ESRF	**Experiment title:** ***Deformation and interfacial structure of ultra-thin bonded Silicon on Silicon wafer.***	**Experiment number**: HS-889
Beamline: ID 10 A	**Date of experiment**: from: 02/07/99 to: 06/07/99	**Date of report**: 09/08/99
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Report:

Aim of the experiment : Well controlled Si grain boundary obtained by « Direct Wafer Bonding » on full 4-inch wafers have been studied by surface X-ray diffraction. The upper crystal is thinned to about 10 nm to increase the interface bonding effect on the surface. The main interest was to quantify the strain fields due to the dislocations accommodating the lattice register : a twist of two crystals bonded with flat and parallel (001) surface (*i.e.* no miscut) induces a square grid of pure screw dislocations (a/2 <110> Burger vectors lying in the (001) plane), whereas a tilt angle (miscut angle of the substrate) induces 60 ° dislocations. In this experiment, mainly twisted samples have been studied. It was a great and successful challenge to study with ESRF X-rays these very new materials which are very promising for microelectronics applications.

Measurements : To prepare the ID 10 A experiment, we have checked the interface quality and surface roughness by specular X-ray reflectivity on BM 32 with F. Rieutord [1]. This technique has shown that the twisted samples (5°, 10°) have very small thickness fluctuations, and no extended defects. A quantitative analysis has proved that the interfacial layer resulting from the bonding was very thin (about 8 Å) with an atomic density significantly different from bulk Si only for large bonding twist angles (>5°). For the small angles, the contrast was very low, indicating a better bonding.

These features have been confirmed with surface X-ray diffraction on ID 10 A. Two samples have been studied corresponding respectively to the small and large twist features. Sample A : Si thickness 140 Å, twist about 1.4° and tilt about 0.4°. Sample B : Si thickness 90 Å, twist about 3° and tilt not yet known. Sample A has already been studied by high resolution electron microscopy, sample B will be studied soon.

Due to the Burgers vectors of the twist boundary dislocation (along <110>), we have started the experiments by measuring intensity near the (220) reflections with a grazing incidence geometry. We have first used a NaI scintillator without an analyser : the divergence of the beam was very low and the distance between the sample and the detector has been maximised to have a good resolution in reciprocal space. Then we used a PSD to measure the truncation rods of these reflections. During the experiments, we have discovered that the multipurpose goniometer of ID 10 A was not able to keep constant the incidence angle of the beam referred to the sample surface during a rotation around the surface normal, so that it was not possible to do fully consistent measurements with the same angle of incidence for different reflections (for example 220 and 2-20). This defect is due to an misalignment of two axis of the 6-circle goniometer (already observed in a previous experiment), and can not be directly taken into account by a SPEC macro. It was not possible to use the matrix orientation and to do grazing incidence reciprocal space mapping to analyse accurately the tilt effect. For this first analysis of the samples, the incidence angle has been checked afterwards, but not really controlled.

Preliminary results : For Sample A (low twist), Fig. 1 shows a transverse scan for a grazing incident angle close to the critical angle (λ=0.93012 Å, θc=0.134°). The dislocation strain field gives rise to two different sets of grating rods. The first group is assigned to the substrate, the second one to the layer. Both have the same period and the same reciprocal grating vectors, but the layer rods are shifted with respect to the substrate rods. A formalism taking into account the general features of these gratings (position and intensity) is under development. The very sharp peaks prove the existence of a strain field with a remarkably perfect long range periodicity. They appear in all the <220> reflections, but for example the 220 and -2 -2 0 reflections have an inverse intensity pattern (weight of the layer satellite intensity compared to bulk satellite intensity) which is connected to the tilt effect.

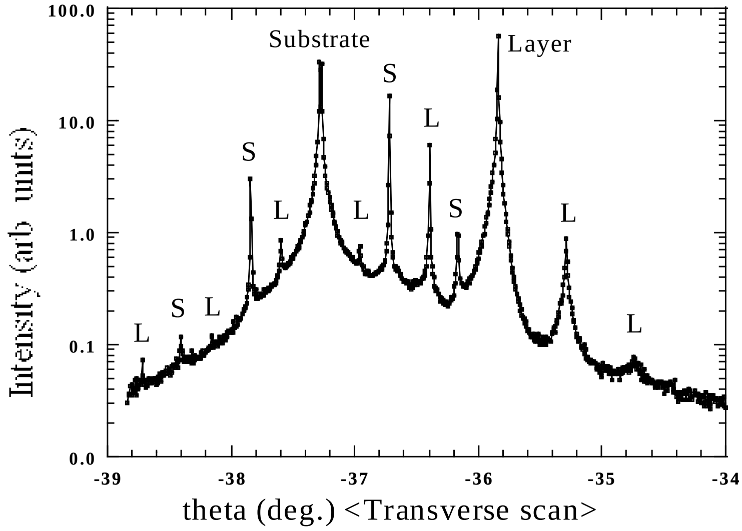

Fig. 1. (220) dislocation peaks of Sample A

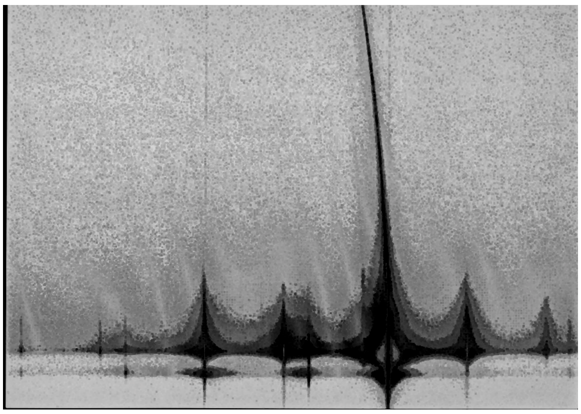

Fig. 2. Mapping around (220) of Sample A showing the dislocation truncation rods. X corresponds to theta (see Fig. 1), Y to gamma (nearly the surface normal).

Fig. 2 shows a full diffraction map of the 220 reflection (Sample A). The two groups of sharp truncation rods are clearly seen. They will be analysed to deduce the strain field normal to the surface and compared to the prediction of continuum elasticity theory [2].

The diffraction features of Sample B are