ESRF	**Experiment title:** Local stresses derived from diffraction by a periodic strain field	**Experiment number**: **32-02-627**
Beamline:	**Date of experiment**: from: 18 March 2005 to: 21 March 2005	**Date of report**: 27/02/06
Shifts:	**Local contact(s)**: J-S. MICHA	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

A. Loubens, M. Gailhanou, O. Thomas

TECSEN, UMR CNRS 6122, Univ. Paul Cézanne, Fac. Des Sciences St Jérôme, 13397 Marseille Cedex 20

Report:

Mechanical stresses in thin films and nanostructures have very important consequences on the reliability of devices made from such structures. For a blanket film on a substrate where both are made of isotropic, homogeneous materials, the stress state in the film is one of uniform equal-biaxial stress (in plane stresses $\sigma_{xx} = \sigma_{yy}$, all other stresses zero) everywhere except for a region within a few film thicknesses of the edge. For lines and dots where the in-plane dimensions are comparable to the thickness, the stress state can be quite inhomogeneous. Moreover very high stresses are induced in the substrate close to the geometrical singularities. With the general trend of reduced dimensions in electron devices mechanical stresses are more and more considered a very important issue. Since local stresses need to be known accurately and compared with calculations like Finite Element Modeling (FEM) a lot of research is devoted to the experimental determination of local stress fields. Microdiffraction or MicroRaman spectroscopy have lateral resolutions of the order of 0.2 μm in the best cases [1, 2]. Convergent Beam Electron Diffraction (CBED) has the required atomic resolution but requires a painful thinning of the sample down to electron transparency. Moreover, such a procedure is likely to modify the stress state in the object.
In this experiment we have evaluated local strain fields by performing high resolution reciprocal space mappings [3] on arrays of SOI lines. The sample structure is sketched in figure 1.
Figure 2 represents the reciprocal space maps recorded on BM32, using a three reflections Si (111) analyser. The Si lattice in the lines is rotated by 45° from the base Si lattice, which ensures the separation between reflections with an in-plane component. On the other hand symmetric reflections such as 004 may overlap. In our sample an angle of 0.6 degrees between the two [001] directions has made possible the separation between the two 004 reflections and thus the observation of the much weaker one from the top layer. The two reflections have very distinct shapes which are directly correlated with the displacement field in the lines. Indeed the lines are covered with a highly stressed Si_3N_4 cap.

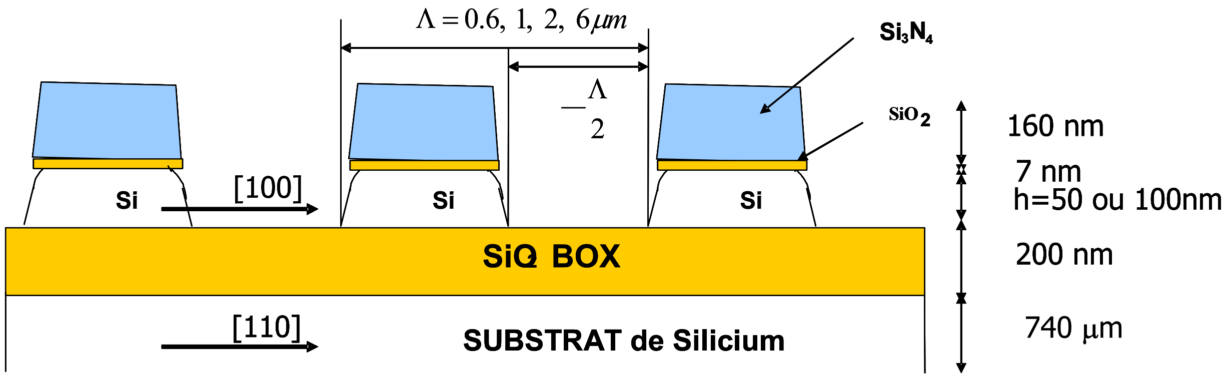

Figure 1: Schematic drawing of the sample structure. In the experiment performed in march 2005 we have focused on the 2 µm period-100 nm Si thickness structures.

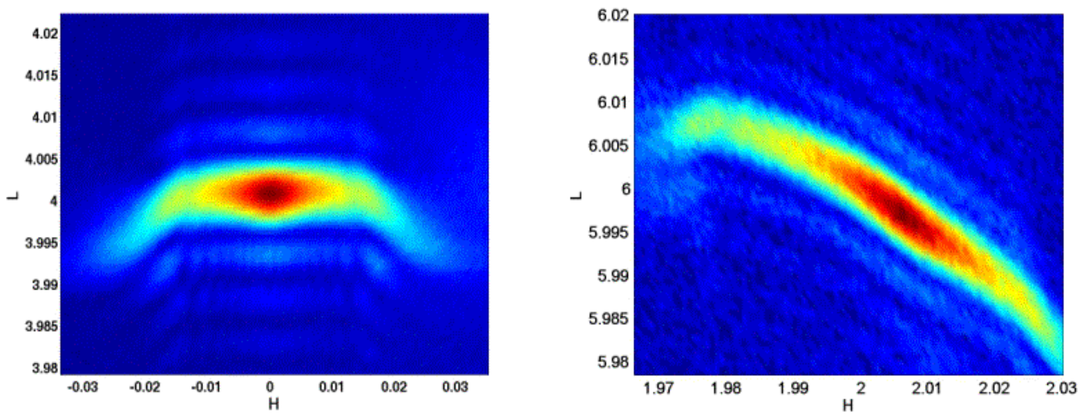

Figure 2: Map of reciprocal space around Si 004 and 206 from SOI line array with a period of 2 µm. The intensity scale is logarithmic. H and L are the scattering vector components in units of $2\pi/a_{Si}$.

Preliminary calculations with Finite Element Modeling together with diffracted intensity calculations (kinematic approximation) show a rather good agreement with the measurements (see Figure 3 and 4).

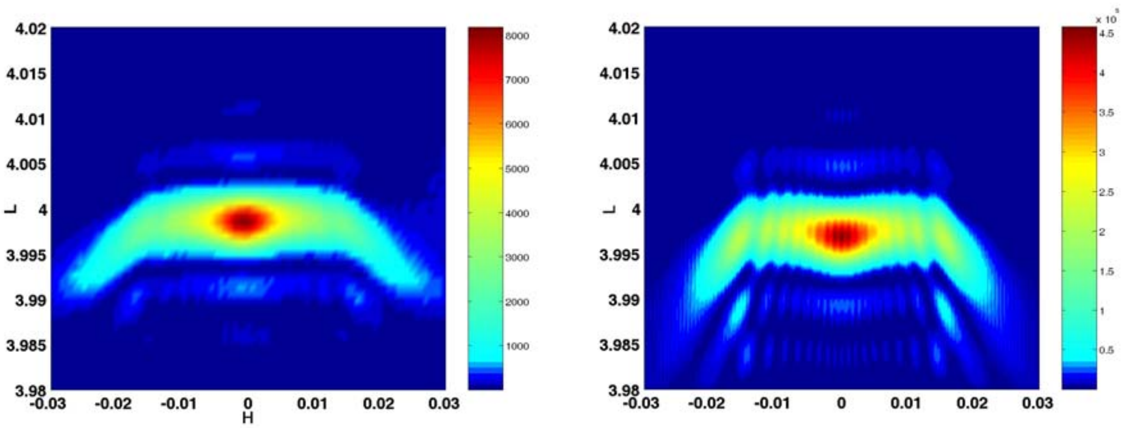

Figure 3: Experimental (left) and calculated (right) reciprocal space maps around Si 004 from SOI line array with a period of 2 µm. The intensity scale is logarithmic. H and L are the scattering vector components in units of $2\pi/a_{Si}$.

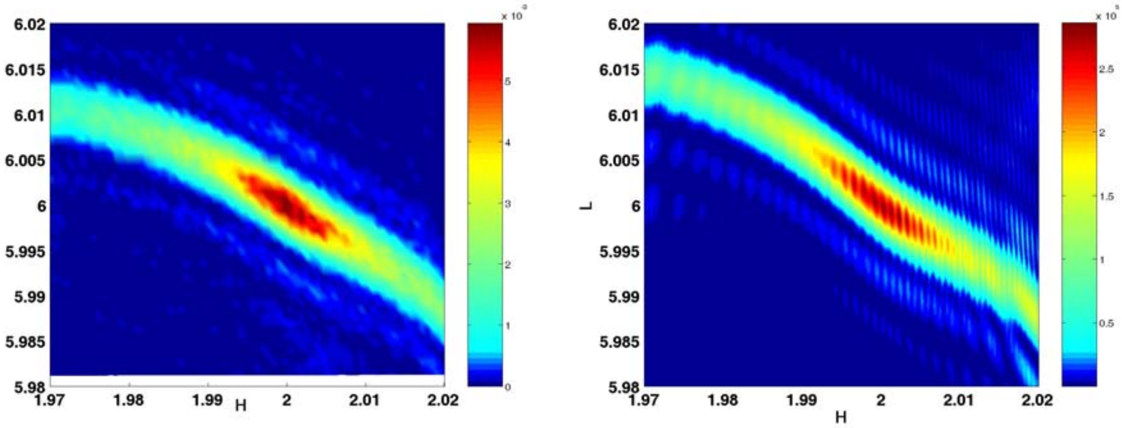

Figure 4: Experimental (left) and calculated (right) reciprocal space maps around Si 206 from SOI line array with a period of 2 µm. The intensity scale is logarithmic. H and L are the scattering vector components in units of $2\pi/a_{Si}$.

These calculations indicate that the peculiar moustache-like shape is a direct consequence of the strain field inhomogeneity arising close to the edges. Moreover many diffraction satellites have been observed around the base substrate diffraction peaks. They arise from the periodic strain field induced by the line array through the 200 nm SiO_2 BOX into the bulk Si. The very specific reciprocal space maps shown in figure 2 indicate that we probably have here the complete information from the strain field in a single line.

1. S. Di Fonzo *et al*., Nature 403, 638 (2000).
2. S. Jain, H. Maes, K. Pinardi, I. de Wolf, J. Appl. Phys. 79, 8145 (1996).
3. A. Loubens, these de l'Ecole Nationale des Mines de St Etienne, « Champ de déformation induit dans un monocristal par un réseau de dimensions submicroniques: diffraction des rayons X en mode haute résolution et simulations par éléments finis », january 2006.