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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 using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now 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:** The surface reconstructions of GaSb(001)	**Experiment number**: SI - 541
Beamline: ID 3	**Date of experiment**: from: 8th – 17th May 2000	**Date of report**: 29th September 2000 *Received at ESRF:*
Shifts: 18	**Local contact(s)**: Paul Steadman	

Names and affiliations of applicants (* indicates experimentalists):

* Prof. Colin Norris (University of Leicester)

* Dr. Chris Nicklin (University of Leicester)

* Mr. Simon G. Alcock (University of Leicester)

* Dr. Paul Steadman (ESRF)

Prof. Chris Gilmore (University of Glasgow)

Report:

The III-V semiconductors represent a distinct class of materials, with surfaces characterised by a wide variety of reconstructions that form as a function of sample temperature and incident flux rate. The structures have been the focus of much activity over the last decade, due to their complexity and the extensive use of the (001) surface for epitaxial growth of semiconductor heterostructures. Of the III-V's, the antimony based materials are potentially the most important in optoelectronic devices, where current optimum wavelengths are 1.55μm with the next generation extending to the 2-4μm range. The requirement for high speed sources and detectors is therefore an immediate challenge to device manufacturers. GaSb is highly suited to this role as it is lattice matched to a wide range of ternary and quaternary III-V compounds with band gaps of 0.3-1.58eV (≡0.8-4.3μm). Applications that may use this technology include laser diodes, photodetectors, high frequency devices, infrared imaging sensors and *in-situ* gas monitoring. Despite this potential, few studies of the GaSb(001) surface have been reported. Whitman and colleagues at the NRL in Washington show that unlike other III-V materials which have a c(4×4) mesh under excess group V flux, GaSb reconstructs to (n×5) arrangements. The most stable of these is the c(2×10) structure which forms with 1.8ML of Sb at a temperature of ~350°C. STM results indicate that it violates the electron counting model (ECM - all group III dangling bonds are empty and group V ones full) and has a weakly metallic character. A complete picture of the atomic structure has yet to be obtained.

Following our earlier study of the large unit meshes on InSb(001) [1,2], the aim of this proposal was to determine the GaSb c(2×10) reconstruction. In the event, we were unable to stabilise a single domain c(2×10) surface.

Our collaborators at DERA, Malvern (Dr. A.D. Johnson and Dr. M. Emeny) produced high quality GaSb(001) samples with a 2μm GaSb buffer layer grown on top. An asymmetric (1×3) structure (hereafter referred to as A(1×3)) was observed after annealing at 200°C for approximately 6 hours and corresponds to the sample still being covered by a native oxide layer. This reconstruction was stable and persisted even after heating the sample to 500°C for 15 minutes. After the sample had cooled to room temperature an extensive set of in-plane data was recorded. This unexpected result was fully investigated and the analysis is continuing. The structure is not consistent with the theory of de Oliveira *et al* [3], who suggested that similar assymetric patterns in InSb(001) are formed by long range superperiodicity in one direction and a lack of order perpendicular to it. Analysis of the structure is continuing.

Cooling the sample from 500°C down to 470°C in a low flux of antimony produced the true (1×3) structure. This is illustrated in figure 1, which shows the increase in peak intensity at the [0 1/3] in-plane position in reciprocal space. The slight shift in the peak location corresponds to the transition from the A(1×3) structure to the true (1×3) structure. A series of in-plane scans were recorded to check for differences in the relative intensities for the two different structures. Further cooling, to below 350°C under a slightly increased Sb flux enabled the transition to a reconstruction with a c(2×10) unit mesh to be monitored. Figure 2 shows two in-plane radial scans along the reciprocal space k-axis, indicating that the two structures (1×3) and c(2×10) co-exist at this point. The third order peaks were always present; neither a single domain c(2×10) structure or (1×3) reconstruction were stabilised.

The work forms part of a larger program to investigate antimony based materials. The long term goal is the fabrication of ternary compounds by incorporation of Bi and Tl into III-V semiconductors such as GaSb and InSb. These materials may form the next generation of optoelectronic devices. The synchrotron programme to understand the structures of these compounds is a key factor in establihing the role of the surface in the device performance. We plan to continue this programme in both the measurement of GaSb structures and the growth of ternary systems, where the additional impurity component changes the device performance. This is predicted to enable the optoelctronic wavelength of these devices to be extended into the Long Wave Infra-Red (LWIR) region, without the requirement for extensive sample cooling.

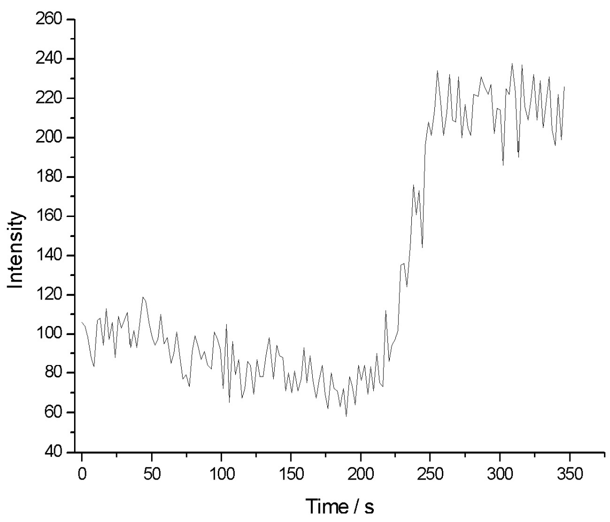

Figure 1

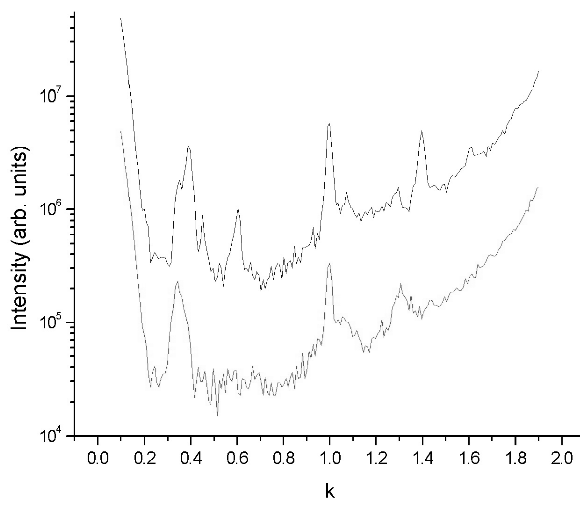

Figure 2

References:

[1] Jones, N, Norris, C, Nicklin, CL, Steadman, P, Baker, SH, Johnson, AD, Bennett, SL, Surf. Sci. 409 (1998) 27-36.
[2] Jones, N, Norris, C, Nicklin, CL, Steadman, P, Taylor, JSG, Johnson, AD, McConville, Surf. Sci. 398 (1998) 105-116.
[3] de Oliveira AG, Parker SD, Droopad R, *et al.* Surf. Sci 227 (1990) 150-156.