3D Atomistic Mapping In Group-IV Ultrathin Silicon Germanium Superlattices

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Abstract

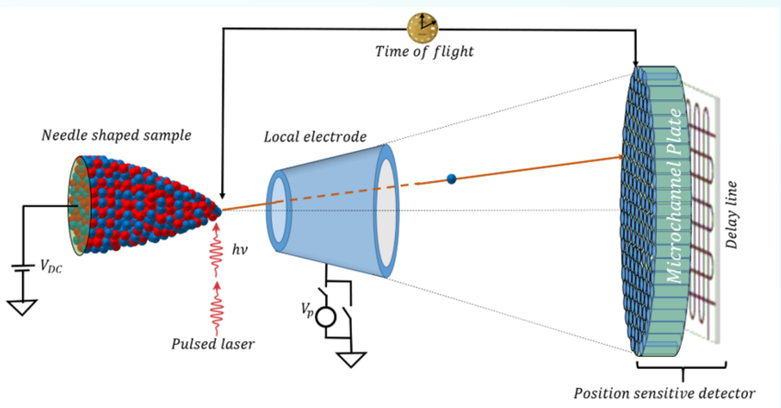
This work describes the atom probe tomographic and cross-sectional transmission electron microscopic investigation on the crystal quality and interfacial parameters of a variety of Si/SiGe ultrathin superlattices. The superlattices of various periodicities and thicknesses were grown using chemical vapor deposition process.

Motivation

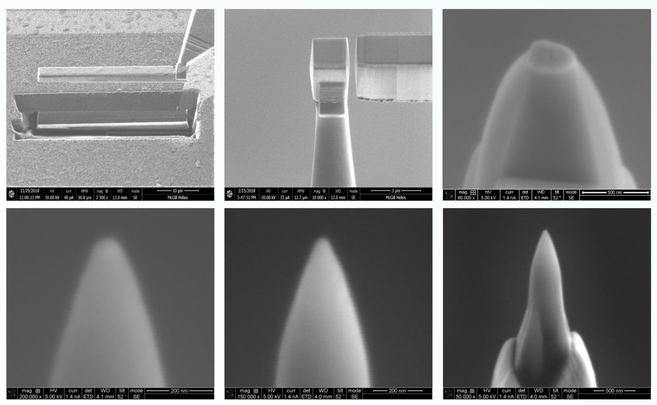
- Si/SiGe-based heterojunctions and superlattices form the core of several stat-of-the-art semiconductor devices from the quantum cascade lasers, resonant tunnel diodes, buried channel transistors to the most recent gate-all-around transistors [1-4]
- The nature of Si/SiGe interfaces is often the critical factor determining the performance of these devices
- A precise quantification the buried interfaces, as a function of growth condition and integration parameters is crucial for material and eventually the device performance optimization

Atom Probe Tomography

Atom Probe: Working Principles



Atom Probe: Tip Fabrication in Dual-Channel FIB



Samples

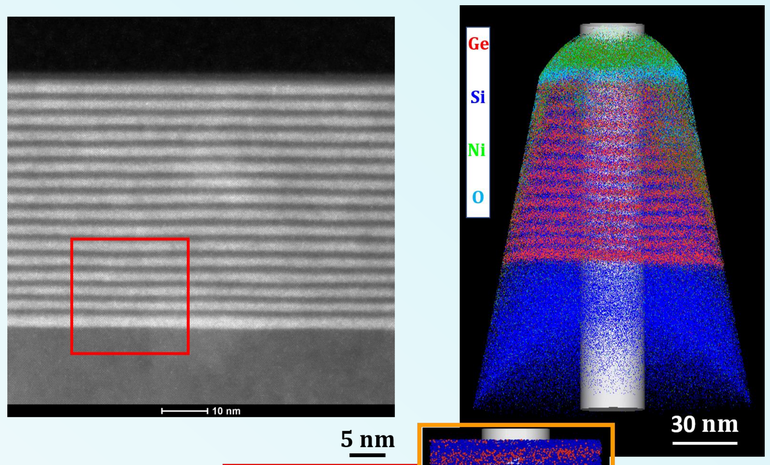
Reactor: RP-CVD; Substrate: 300 mm Si(001) wafers,
Precursors: Di-silane and Germane; Carrier Gas: Hydrogen
Temperature: 500℃ –650℃

Sample No.	Periodicity	Mean '*x*' in $Si_{1-x}Ge_x$ from APT	Mean thickness in nm from XTEM	
			SiGe	Si
S-3	3	0.307±0.004	7.3±0.2	6.0±0.2
S-6	6	0.285±0.003	5.8±0.3	4.3±0.2
S-12	12	0.255±0.003	2.6±0.2	2.0±0.1
S-16	16	0.256±0.004	2.2±0.3	1.3±0.2

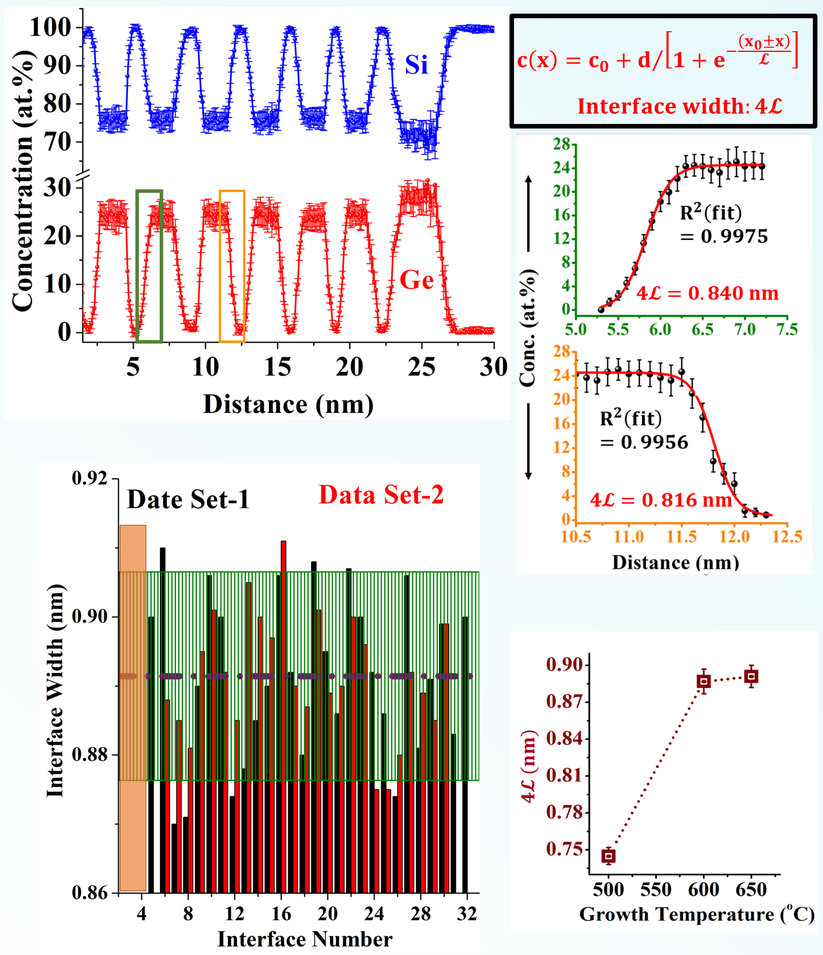
Results

XTEM and APT reconstruction

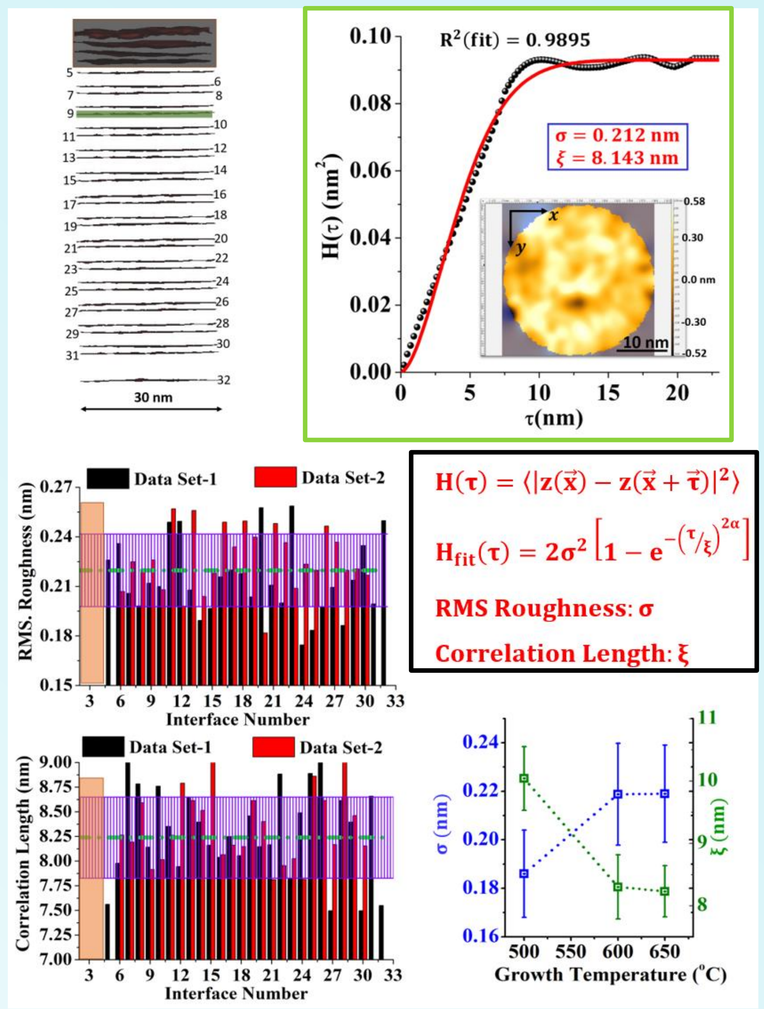
Sample S-16 (16 Period Superlattice)



Interface Sharpness



Interface Roughness and Correlation Length



Conclusion

- Interface width and interface roughness are known to be affected mainly by Ge segregation rather than bulk diffusion.
- We found the interface parameters to be the same for Si→SiGe transition and SiGe→Si transition
- The surfactant atoms (H) plays an important role in suppressing the rate of surface segregation and the surface-subsurface atom exchange processes
- The interface width increases from the samples grown at 500℃ to those done at higher temperatures (600 ℃ and 650 ℃)
- The interface rms. roughness also increases from the samples grown at 500℃ to those done at higher temperatures (600 ℃ and 650 ℃)

References

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