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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:** Strain distribution in spintronic transistor structures with piezoelectric stressors	**Experiment number**: **SI- 1964**
Beamline:	**Date of experiment**: from: 12.2.2010 to: 19.2.2010	**Date of report**: 7.8.2010
Shifts: 15	**Local contact(s)**: Dr. Frederico Zontone	*Received at ESRF:*

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Report:

The aim of the beamtime was to determine the periodic elastic strain in a GaMnAs layer deposited onto a periodic array of InAs quantum dots grown by molecular-beam epitaxy on a lithographically patterned GaAs substrate.

We have been able for the first time to prepare GaMnAs thin layers with periodic modulation of the epitaxial strain. We selected the period of the modulation by changing the preparation of the samples, namely GaMnAs layers have been grown at low temperature on top of an ordered array of InAs quantum dots. The inter-dot distance (and consequently the period of the strain modulation in the capping GaMnAs layer) is determined by a two-dimensional pre-patterning the GaAs substrate using dry-etching lithography, which results in a square array of etch pits with a given period. The patterned GaAs substrate was covered by a thin GaAs buffer, on which an InAs layer was deposited. During the deposition, self-organized InAs quantum dots nucleated in the etch pits resulting in a periodic two-dimensional array of InAs quantum dots, on which a GaMnAs layer was grown by a low-temperature deposition step.

Figure 1a and 1b show the SEM images of the patterned GaAs substrate and the GaMnAs layer, respectively.

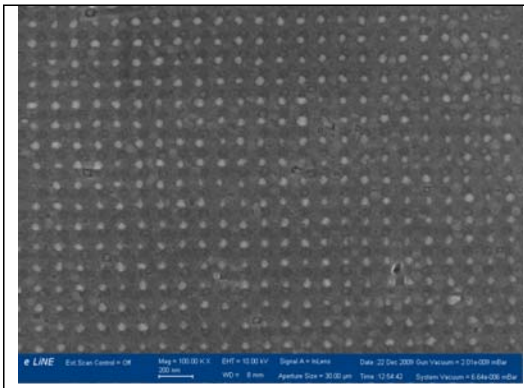

Fig 1a

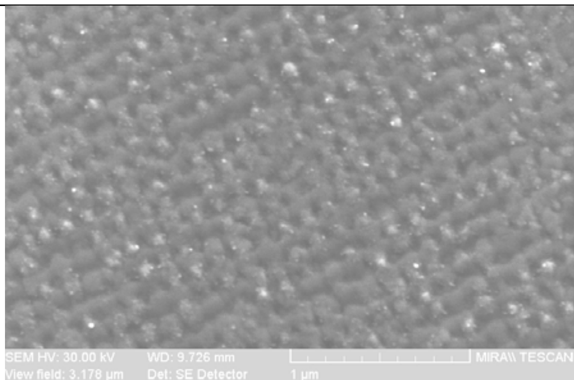

Fig 1b

Fig. 1 Scanning electron microscopy (SEM) images of a patterned GaAs substrate (a) and of the surface of the GaMnAs capping layer (b).

Our simulations indicate that the strain in the GaMnAs layer on top of the InAs dots is tensile whereas it is compressive elsewhere. It turns out that the amount of the GaMnAs material under tensile strain can be tuned at wish by selecting the InAs dot density through the patterning of the GaAs substrate, by changing the period of the dot array.

Our XRD experiments performed at ID10B reveal the presence of intensity satellites in reciprocal space along the in-plane directions revealing an in-plane periodicity (Fig. 2), both in the surface morphology and in the elastic strain in the GaMnAs layer. Figures 2 (a,b) show the intensity distributions in reciprocal space in symmetric and asymmetric diffractions, as well as the horizontal cuts through the intensity maps (Fig. 2(c-f)). The intensity maps exhibit GaAs and GaMnAs diffraction peaks; the diffraction maximum stemming from the InAs dot volumes is shifted towards negative ΔQ_z (far away from the visible graph range). Interestingly, the GaMnAs periodicity is in perfect agreement with the patterning of the GaAs substrates. It can be shown from diffraction theory that the visible asymmetry in the satellites intensity in an asymmetrical reflection denotes that a periodic elastic strain is present in the GaMnAs layer.

The preliminary magnetic characterization confirms that the out-of-plane component of the magnetization increases as the inter-dot spacing increases in agreement with the familiar magnetic anisotropy versus strain dependencies (Fig 3).
This finding indicates a new way to control the magnetic anisotropy of a diluted magnetic semiconductor by elastic strains.

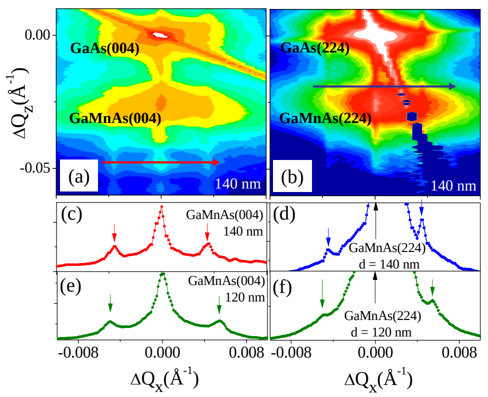

Fig 2a

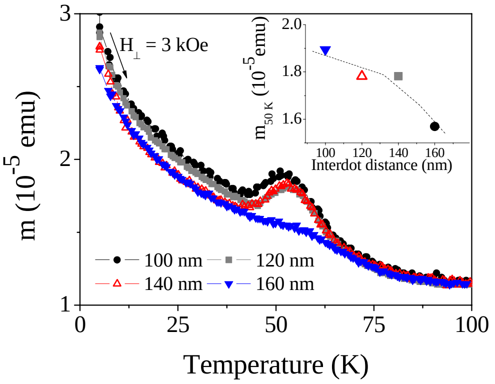

Fig 3

Fig. 2a Reciprocal-space distributions of x-ray intensity diffracted in symmetric 004 (panel a) and asymmetric 224 diffractions (b). The panels (c-f) show the cuts of the measured intensity maps through the GaMnAs maximum in the horizontal direction for two different dot periods 120 nm (e,f) and 140 nm (c,d). The panels (c,e) and (d,f) refer to the diffractions 004 and 224, respectively. A distinct asymmetry in the satellite intensities in panels (d,f) demonstrates the presence of a periodic strain in GaMnAs.

Fig. 3. The temperature dependence of the perpendicular magnetization measured in constant magnetic field of 3 kOe in samples with various periods of the InAs dots. The inset shows the dependence of the magnetization at 50 K on the dot distance.