MBE-grown Ge-rich nanosheets on silicon-on-insulator as a planar platform for nanoelectronic devices

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Heteroepitaxial layers comprising crystalline stacks of Group-IV alloys, predominantly SiGe, have been employed to enhance the operational efficiency of Si-based devices [1]. However, achieving defect-free pseudomorphic (Si)Ge layers on Si(001) substrates with high Ge compositions ($x \gtrsim 50\%$) poses significant challenges due to strain-induced relaxation beyond a layer thickness of a few monolayers [2].

This study explores molecular beam epitaxy (MBE) growth at ultra-low temperatures (ULT), ranging from 100°C to 350°C, departing from conventional epitaxy temperatures >500°C. Reduced surface kinetics in ULT conditions leads to notable layer supersaturation, allowing for the growth of thicker pseudomorphic layers than previously achieved [3]. We show that maintaining pristine growth pressures at the lower end of the ultra-high-vacuum range ($<3\cdot10^{-10}$ mbar) is crucial to minimizing impurities and preserving superior electrical and optical properties of the heterostructures. This is particularly true during ULT growth, where a limited thermal budget hampers efficient gas desorption.

Here, we show that combinig ULT and excellent growth pressures enables the fabrication of high-quality, fully strained, defect-free (Si)Ge epitaxial layers directly grown on Si and silicon-on-insulator (SOI) substrates. These layers exhibit remarkable structural qualities, as confirmed by Atomic Force Microscopy (AFM), X-ray diffraction (XRD) and transmission electron microscopy (TEM) experiments [3]. Furthermore, these nanosheets serve as a scalable platform for advanced multi-functional SiGe and Ge-based transistors such as reconfigurable field-effect transistors, capable of run-time switching between n-type and p-type operation, exhibiting outstanding performance for adaptive electronics [4], [5]. For these devices, high-resolution TEM reveals sharp and reproducible interfaces with single-element crystalline Al contacts formed through a thermally induced Al-$Si_{1-x}Ge_x$ exchange reaction [6]. The precisely chosen (Si)Ge channel stoichiometry and abrupt interfaces contribute to exceptional symmetric I-V operability in RFET devices, as observed in their transfer characteristics [4].

References

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