ESRF	**Experiment title:** Role de l'eau dans le collage moléculaire Role of water in wafer bonding	**Experiment number**: 32-2-685
Beamline: BM32	**Date of experiment**: from: 19-Mar-08 to: 25-Mar-08	**Date of report**: 25-Sep-08 *Received at ESRF:*
Shifts: 18	**Local contact(s)**: Rieutord	
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Report:

We have studied the evolution of hydrophilic silicon bonding interfaces with the annealing temperature. We remind here that the effect of the annealing is to increase the adhesion energy. Unfortunately, the annealing also produces defects at the interface, hence motivating research to understand the mechanisms at play at the interface during this important technological step.

We have performed high-energy (30keV) reflectivity experiments on bonded interfaces having received different preparations and thermal treatments.

This allows one to extract the electron density profile across the interface, either by direct inversion (symmetrical bonding) or through fit procedures (all cases). Typical data and electron density profiles extracted are shown below:

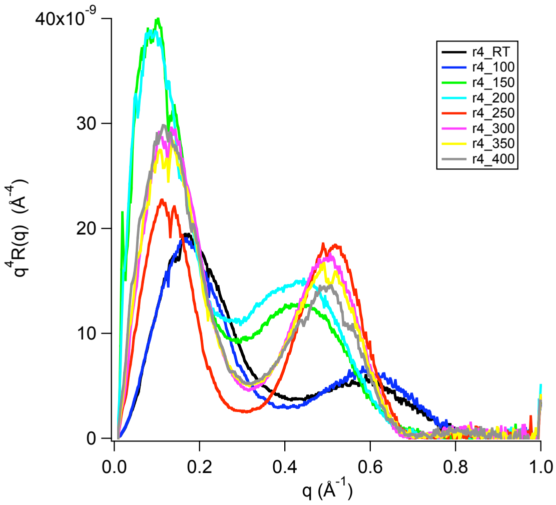

Fig.1 Reflectivity profiles for different annealing temperatures

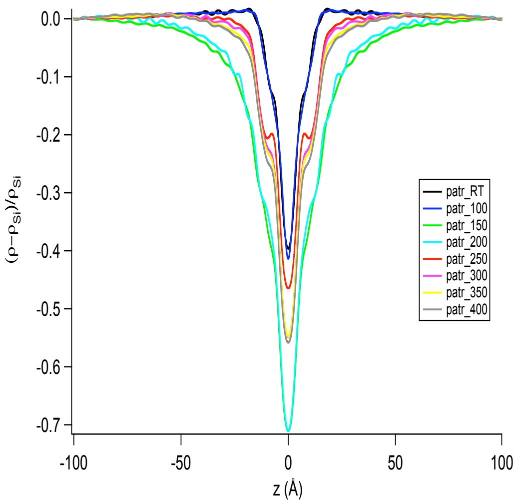

Fig.2. Electron density profiles obtained by direct inversion of Fig.1 data

Such profiles carry information about the width and depth of the bonding interface, but also of the oxide layers.

The width and density of the interface are related to the interaction between the two asperity distributions of the facing surfaces, and the amount of water filling the gap in between.

The width and density of the oxide layers can also be recorded, allowing a detailed balance of the species reacting close to the interface

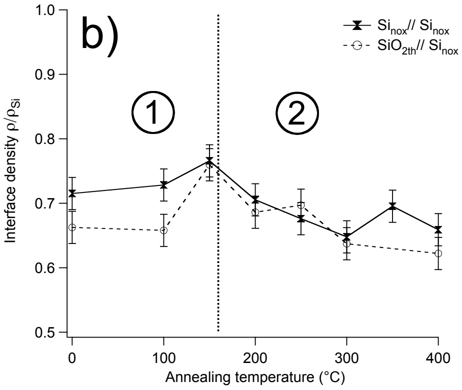

Fig.3: Evolution of interface density

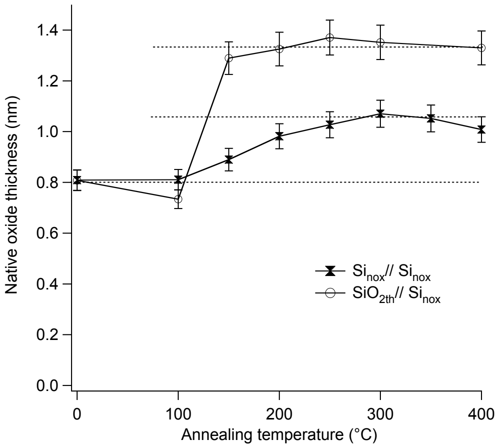

Fig. 4 Evolution of native oxide thickness

Such data were taken both for Si/Si and Si/SiO_{2th} bonding. (NB:when Si is noted, Si covered with native oxide should be understood). The data showed clearly an interface evolution at a temperture of about 150-200°C where the bonding energy is known to increase. We can observe an increase of the interface density at this temperature (Fig. 3) together with a growth of the native oxide thickness (Fig.4). The width of the interface does not change significantly in these cases (not shown).

In conclusion, using interfacial X-ray reflectivity complemented by FTIR-MIR spectroscopy data, we could determine the closing mechanism of hydrophilic silicon bonding (below):

- in a first stage, the sealing proceeds by extension of the contact points driven by the establishing of chemical bonds between the wafers. The density of the interface increases as more silicon come into the interface zone
- in a second stage, water escapes the interface, with a decrease of the electron density.

During the two steps, the water trapped at the interface or produced by the sealing reaction is consumed by oxidation of silicon after diffusion through the native oxide only , as demonstrated by the increase of native oxide thickness. This releases hydrogen gas which is at the origin of bonding defects.

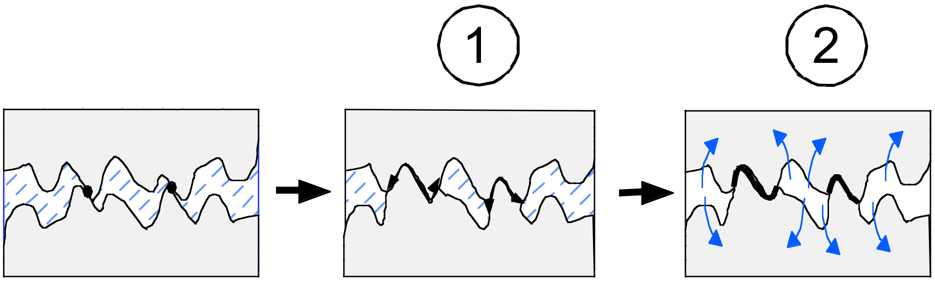

Fig.5: Scheme of the mechanism of interface closing upon annealing

<u>Reference:</u> C.Ventosa, F.Rieutord, L. Libralesso, F. Fournel, C.Morales, H. Moriceau, *J. Appl. Phys.* (2008) , accepted.