ESRF	**Experiment title:** Cu/SiO2 hybrid bonding: how does Cu microstructure influence bonding quality?	**Experiment number**: MA-4741
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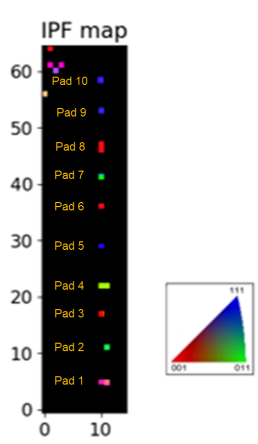
Report:

Hybrid Cu bonding is a recent innovative approach for 3D integration in the semiconductor industry. It relies on the thermomechanically induced contact between Cu pads embedded in SiO_2. Mechanical simulations have failed so far to predict the bonding behavior because of the lack of knowledge on the Cu microstructure (grain orientation, strains, defects). The aim of this experiment was to characterize the microstructure of single Cu pads as a function of pad size and processing conditions. In addition, we have performed in situ annealing experiments in order to follow the thermomechanical behavior
of Cu pads as a function of temperature.

Simple square and periodic Cu pads structures (see Fig. 1) have been prepared at STMicroelectronics in different states: 1) before bonding and 2) after bonding with a 400°C anneal. Four different pad sizes have been investigated: 300 nm, 1 µm, 2 µm and 3 µm. We have also investigated the influence of Cu thickness (between 750 and 2700 nm). In total 10 samples have been analyzed *ex situ* and 2 samples have been followed *in situ* during heat treatment.

Figure 1 : Example of analyzed structures for 300nm pads in width.

All samples have been analyzed with Laue diffraction in reflection mode. The white beam has been focused with KB mirrors down to 500 nm x 200 nm (V x H). Scanning the sample in x and y under the beam allows getting scanning diffraction maps around the Cu pads. Laue patterns are analyzed with Laue Tools software developed at BM32 beamline. In the following we will focus on the smallest diameter pads (324 nm). Figure 2 shows the orientation of 10 different pads as deduced from Laue patterns indexation. All these small diameter pads are monocrystalline but the orientation differs from one pad to the other. This finding has important consequences concerning the thermomechanical behavior of these pads because of the very large elastic anisotropy of copper.



Pad Number	Orientation in Z			Young's Modulus (GPa) along Z
	h	k	l	
1	1	0.6	0.37	127
2	1	0.76	0.24	130
3	1	0.1	0.02	68
4	1	0.9	0.6	169
5	1	0.89	0.87	188
6	1	0.24	0.47	102
7	1	0.85	0.56	164
8	0.7	1	0.2	132
9	1	0.56	1	172
10	1	1	0.9	198

Figure 2 : Crystallographic orientation of different pillars with 324 nm diameter and its consequence on Young's modulus.

The same pads have been mapped in situ during heating up to 400°C. From their Laue patterns, the deviatoric strain tensor has been derived. Figure 3 shows the deviatoric strain ε'_{zz} along the pad axis as a function of temperature. All pads exhibit a linear elastic behavior followed at higher temperature by a plastic behavior. Cooling down shows a permanent change in the strain. A clear difference is observed between the different pads, related to their crystallographic orientation. This result bears important consequences for the control of the bonding process. Mechanical modeling (FEM) is underway to better understand the observed trends. These results will soon be published in an international journal.

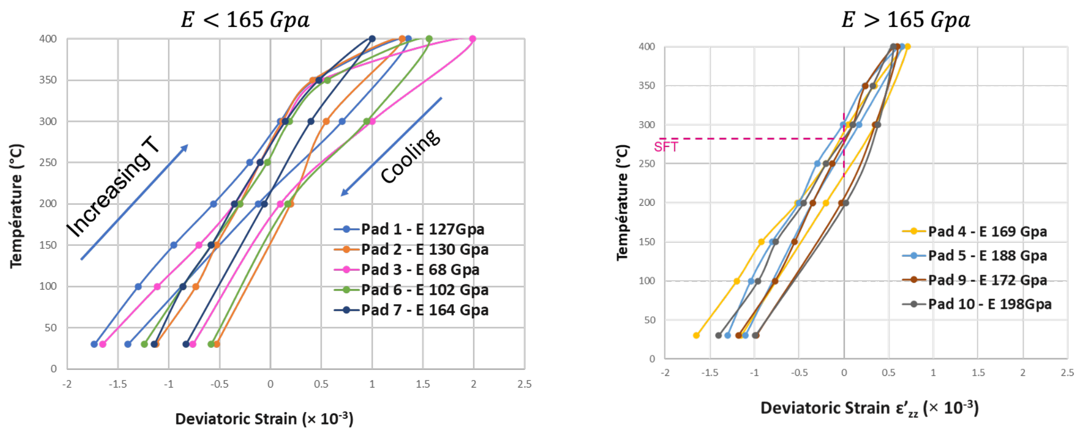


Figure 3 : Temperature vs Deviatoric strain ε'_{zz} for all different pads with 324 nm diameter.

Aside from these smallest sized pads we will treat the data concerning the larger pads, which contain several grains. Again we will investigate the different thermomechanical behavior of the pads in relation with the orientation of the grains.

It is worth noting that such results could not have been obtained without the unique disposal of a submicron polychromatic beam, as it is available on BM32 beamline.