Direct MBE growth of GaSb on Ge, Ge-on-Si and Ge-on-SiGe-on-Si platforms for integrated mid-infrared photonics

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Monolithically integrated mid-infrared (MIR) photonics is of major interest for free-space communications, bio-sensing, etc. While Si is transparent up to ~7 µm, longer MIR wavelengths require other materials [1]. Ge being transparent up to ~15µm, a variety of photonic integrated circuits (PICs) covering a broad wavelength range from the near-IR to the MIR has recently been developed based on Ge-on-Si and Ge-on-SiGe-on-Si waveguides with various Ge contents and composition profiles [2]. The epitaxial growth of MIR lasers on these PICs is now the missing brick to develop fully integrated active devices.

In this work, we studied the MBE growth of GaSb-based materials on various Ge-based templates grown on silicon wafers by low energy plasma enhanced CVD [3]. Similar to the growth of III-Vs on Si, the main issue is removing anti-phase domains (APDs) delineated by anti-phase boundaries (APBs), a defect detrimental to devices because they create short circuits in lasers [4].

As a preliminary step, we first investigated the growth of GaSb layers on (001) Ge substrates. We will show that the APD burying mechanism previously established for GaSb-on-Si growth, which relies on the substrate surface organization and step-flow growth of GaSb [5], also operates during growth on Ge substrates, but only when they are prepared by UHV annealing in a narrow temperature window.

Next, we studied the growth of GaSb on Ge-on-Si and on Ge-on-SiGe-on-Si relaxed-buffer layers with various Ge-composition profiles. In this case, the cross-hatch pattern on the template surfaces (Fig. 1 c)) prevents the proper surface organization prior growth for on axis (001) substrates. However, this effect can be alleviated by using slightly miscut (1°) substrates. By carefully adjusting the surface preparation and GaSb growth conditions, APB-free GaSb layers with a roughness rms as low as 1.0 nm can then be achieved on these templates (Fig. 1 b)). Such layers can be used for the direct growth of III-V lasers on germanium-based photonic platforms, and represent a further step in the development of integrated MIR photonics.

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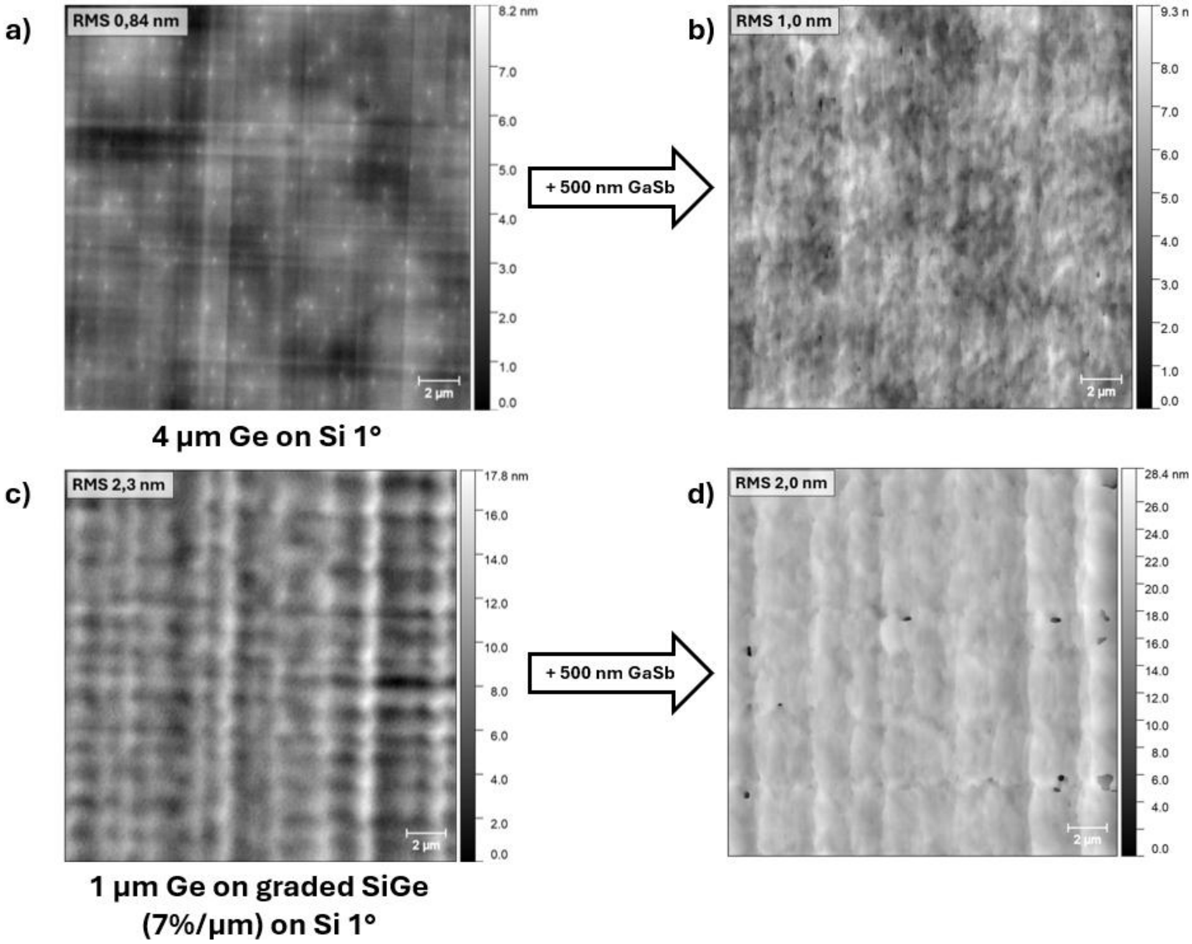

Fig. 1: AFM images of a) 4 µm of Ge template grown on Si with 1° offcut, before GaSb growth. A faint cross-hatch is visible. b) Surface after the growth of 500 nm of GaSb on template a). The surface is APB-free. c) Surface of 1 µm Ge gown on graded SiGe buffer on Si with 1° offcut, before GaSb growth. Surface roughness is due to cross-hatch patterns. d) Surface after the growth of 500 nm of GaSb on template c).