X-RAY STUDIES OF PLASMA ASSISTED WAFER BONDING

Mette Poulsen[1,2], Anne Egebjerg[1,2], Robert Feidenhans'l[1], Flemming Jensen[2], Oliver Bunk[1].

[1]Materials Research Department, Risø National Laboratory, Frederiksborgvej 399, Build. 228, P.O. 49, DK-4000 Roskilde.

[2]Mikroelektronik Centret, Ørsteds Plads, Building 345 east, DTU, DK-2800 Kgs. Lyngby.

Silicon to silicon fusion wafer bonding is an important technique used in the industry e.g. for manufacture of microsystems and SOI materials. To achieve reliable properties the bonding has to be strengthened by a heat treatment up to 1100ºC. This heat treatment can be a problem for some applications and therefore it is of great interest to find a method for bonding at room temperature. One promising way, which has achieved much attention, is room temperature bonding of wafers that has been exposed to oxygen plasma before the bonding (plasma assisted bonding) [1].

Understanding the bonding mechanism is important in order to be able to control the bonding step for instance when used in Microsystems. For obtaining structural information about the bonding mechanism on the atomic scale we perform X-ray reflectivity measurements on different prepared plasma-bonded samples. Furthermore we evaluate the bonding quality using conventional methods like infrared measurements (void formation at the interface) and measure strength of the bonding using "the crack-opening method".

All samples are 4 inch p-doped Si(100) wafers treated with either a standard RIE (Reactive Ion Etching), or an ASE (Advanced Silicon Etcher) system for plasma activation.
In order to optimise the parameters in the activation process we have made a significant amount of tests varying the process time, radio frequency (RF) power and pressure in the chamber. The thickness of the oxide has been measured with an ellipsometer in order to investigate the relation between the exposure time, the oxide thickness and the bond strength. The measured bond strengths seems to show a tendency; the strongest bond strengths are obtained using RF powers for the process in the lower region around 40W, activation times around 150s and a chamber pressure of 280 mTorr. These parameters give a typical bond strengths of 1.3 J/m^2.

To determine the density profile across the interface we have made X-ray reflectivity measurements on different plasma-bonded samples [2]. The sample set up is shown in figure 2. Measurements have been performed both a few hours after bonding and up to several weeks after, due to the fact that the bonding is changing within the first few days but becomes almost stable after a week.
We clearly observe a difference in the reflectivity scans measured from different prepared samples. Also there is a clear difference in the shape of the reflectivity curves for samples prepared the same way but measured at different times after bonding.

We believe that this technique is a suitable technique for obtaining new information about the plasma bonding, and we expect within the next months to establish a model, which describes the chemical structure of the bonding interface.

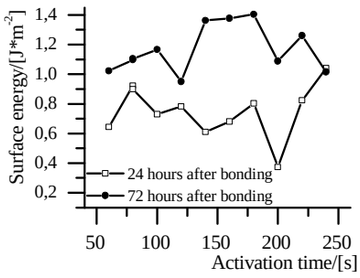

Figure 1. Surface energy versus activation time.

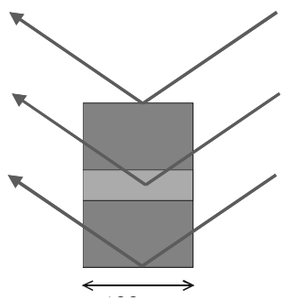

Figure 2. X-ray set-up.

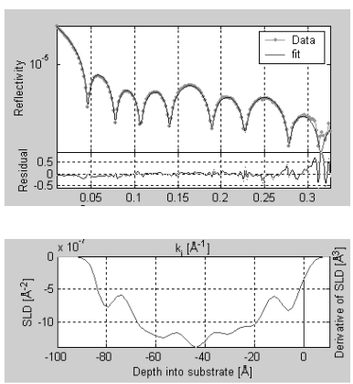

Figure 3. Example of measured X-ray data and model calculations.

[1] A. Weinert, P.Amirfeiz, S.Bengtsson, "Plasma assisted room temperature bonding for MST". Sensors and Actuators A, 92(2001) 214-222

[2] F. Rieutord, J. Eymery, F. Fournel, D. Buttard, R. Oeser, O. Plantevin, H. Moriceau and B. Aspar. "High-energy x-ray reflectivity of buried interfaces created by wafer bonding" PHYSICAL REWIEW B, Volume 63, 125408(2001).