



HAL
open science

X-ray Coherent Scattering on GaP/Si for III-V Monolithic Integration on Silicon

Yanping Wang, Antoine Létoublon, Ida Lucci, Charles Cornet, V.
Favre-Nicolin, G. Chahine, J. Eymery, Laurent Pedesseau, M. Bahri, L.
Largeau, et al.

► **To cite this version:**

Yanping Wang, Antoine Létoublon, Ida Lucci, Charles Cornet, V. Favre-Nicolin, et al.. X-ray Coherent Scattering on GaP/Si for III-V Monolithic Integration on Silicon. International Workshop on Phase Retrieval and Coherent Scattering (COHERENCE 2016), Jun 2016, Saint-Malo, France. 2016. hal-01496666

HAL Id: hal-01496666

<https://univ-rennes.hal.science/hal-01496666v1>

Submitted on 27 Mar 2017

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.

Y. Ping Wang¹, A. Létoublon¹, I. Lucci¹, C. Cornet¹, V. Favre-Nicolin², G. Chahine², J. Eymery³, L. Pedesseau¹, M. Bahri⁴, L. Largeau⁴, G. Patriarche⁴, A. Ponchet⁵, M. Vallet⁵, J. Stodolna⁵, S. Charbonnier⁶, P. Turban⁶, Y. Leger¹, P. Guillemé¹, T. Shüllü², and O. Durand¹

¹UBL, INSA, FOTON, UMR 6082, Rennes, France

⁴LPN, UPR 20, Marcoussis, France

²ESRF, Grenoble, France

⁵CEMES, UPR 8011, Toulouse, France

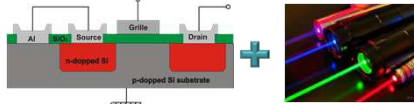
³Univ. Grenoble Alpes, CEA, DRFMC, INAC, Grenoble, France

⁶IPR, UMR 6251, Rennes, France

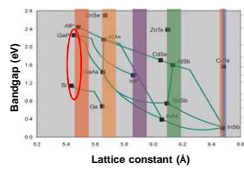
Motivation: Imaging of APB and other crystalline defects in GaP/Si nanolayers in the framework of III-V monolithic integration for photonics and PV on Si

Introduction

Silicon Photonics



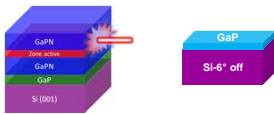
Microelectronic material: Si



GaP/Si: $\Delta a/a = 0.4\%$ at 300K

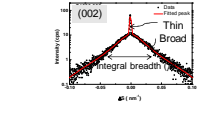
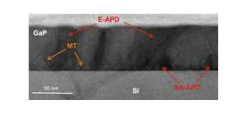
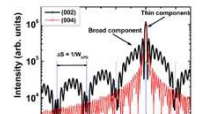
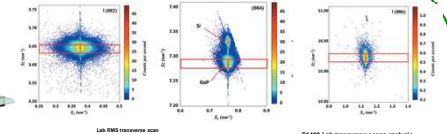
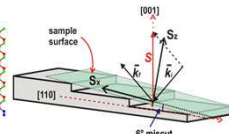
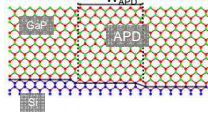
Ref [1]&[2]

GaP as template for III-V/Si monolithic integration



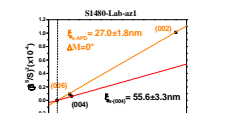
Schematics of a target structure for III-V laser emission on silicon.

photonics and PV on Si



$$\left[\frac{\beta(s)}{S} \right]^2 = \frac{1}{\xi_x^2} \frac{\beta(s)}{S^2} + \Delta M^2$$

Correlation length Mosaic term



Macroscopic characterisation of antiphase boundaries

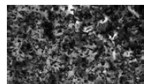
Williamson-Hall like analysis applied to APB (ref [3])

Coherent diffraction

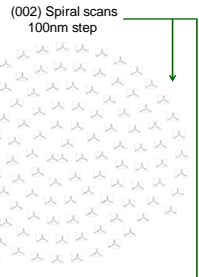
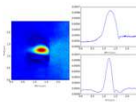
250nm (V) x 500nm (H) coherent beam

S1: 45nm GaP/Si

- Too high APB density / beam size
- Quite uniform XRS
- No Ptychography convergence

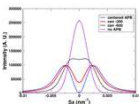


(002) DF-TEM plan view of a similar sample



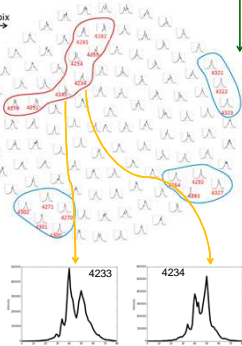
S2: 218nm GaP/Si

- Lower APB density
- Large contrast
- But no ptychography convergence
- Still too high defect density (APB&strain)



Simulation of a single APB lateral scan ~75nm step

- Symmetric peak profile
- Peak splitting extension ~300nm for ~500nm beam width



- Peak splitting (single APB)
- Peak broadening (several APB)

- Asymmetric peak profiles
- Tilt contribution ?

References:

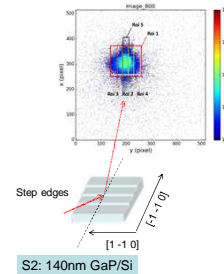
- [1] Y. Takagi, H. Yonezu, K. Samonji, T. Tsuji, N. Ohshima J. Cryst. Growth. **187** (1998) 42-50.
- [2] Volz, K. et al. GaP-nucleation on exact Si (001) substrates for III/V device integration. J. Cryst. Growth **315**, 37 - 47 (2011).
- [3] Y. Ping Wang, A. Létoublon et al., Journal of Applied Crystallography, 2015, 48 (3), pp.702-710.
- [4] M. I. Richard, ACS Appl. Mater. Interfaces **2015**, 7, 26696-26700.
- [5] M. H. Zoellner et al., ACS Appl. Mater. Interfaces **7**, 9031 (2015).
- [6] P. Guillemé et al. accepted in Optics Express.

We acknowledge:

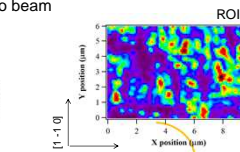
Region Bretagne for financial support, V. Demange of Sciences Chimiques de Rennes for XRD lab setup facility access, ANR project ANTIPODE 14-CE26-0014 and the Chinese Scholarship Council.

Fast XRS scanning kmap technique

100nm (V) x 300nm (H) nano beam



S2: 140nm GaP/Si

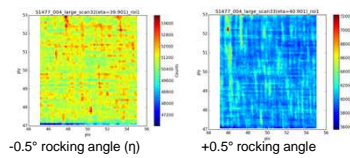


(002) kmap

- Combined Roi 3 & 4 image
- +Tilt regions aligned along [1 -1 0]

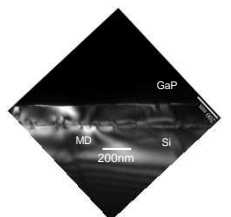
- Strain related to APB ?

(004) Kmap « Weak beam » conditions



Straight lines of contrast parallel to [110] & [1-10] directions

This high tilt contrast, may corresponding to regions surrounding misfit dislocations (see ref [4]&[5])



Conclusion and projects

First ptychography attempt

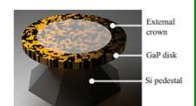
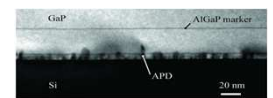
- **Observation of strong contrasts**
 - splitting, broadening, tilt

Fast scan kmap: 2 different contrasts

- **Weak tilt => strain related to APB ?**
- **High tilt => misfit dislocation ?**

Prospects:

- **Reproducible APB annihilation after 10nm**
 - high perfection samples below critical thickness => ptychography imaging
- **Combined analysis of local properties (crystallographic and physical)**
 - Better comprehension of device performances
- **Requires massive 3D Bragg peak analysis (WHL, strain&tilt...)**



GaP/Si microdisk for Second Harmonic Generation [6]