

Sn-enabled tunable hole spin group IV heterostructures

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In recent years, direct band gap GeSn semiconductors have gained major attention for the monolithic integration of infrared emitters and detectors on a Si wafer.[1] A variety of GeSn infrared sensing and imaging technologies are now being developed using industrial-compatible fabrication processes. In addition to the high potential for integration in photonic technologies, GeSn quantum materials have been proposed for the design of novel solid-state qubits architectures.[2-3] Tensile-strained Ge/GeSn quantum wells (QWs) grown on a Si wafer result in a confined 2D hole gas with light-hole (LH) states lying above the heavy-hole (HH) ones. The LH-based nature of the Ge/GeSn QW is in striking difference with canonical Si/SiGe and Ge/SiGe QWs where electrons and HH are confined, respectively.[4] Achieving LH confinement paves the way to engineering ultrafast gate-defined spin qubits and integrate them into a spin-photon interface by leveraging the direct band gap absorption in the Ge/GeSn QW. Scalable all-group IV semiconductor quantum devices will thus be at reach by using the existing large-scale Si manufacturing processing.

In this presentation, we will discuss the epitaxial growth of Ge/Ge_{0.86}Sn_{0.14} QWs using a CVD reactor, reaching sharp interfaces and in-plane biaxial tensile strain up to 1.65%. [2] Coherent QW epitaxial growth with a Ge layer thickness in the 1.5-12 nm range will be discussed by combining TEM and XRD

measurements. Atom probe tomography (APT) measurements will be shown to precisely probe the sharpness of the Ge/GeSn interfaces and to show the absence of impurities in the QW down to the atomic level. Spectroscopic ellipsometry (SE) measurements will be discussed to demonstrate LH confinement in the Ge/GeSn QW. The effect of strain and thickness of the QW on the excitonic optical transitions identified by SE will provide clear signature of LH confinement. The integration of Ge/GeSn QW in practical LH qubits devices will be further motivated through eight-band $k\cdot p$ simulations of the g factor anisotropy, dipole moment, and spin-orbit interaction as a function of the QW parameters and external magnetic fields.[3,5] Lastly, strategies to engineer HH spin qubits using GeSn/Ge QWs will be discussed to enrich the available architectures for solid-state qubits on Si.[6]

References

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Figures

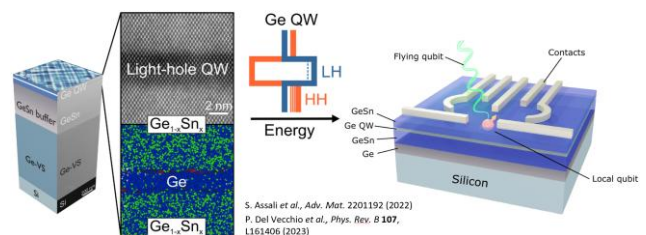


Figure 1: Optically-active LH qubit on Si.