environment

A unique scientific, industrial and cultural environment, with its research centers, university campus, 500 foreign companies and 40,000 scientists, engineers and technicians employed in the area, the Grenoble-Isère region, otherwise known as France's Silicon Valley, mixes world-class intellectual and scientific dynamism with exceptional quality of life. It is the ideal springboard for Leti's expansion.

Located in the heart of a unique scientific, industrial and cultural environment, the CEA-Leti Institute for micro- and nanotechnology research offers researchers alike a rewarding place to work. You will grow in an environment where the scientific community is passionately engaged in technological research: men and women who are ready to share their expertise with you in your scientific and professional development. From technologies to applications, Leti is a world leader in the creation and transfer of innovation within Europe. With 1,400 patents, its intellectual property portfolio is unusually rich for a research institute.

With Minatec, Leti boasts a concentration of resources that is unrivalled in Europe. An international benchmark in micro- and nanotechnology, the Minatec campus is home to state-of-the-art infrastructure and equipment that is available to every researcher working at Leti. Leti's special place in the global research community is partly due to its natural surroundings in the heart of the French Alps, which offer an excellent quality of life. Leading experts who have been attracted to this natural environment have helped Leti form its mutually rewarding industrial alliances that provide students an unmatched learning experience (***http://www-leti.cea.fr/en).***

Thesis project description

Progress achieved in the field of microelectronics during the past half-century has essentially relied on silicon (Si) technology development. Following several decades of research and the introduction of novel materials (*e.g.* high-κ dielectrics and metal gate) in order to meet requirements in terms of performance and power consumption, CMOS technological platforms remain Si-based to this day.
Over the course of the last few years, it was shown that silicon and silicon-germanium alloys (SiGe) could be suitable material candidates for studying new generations of quantum electronics devices. By analogy with classical electronics, the quantum bit (*qubit*) is the fundamental building block for quantum computing[1]. As opposed to conventional computing for which a bit can only carry one among two possible logic states (0 or 1), the *qubit* is a superposition of the |0> and |1> eigenstates, thus considerably increasing the information processing capability. Various physical systems are currently being studied in order to create *qubits*. A promising approach, based on silicon technology, consists in encoding quantum information within the spin state of strongly confined electrons (an electron under a magnetic field naturally forms a two-state quantum system derived from the two opposite spin directions, parallel and anti-parallel to the field). The spin presents the advantage of a relatively low coupling to electromagnetic noise, hence enabling long-lived quantum coherence. Achieving control over coupling between the *qubits* themselves remains one of the major challenges in fabricating a quantum computer. To this end, the versatility in circuit design and fabrication inherited from the microelectronics industry is a major asset.

The proposed PhD project will firstly consist in carrying out a state-of-the-art review of design and integration schemes currently implemented for fabricating *spin qubits*, in order to reach a thorough understanding of their operation, advantages and limitations. Building on the basis of a solid grasp of the physical mechanisms at stake in such structures, novel integration schemes aiming at improving their characteristics will be investigated. To this purpose, the student will fully benefit from the silicon technological platform at CEA-LETI, and from the maturity of technological processes used nowadays in microelectronics. Advanced lithography techniques and reticles used for the fabrication of “SETs” (Single Electron Transistors) and “electron pumps” will be leveraged for developing these novel devices. Quantum devices fabrication will be carried out in close partnership with the platform and will benefit from the *nanowire* technology developed at CEA-LETI (currently used for SETs fabrication). This work will take place within the Silicon Components Division at CEA-LETI, Advanced CMOS Integration Laboratory, in very close partnership with the LaTEQs (Laboratory of Quantum Electronic Transport and Supraconductivity) at CEA-INAC.

Sylvain Barraud
CEA, LETI, Minatec Campus
17, rue des Martyrs, 38054 Grenoble
Tel. : (33) 4 38 78 98 45
e-mail: sylvain.barraud@cea.fr

Marc Sanquer
CEA, INAC-SPSMS
17, rue des Martyrs, 38054 Grenoble
Tel. : (33) 4 38 78 43 67
e-mail: marc.sanquer@cea.fr

[1]D.Loss and D.P. DiVincenso, “Quantum computation with quantum dots”, Phys. Rev. A, 57, 120 (1998)