EUROPEAN SYNCHROTRON RADIATION FACILITY

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ESRF

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Reports supporting requests for additional beam time

Reports can be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** **Proposal title:** Crystal perfection characterization of GaP(N)/Si for light emission applications on silicon.	**Experiment number**: 02-02-792
Beamline:	**Date of experiment**: from: 15/11/12 to: 19/11/12	**Date of report**: 15/02/13
Shifts:	**Local contact(s)**: Jean-François BERAR	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

FOTON-OHM, INSA-RENNES 20 av. des Buttes de Coesmes, 35708, France:

A. Létoublon*, T. Tahn Nguyen*, Y. Wang*, O. Durand*, C. Cornet

CEMES, CNRS, Université de Toulouse, 29 rue J. Marvig BP 94347, 31055 Toulouse Cedex 4, France:

J. Stodolna*

Report:

In order to extend light emission III-V semiconductors on Si for very large scale and low cost integration, the growth of GaP and related ternary and quaternary (GaAsPN) materials lattice matched to Si are studied.

The best optical properties can be obtained with GaP as starting layer on Si. But, the structural properties of this interface are of primary importance and is the main motivation of the present project. Several types of defects are observed on III-V growth on IV monolithic substrates: point defects, misfit dislocations, anitphase boundaries (APB) microtwin (MT) and stacking faults (SF). These defects are detrimental for optical properties and must be eliminated or at least confined near the Si interface [1,2]. Amongst them, APB and MT are difficult to avoid and are our main concern in this work since XRD has been proved to be a very efficicent tool for characterization of such planar defects [3-6].

A first experiment on D2AM has been carried out november 2011, showing the advantage of using a large 2D low noise pixel detector for detection of both MT and APD [7]. In this new experiment, 6 samples of GaP(45nm)/ Si have been studied in 12 shifts. The differences between the samples are at the level of prelayer, miscut, and buffer of silicon; layer have been grown on 6° miscut substrate and with silicon buffer unless mentionned: S1: Ga prelayer without buffer of silicon, S2: Ga prelayer with buffer but without miscut, S3: Ga prelayer, S4: Al prelayer, S5 Sb prelayer, S6 P prelayer. The large 2D detector XPAD 3 has been used for fast data acquisition. For each sample, snapshot images centered on (002), (004), (006) GaP reflections and (002) micro-twins reflections for 2 azimuths (azimuth φ=0°, ie the column direction of the detector is parallel to [1 -10], opposite the step edge direction; azimuth φ=90°, ie the columns direction is almost parallel to [110]) have been performed. A specific broadening of the weak reflections (002) and (006) can be directly imaged for only 30 secondes exposure, as shown in Fig.1.

Transverse scan cutlines extracted from the (002) and (006) GaP reflections images along the columns direction have been analyzed to evaluate the antiphase domaine. A PsdVoigt function is used to fit the profile in order to obtain the integral breadth (IB), as shown in Fig.3. For transverse scans, two braodening mechanisms have to be considered: the in-plane correlation length and the mosaicity tilt. The two contributions are extracted from IB by using the Williamson-Hall-like method. From these analysis, the mosaicity tilt is from 0.6° to 1.5°, and the correlation length from 28nm to 60nm. These results are different from previous samples grown on 4° miscut and must be thoroughly interpreted.

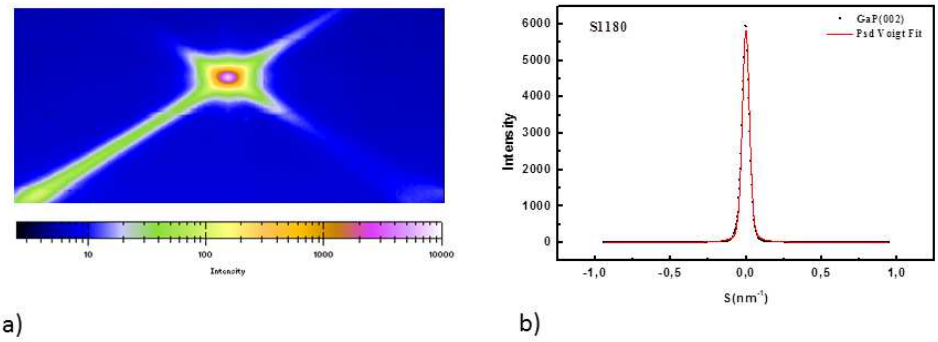

Fig. 1. a) 2D image using XPAD3 D2AM detector of sample 2 on (002) GaP reflection for φ=0°. Exposure time is 30 secondes. b) The corresponding cutline in the transverse column direction of the image.

Different microtwins (MT) variants are also detected and quantified (relative density, correlation lengths) for the 6 samples using 4 MT reflections depicted schematically on fig. N. The goniometer angles are seted in order to get one of the reflection type described fig.b) and 11 Xpad exposures of 30 seconds are taken by step of 0.25° in eta. An original integration methods has been developped using a rectangular ROI inclined along the MT streak axis. The relative intensity of MT reveals an important anisotropy for miscut surfaces, that is not present for the nominal one. The use of silicon buffer also allowed to reduce the osberved MT density and beyond this, the use of a Al prelayer also allowed a MT density limitation.

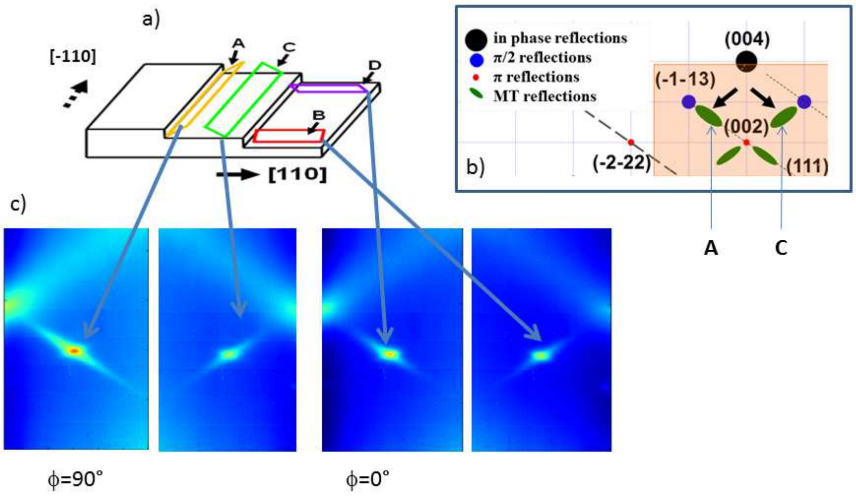

Fig. 2 MT reflections reflections recording around (002) GaP reflection for Sample 1 (grown on Si(001) 6°miscut without buffer).

Observation of micromosaic and correlation length contributions to broadening of transverse scans have been performed along 2 directions of the surface. An anisotropic effect has been demonstrated. An original integration method has been developed for extended MT reflections. This allowed a clear demonstration of anisotropy MT ratio for growth on miscut surfaces. Al prelayer also exhibits lower MT denssity. Based on this result we propose to study optimized AlP layers.

References:

[1] H. Yonezu, Y. Furukawa, A. Wakahara, J. Crystal Growth **310** (2008) 4757.

[2] T. Nguyen Thanh, C. Robert, W. Guo, A.Létoublon, C.Cornet et al. J. Appl. Phys. **112** (2012) 053521

[3] W. Guo, A. Bondi, C. Cornet, A. Létoublon et al. Appl. Surf. Science **258** (2012) 2808.

[4] T. Nguyen Thanh, et al., Thin Solid Films (2012), http://dx.doi.org/10.1016/j.tsf.2012.11.116

Justification and comments about the use of beam time (5 lines max.):

12 shifts combined with the use of an efficient 2D detector allowed us to study 6 samples grown under various conditions. The use of synchrotron is here very important for detection of low density nanodefects.

Publication(s):

- 1 paper in preparation from this experiement, 1 paper published from the previous one [7] + several conf. contributions