Sn PRECIPITATION IN CARBON IMPLANTATED SiSn LAYERS

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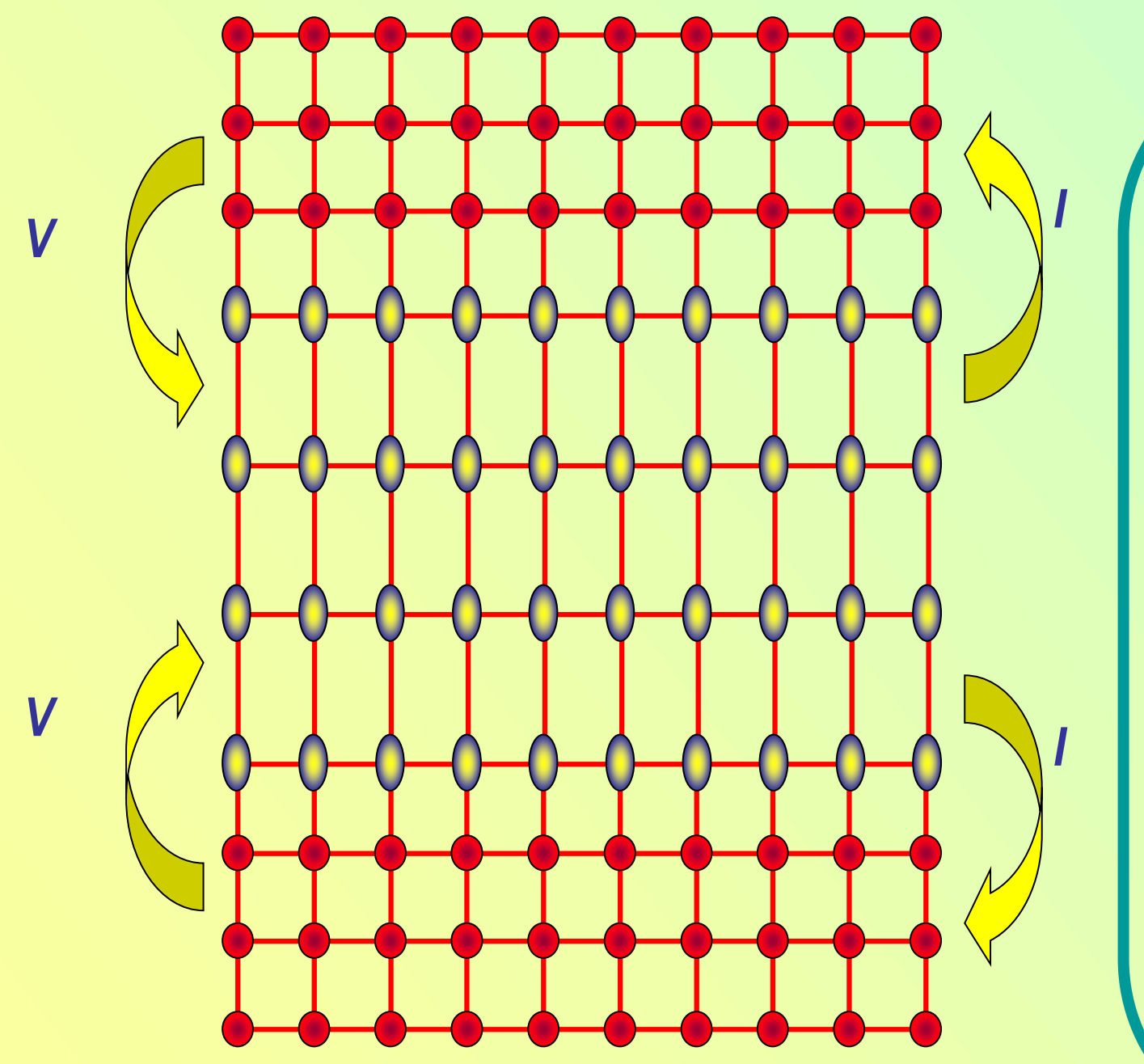
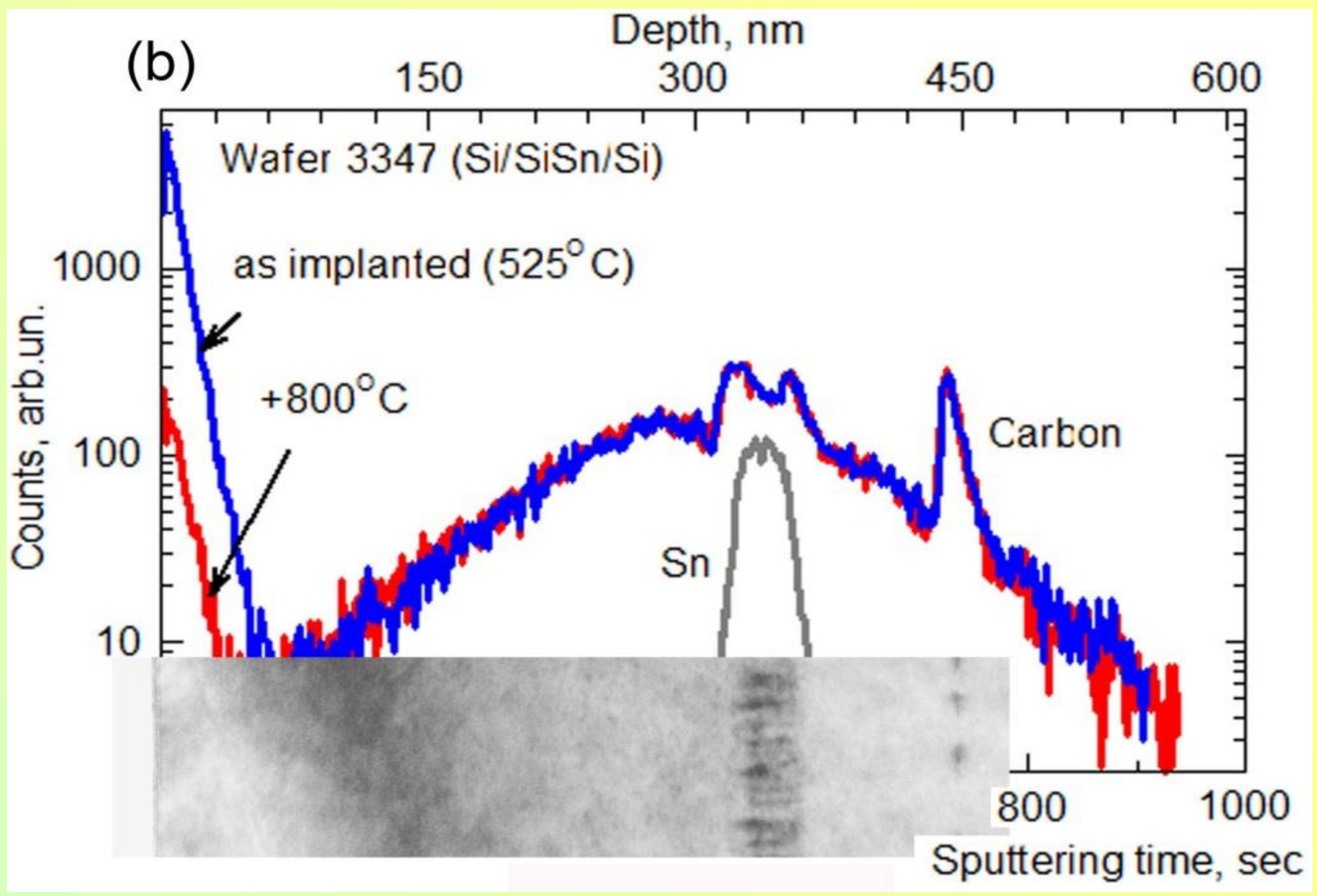
Motivation

- SiGe and SiSn alloys are attractive for advanced nano- and opto-electronic devices;
- There are potentials for strain accommodation and lattice matching because carbon leads to shrinkage and Ge (Sn) – to expansion of the Si lattice;
- Substitutional carbon (C_S) effectively trap self-interstitials;
- Ion implantation of C^+ into compressively strained SiSn or GeSn layers result in spatial separation of point defects and carbon atoms.

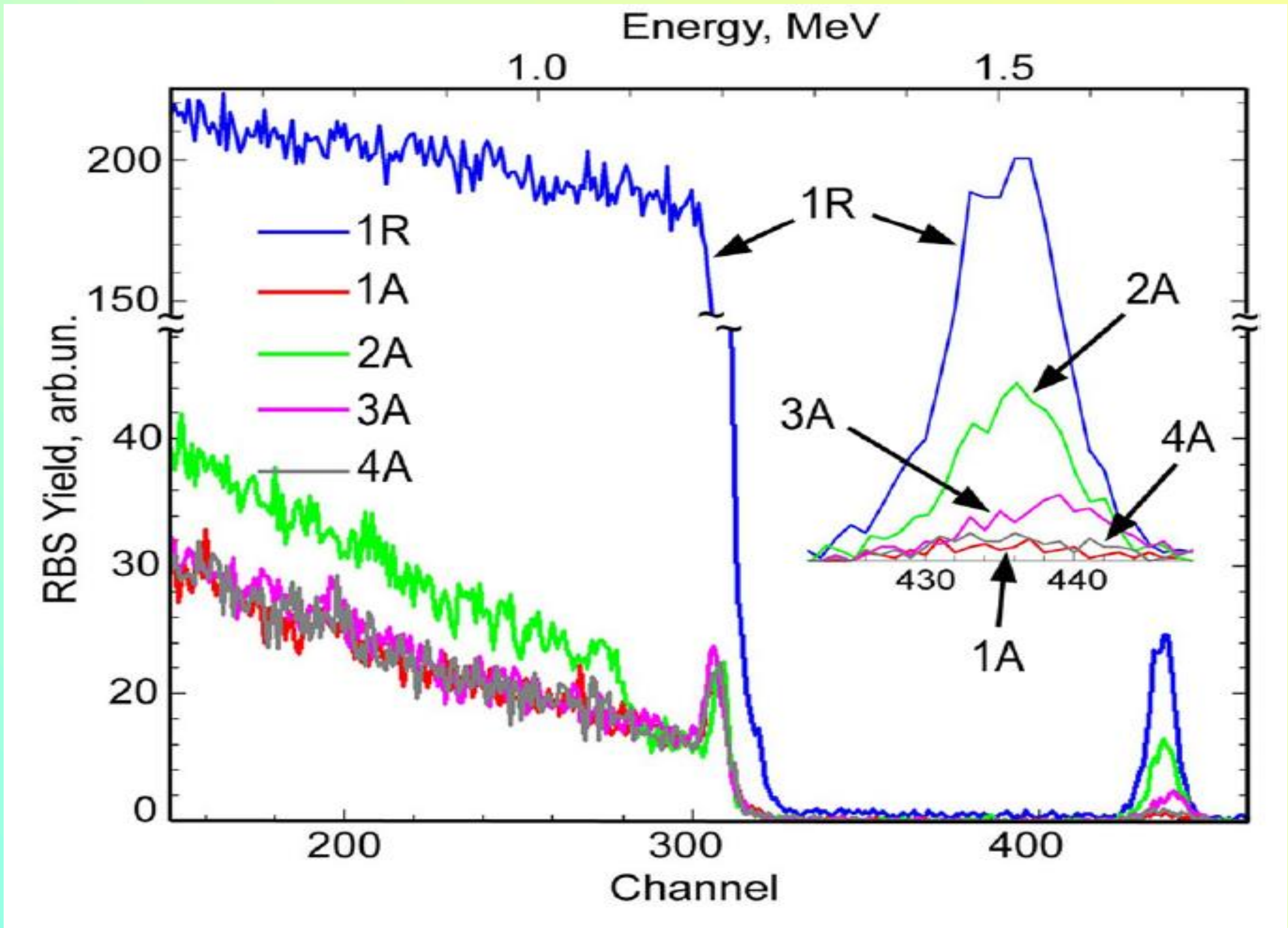


Experimental

- MBE growth of Si/(11nm $Si_{70}Ge_{30}$)/Si and Si/(30nm $Si_{98}Sn_2$)/Si structures;
- 100 keV C^+ implantation to (2-20)x10^{14} cm^{-2} at RT or at 525 ºC;
- Furnace-thermal annealing in N_2 ambient at 900 ºC for 30 min;
- Investigations: PV- and X-TEM, TED (200 kV Philips CM20 instrument), RBS/Channeling (2 MeV He^+) , Ion TOF SIMS;



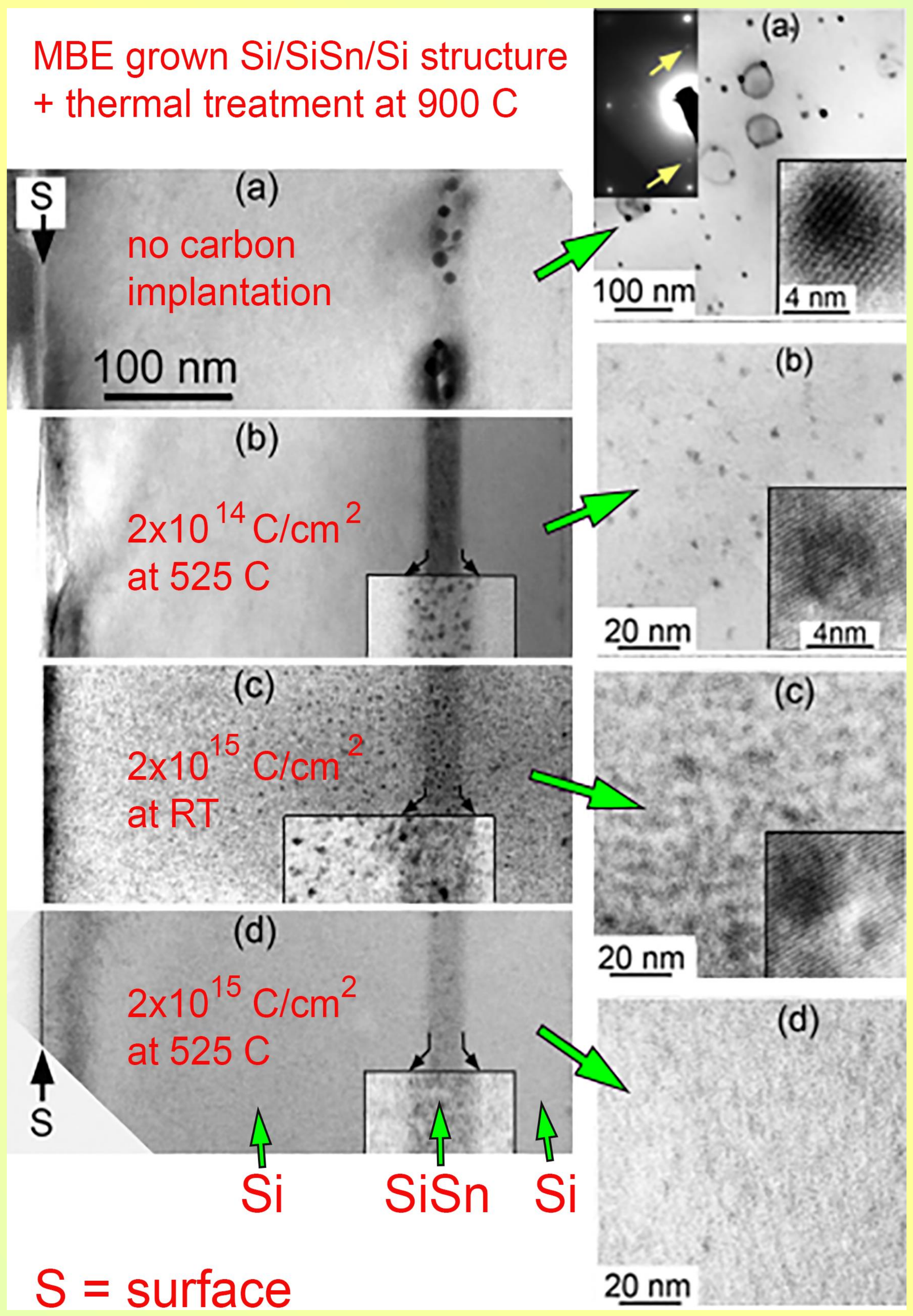
- SIMS of carbon: as implanted and after thermal treatment
- X-TEM picture of as grown sample



- Si/SiSn layered structure; RBS: R=random, A=aligned

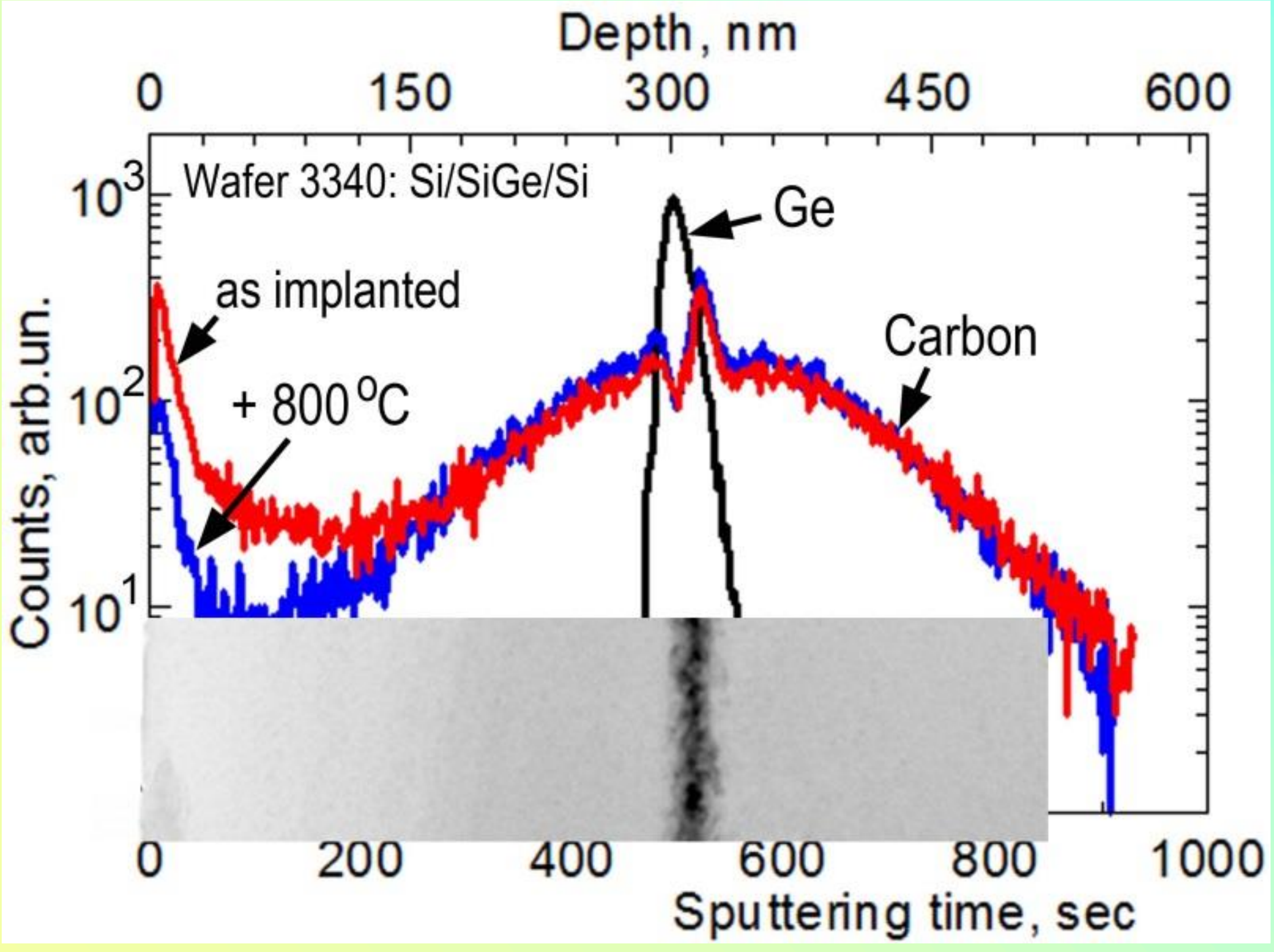
1 – as grown; 2 – MBE + 900 C, no carbon implantation;
3 – 2e14 C/cm² at 525 C +900 C;
4 – 2e15 C/cm² at 525 C +900 C

Suppression of dislocations and Sn-precipitation in SiSn

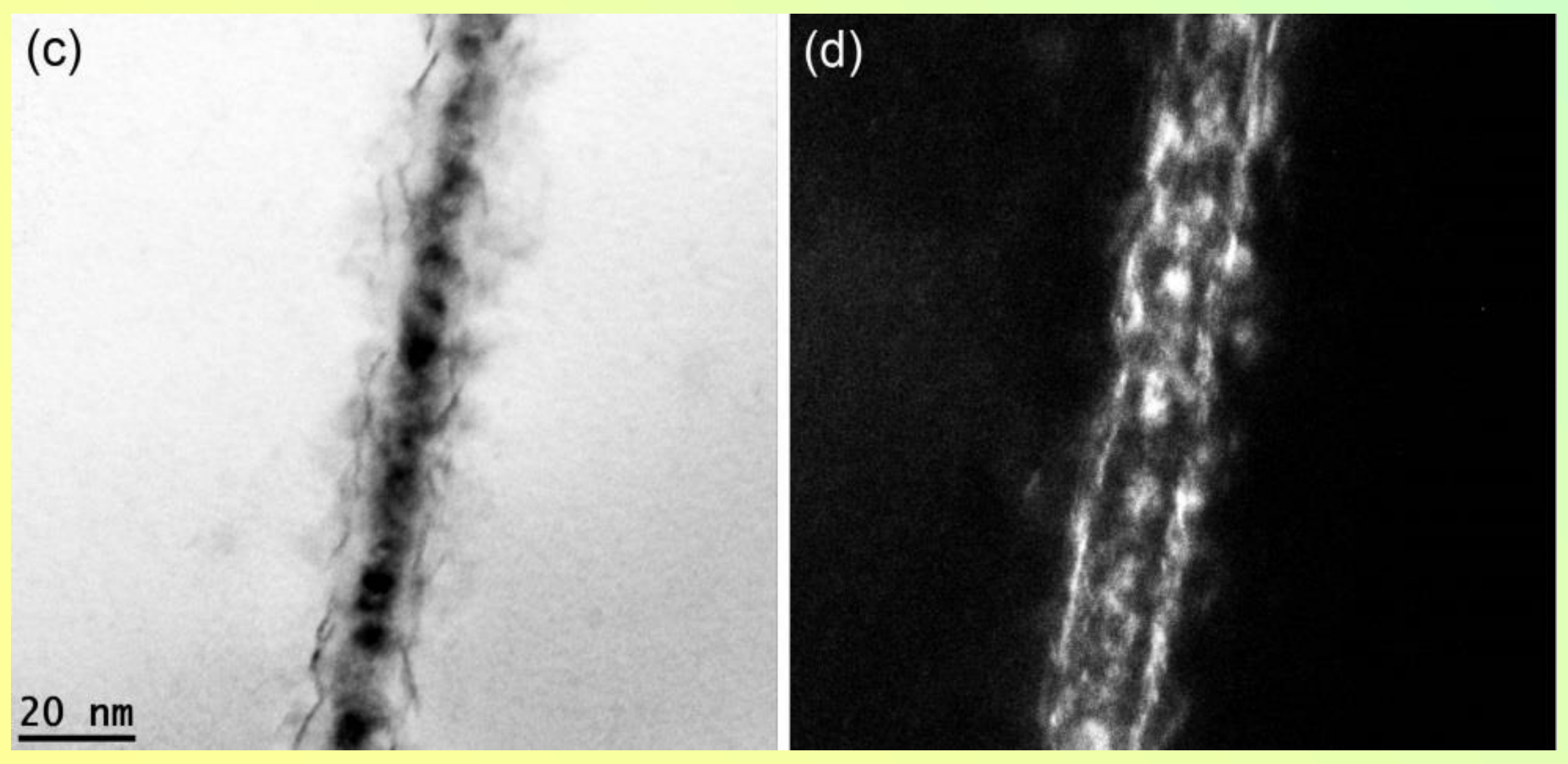


- Implanted carbon improves the thermal stability of SiSn layers, prevents dislocation loops, and suppresses Sn precipitation

Carbon flakes in mono-Si/SiGe



- Despite similar strain distribution in the Si-SiSn-Si and Si-SiGe-Si structures, carbon accumulates in the SiSn layer but is depleted in the SiGe.



- In the Si/SiGe/Si structure the formation of plate-like defects and carbon nano-flakes takes place. These defects assemble at the Si/SiGe interface.

Summary and conclusion

By combining TEM and RBS, it is identified carbon related suppression of dislocations and tin precipitation in supersaturated MBE grown SiSn alloy layers. After MBE, a set of samples were implanted with 100 keV carbon ions to fluences of 2×10^{14} or 2×10^{15} cm^{-2} at room (RT) or at high (HT = 525 °C) temperature. The mean range of the implanted carbon ions was correlated with the depth position of SiSn layer, and the implanted carbon atoms are penetrated through the whole epitaxial layer. Furnace-thermal annealing in an N_2 ambient was performed at 900 °C for 30 min: a decomposition of supersaturated SiSn layer was expected to perform. About 3×10^{10} cm^{-2} of β-Sn phase precipitates of size 8-10 nm and high density of dislocation loops are registered in the samples which were not implanted with carbon but annealed at 900 °C. Opposite effect is registered in the case of carbon implanted layers. It follows from the TEM and RBS data that the carbon implantation improves the thermal stability of SiSn supersaturated layers, prevents dislocation loops formation, and suppresses Sn segregation and precipitation. Strain-enhanced separation of point defects and formation of dopant-defect complexes are suggested to be responsible for these effects. The possibility for segregation-free high temperature growth of heteroepitaxial SiSn/Si structures is discussed. We suggest that thermally stable supersaturated SiSn alloy layers might be epitaxially grown (e.g. by MBE) via incorporation of carbon atoms either during the growth (in-situ) or by ion implantation (ex-situ).

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