ESRF

ESRF	**Experiment title:** Depth profiling the tri-axial stress of sub 50 nm copper interconnects fabricated in SiO2, advanced Low-k and future Airgap technology	**Experiment number**: MA1070
Beamline: ID01	**Date of experiment**: from: 15/12/2010 to: 20/12/2010	**Date of report**: Aug 2011 *Received at ESRF:*
Shifts: 15	**Local contact(s)**: Vincent Jacques	

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Report:

The introduction of highly porous materials, used to lower the effective k-value of the back end stack, requires consideration of the structures mechanical stability. Our previous work revealed significant changes in stress when changing dielectric. The purpose of this work was to determine the tri-axial stress of interconnects fabricated in dense SiO2 and porous low-k dielectrics, and novel airgap (no dielectric) structures at scaled geometries as a function of depth.

Publications on the results outlined below are in-preparation or submitted at the time of preparing this report.

At the start of this beam time we continued to be affected by focusing problems as the slits and detector used previously were not available. Although much time was spent in the time of MA1071 some optimisation was still needed. In hindsight, also a higher beam energy was used compared to our previous work, lowering the Bragg angle, and contributing to the lower resolution in peak position. This should be improved next time.

Using two students on shifts we managed to run samples for an average of 20+ hours day. This beam time was scheduled after MA1071 which had similar goals, so the time was split between the two experiments to make the most the beam down day in the middle for hutch modifications. We used the beam down day prior to our beam time to install the high temperature stage. However, this installation altered our alignment requiring a day of beam time to set this up again. The same loss of beam time for the removal of the stage was also needed. Each change in alignment requires additional measurements for calibration unnecessarily wasting time. Such loss in beam time from this task significantly reduces the available beam time for experiments and should be improved on future occasions.

The typical stack used for all measurements is shown in figure 1.

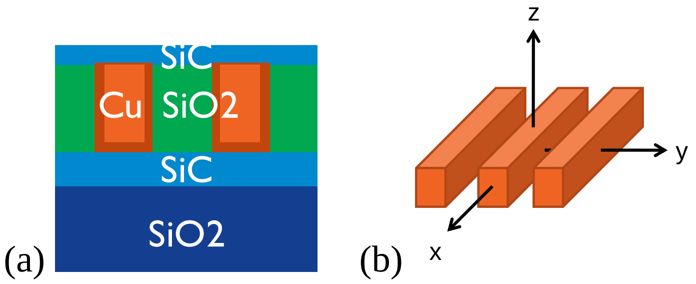

Figure 1. (a) Typical stack used for stress measurements and (b) Co-ordinate system

To study the mechanical stability of Cu interconnects patterned in different dielectric, the tri-axial stress was determined for lines patterned in advanced organo silicate glass (OSG) and spin on glass (SOG) dielectrics. Table 1 shows the differences in the mechanical properties of these materials. The principle differences between the SOG and OSG dielectrics are the higher coefficient of thermal expansion (CTE). Figure 2 shows the stress in SOG polymers is comparable to OSG materials. The out of plane stress (σz) is however constantly higher increasing both in-plane components, possibly due to larger CTE.

Material	**E (GPa)**	**CTE (ppm/^{o}C)**
SOG2.2	6	30
SOG2.3	5	57
OSG3.0	12	20
OSG2.5	7	20

Table 1. Mechanical properties of the dielectric materials tested

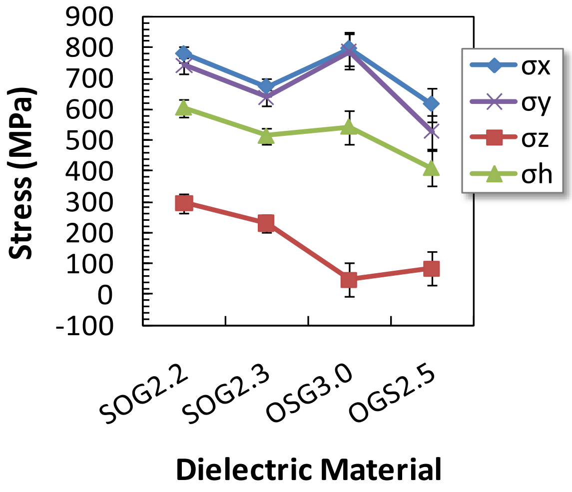

Figure 2. Cu tri-axial stress as a function of insulator dielectric

To further understand the how the mechanical properties of the insulating dielectric effects the stress in Cu lines we spent two days performing strain measurements as a function of temperature. Figure 3 shows a small change in slope is apparent for different materials. This change in strain with temperature likely causes the different strains (stresses) measured at room temperature (fig. 2). A clear change in zero strain intercept is observed for the SOG2.3 material, likely affected by the high CTE compared to the other materials. This shift in zero strain enables us to explain reliability results performed on identical samples where this sample performed consistently worse than the others. Such measurements provide a very interesting method of probing the mechanical stability of interconnect stacks.

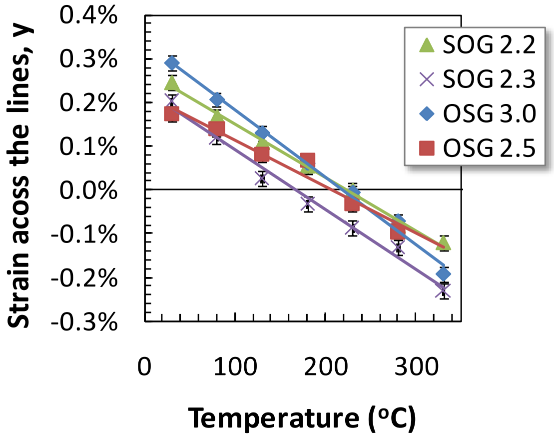

Figure 3. Strain across the lines as a function of temperature

In the remaining beam time we developed a depth dependant strain methodology on patterned lines. A number of calibration scans were also performed on blanket samples. Figure 4 shows a typical result obtained for narrow lines for the first time, showing a stress gradient.

The measured signal is averaged over entire penetration depth however a clear gradient is visible. This gradient will drive failure during manufacturing and metal reliability. Interestingly the strain converges to that obtained using standard measurement (equivalent to 670 MPa). These results show some misalignment in the incident angle thus greater calibration of incident angle is needed to gain more points over Cu thickness next time. In future work our developed methodology can be applied to more complex multilayer structures and layouts and correlated processing conditions and reliability experiments.

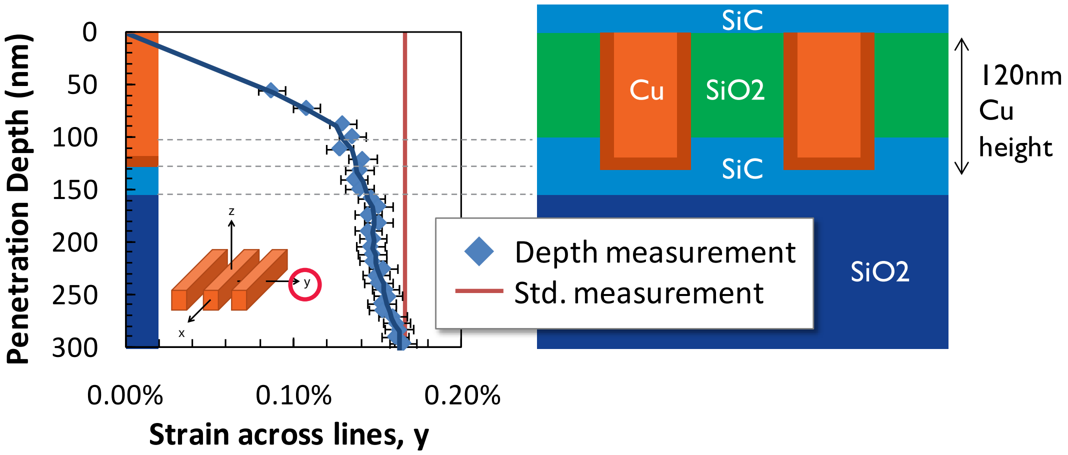

Figure 4. Strain across narrow lines as a function of x-ray penetration depth (right shows a schematic of the structure to scale)