Ferroelectric memcapacitor functionality in a cryogenic environment

Record number : OPR-1427

Overview

RESEARCH DIRECTION

Dominique Drouin, Professeur - Department of Electrical and Computer Engineering

INFORMATION

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ADMINISTRATIVE UNIT(S)

Faculté de génie
Département de génie chimique et de génie biotechnologique
Département de génie électrique et de génie informatique
Département de génie mécanique
Institut interdisciplinaire d'innovation technologique (3IT)
Institut quantique

LEVEL(S)

3e cycle

LOCATION(S)

3IT - Institut interdisciplinaire d'innovation technologique
Institut Quantique Sherbrooke

Project Description

Context: Recent advances in quantum computing have demonstrated the potential of several hardware platforms, ranging from superconducting circuits to spin‑based qubits implemented in silicon or germanium quantum dots. The latter approach is particularly attractive because it builds directly on mature CMOS technologies, offering a realistic pathway toward cost‑effective, compact, and industrially scalable quantum processors.
However, the large‑scale integration of semiconductor qubits is currently limited by the complexity of cryogenic control. The high number of control lines, power dissipation, and manual tuning procedures represent major bottlenecks for the deployment of thousands of qubits on a single chip. Overcoming these limitations requires integrating adaptive control and tuning functionalities directly in the cryogenic environment, while preserving CMOS compatibility and ultra‑low power consumption.
In this context, $HfZrO_2$ (HZO)‑based ferroelectric memcapacitors emerge as a highly promising technology. Their non‑volatility, analog tunability, and compatibility with advanced industrial processes make them strong candidates for fully integrated, compact, and scalable cryogenic control electronics. Nevertheless, their operation, performance, and reliability in the deep‑cryogenic regime relevant to quantum computing remain to be experimentally demonstrated.

Research project: The aim of this thesis is to study the operation of ferroelectric memcapacitors in a cryogenic environment and to evaluate their potential for the control and tuning of semiconductor qubits. The objective is to demonstrate that these non volatile, analog tunable, and low power components can constitute a key technological building block for cryogenic integrated control electronics, which is essential for scalable quantum computing.

Supported by the expertise of 3IT and the Institut Quantique (IQ), the recruited candidate will be responsible for:

(i) Designing and fabricating cryogenic‑compatible $HfZrO_2$ ferroelectric memcapacitors, including single devices and crossbar arrays, with the integration of superconducting electrodes (TiN, NbN) to improve signal integrity and scalability;
(ii) Carrying out the associated micro‑ and nanofabrication processes (lithography, dry etching, passivation), as well as physico‑chemical and morphological characterizations (AFM, SEM, TEM) to validate device quality and stability;
(iii) Performing comprehensive electrical characterizations at room temperature and in a deep‑cryogenic environment (down to ~20 mK), including the study of capacitive hysteresis, retention, endurance, analog programmability, and noise sources;
(iv) Analyzing the impact of superconducting interconnects on memcapacitor performance and reliability, and assessing their potential for impedance matching and semiconductor qubit control.

At the end of this PhD, the candidate will have demonstrated fully functional ferroelectric memcapacitors operating in the cryogenic regime, thereby laying the foundations for compact, integrated, and scalable control electronics for next generation semiconductor quantum processors.

Supervision & work environment: The project will be realized under the direction of Pr. Dominique Drouin. The work will be carried out mainly at the Interdisciplinary Institute for Technological Innovation (3IT) and at the Quantum Institute (IQ) of UdeS. 3IT is a unique institute in Canada, specializing in the research and development of innovative technologies for energy, electronics, robotics and health. The IQ is a state-of-the-art institute whose mission is to invent the quantum technologies of tomorrow and transfer them to the industry. The student will thus benefit from an exceptional research environment that combines students, professionals, professors working hand-in-hand to develop the future technologies for AI and QC.

Researched profile:
• Specialization in nanotechnology, electrical engineering, or materials science
• Strengths: knowledge in nanofabrication, resistive memories, in-memory computing, cryogenic measurements
• Excellent adaptability, autonomy, teamwork and problem solving skills
• Strong interest for design, experimental cleanroom work and interdisciplinary research and development
• Fluent in French and English

Documents to provide to inpaqt@usherbrooke.ca: Letter, CV, list of publications and references

Discipline(s) by sector

Sciences naturelles et génie

Génie chimique, Génie électrique et génie électronique, Génie mécanique

Funding offered

To be discussed

The last update was on 30 June 2026. The University reserves the right to modify its projects without notice.