



HAL
open science

Direct growth of gasb on Ge, Ge-On-Si and SIGE-On-Si platforms for integrated MID infra-red photonics

Milan Silvestre, Audrey Gilbert, Stefano Calcaterra, Giovanni Isella,
Jean-Baptiste Rodriguez, Eric Tournié

► To cite this version:

Milan Silvestre, Audrey Gilbert, Stefano Calcaterra, Giovanni Isella, Jean-Baptiste Rodriguez, et al.. Direct growth of gasb on Ge, Ge-On-Si and SIGE-On-Si platforms for integrated MID infra-red photonics. Journées Nano, Micro et Optoélectronique (JNMO 2024), Oct 2024, Sète, France. . hal-04738104

HAL Id: hal-04738104

<https://hal.science/hal-04738104v1>

Submitted on 15 Oct 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

DIRECT GROWTH OF GASB ON GE, GE-ON-SI AND SIGE-ON-SI PLATFORMS FOR INTEGRATED MID INFRA-RED PHOTONICS

M. Silvestre^{1,2}, A. Gilbert,¹ S. Calcaterra³, G. Isella³, J-B. Rodriguez¹, and E. Tournié^{1,4*}

¹IES, University of Montpellier, CNRS, F – 34000 Montpellier, France

²RIBER SA, F – 95870 Bezons, France

³L-NESS, Politecnico di Milano Dipartimento di Fisica, I - 22100 Como Italy

⁴Institut Universitaire de France (IUF), F-75005 Paris, France

*E-mail: milan.silvestre@umontpellier.fr

SUMMARY

We study the growth of GaSb on germanium-based platforms for mid-infrared photonics. Anti-phase domain are buried in a 500 nm GaSb buffer layer on Ge and Ge-on-Si templates thanks to slightly miscut substrates or chemically-mechanically polished surfaces.

1. INTRODUCTION

Integrated mid-infrared (MIR) photonics is of major interest for free-space communications, bio-sensing, etc. III-V antimony-based lasers are efficient MIR light sources that can be grown on passive Si photonic circuits. However, most Si-based materials absorb a large part of the MIR spectrum above 8 μm , in contrast to germanium which has a wide MIR transparency window [1]. The direct growth of III-Sb materials on Ge substrates or Ge-on-Si templates would allow the development of integrated photonic circuits operating at long wavelengths (up to 14 μm). Still, III-V heteroepitaxy on group-IV substrates is plagued by various crystal defects. In particular, anti-phase boundaries (APBs) are 2D defects delineating antiphase domains (APDs). They are particularly detrimental to devices because they act as short circuits. In this work, we investigated the growth of GaSb on Ge substrates and on Ge-on-Si templates grown by low-energy plasma-enhanced CVD (LEPECVD) [2].

2. ANTI-PHASE DOMAINS BURYING

Recently, a growth strategy has been developed to bury APDs and thus suppress emerging APBs during the MBE growth of GaSb on (001) Si substrates [3,4]. It consists in using the residual miscut angle of the substrate ($<0.5^\circ$) to organize the Si surface and to grow GaSb in the step-flow mode. The anisotropic incorporation rate in III-V growth results in the Sb-polar phase progressively overgrowing the Ga-polar phase, resulting in APD burying (Fig. 1) [4]. In this work, we have adapted this strategy to the growth of APB-free GaSb layers on germanium substrates and Ge-on-Si templates.

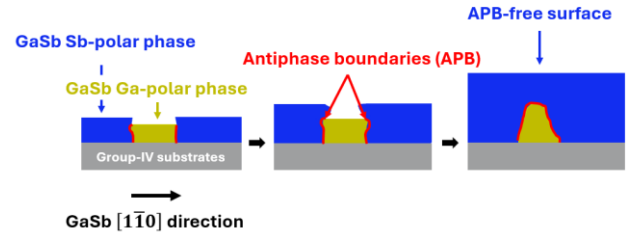


Figure 1 APB burying mechanism during GaSb growth on group-IV elements

3. RESULTS

The starting surface preparation is critical for growing APB-free GaSb films on group-IV substrates [4]. We found that APB-free GaSb layers can be achieved only when the Ge substrates are prepared by UHV annealing in a narrow temperature window. The Ge-on-Si and SiGe/Si templates, however, exhibit cross hatch patterns arising from strain relaxation during template growth, which prevents proper surface organization prior and during III-V growth. This, in turn, precludes APB annihilation. We found that this effect can be alleviated either by using slightly miscut ($1^\circ - 2^\circ$) Si substrates, or by smoothing the starting surface of on-axis Ge-on-Si templates by chemical-mechanical polishing. Under these conditions, APB-free GaSb layers can be achieved after 500 nm growth. They exhibit a rms roughness of 1.0 nm.

4. ACKNOWLEDGMENTS

Part of this work was sponsored by "France 2030" (Equipex EXTRA, ANR-11-EQPX-0016, Equipex+HYBAT, ANR-21-ESRE-0026) and the ANR-LightUp project (ANR-19-CE24-0002).

5. REFERENCES

- [1] R. Soref, Nature Photon **4**, 495 (2010).
- [2] G. Isella *et al.*, Solid-State Electron. **48**, 1317 (2004).
- [3] C. Cornet *et al.*, Phys. Rev. Mat. **4**, 053401 (2020).
- [4] M. Rio Calvo *et al.*, Adv. Electron. Mat. **8**, 2100777 (2022).