Tailoring Novel Group IV Quantum Material Heterostructures

Mathieu Turmel[1]
M. Giacoia[1], V. Schmitt[1], E. Rahier[2], S. Koelling[2], N. Pauc[1], V. Calvo[1], O. Moutanabbir[2], S. De Franceschi[1], S. Assali[1].

[1] Université Grenoble Alpes, CEA, Grenoble INP, IRIG, PHELIQS, 38000 Grenoble, France
[2] École Polytechnique de Montréal, Department of Engineering Physics, Montréal, Québec, Canada

mathieu.turmel2@cea.fr

Superconductor/semiconductor hybrid junctions are widely used in superconducting and topological qubits. Developing epitaxial superconductor/ semiconductor interfaces using Molecular Beam Epitaxy (MBE) at cryogenic temperatures has increased the transparency of the Josephson junction and led to hard superconducting gaps and large critical currents.[1] Superconducting Al epitaxially-grown on InAs/InGaAs QWs enabled the first demonstration of electron-based gatemon qubits. Another key example is Tin in the tetragonal β phase (β-Sn), which displays higher critical temperature (3.7 K) and larger superconducting gap (600 μeV) than Al when it is epitaxially-grown by cryogenic MBE around InSb and InAs nanowires.[2]

Here, we take the initial steps in the development of the first all-group-IV gatemon qubit where superconducting β-Sn contacts are epitaxially-grown on a Ge/SiGe QW on Si. In recent years, hole-based Ge gatemons [3] and spin qubits [4] have shown promising features for large scale integration using a CMOS-compatible fabrication approach.

In this talk, we will discuss the epitaxial growth of β-Sn on a Ge (100) wafer using MBE. By carefully optimizing the growth parameters, we achieve epitaxial β-Sn islands with lateral sizes typically ranging from 20 to 200 nm, and thicknesses typically in the 10 to 50 nm range. Transmission electron miscroscopy (TEM) and in-plane X-Ray Diffraction (XRD) measurements will be discussed to demonstrate that the epitaxial orientations of the β-Sn islands match the Ge substrate. In addition, we will discuss the MBE growth of Ge/$Si_{0.2}Ge_{0.8}$ QW on a Ge (100) wafer as a promising material system to reduce the threading dislocations density and improve hole mobility.[4] Strategies for the fabrication of JoFETs-based gatemons using β-Sn/Ge QWs will also be discussed.

References

[1] Shabani, J. et al., Phys. Rev., B 93, 155402 (2016).
[2] Pendharkar, M. et al., Science, 372, 508–511 (2021).
[3] Kiyooka E. et al., Nano Lett. 25, 562-568 (2025).
[4] Stehouwer L. E. A. et al, Appl. Phys. Lett. 123 (2023) 092101.

Figure

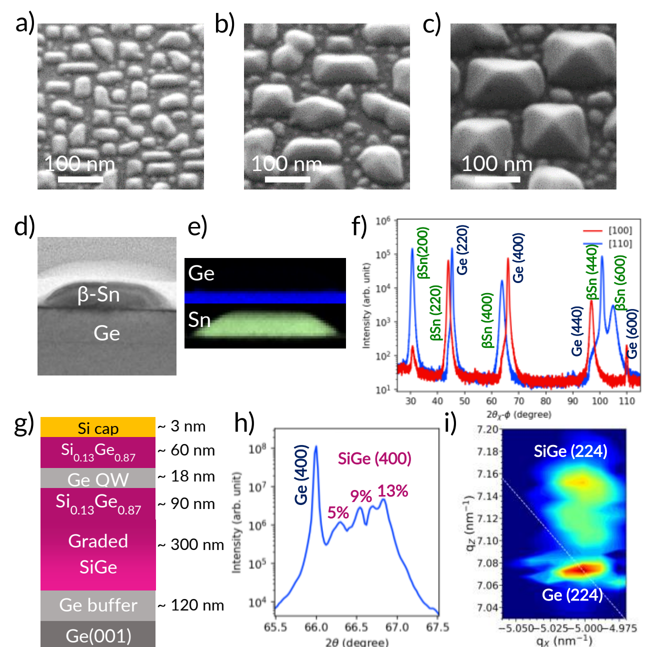

Figure 1: (a-c) MBE-grown β-Sn islands on Ge (100). (d-e) TEM-EDX images. (f) In-plane XRD acquired along the Ge [100]-[110] directions. (g) MBE-grown Ge/SiGe QW on Ge. (h-i) XRD scan and Reciprocal Space Mapping of Ge/SiGe QW.