Forschungszentrum Dresden Rossendorf

Experiment Report Form

The double page inside this form is to be filled in for each experiment at the Rossendorf Beamline (ROBL). This double-page report will be reduced to a one page, A4 format, to be published in the Bi-Annual Report of the beamline. The report may also be published on the Web-pages of the FZD. If necessary, you may ask for an appropriate delay between report submission and publication.

Should you wish to make more general comments on the experiment, enclose these on a separate sheet, and send both the Report and comments to the ROBL team.

Published papers

All users must give proper credit to ROBL staff members and the ESRF facilities used for achieving the results being published. Further, users are obliged to send to ROBL the complete reference and abstract of papers published in peer-reviewed media.

Deadlines for submission of Experimental Report

Reports shall be submitted not later than 6 month after the experiment.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report in English.
- include the reference number of the proposal / experiment to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.
- bear in mind that the double-page report will be reduced to 71% of its original size, A4 format. A type-face such as "Times" or "Arial" , 14 points, with a 1.5 line spacing between lines for the text produces a report which can be read easily.

Note that requests for further beam time must always be accompanied by a report on previous measurements.

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ROBL-CRG	**Experiment title:** SR-μ-XRD stress measurements of ultra low-k vs. low-k dual damascene inlaid copper interconect structures with different line widths at temperatures between RT and 500°C	**Experiment number**: 2002660
Beamline: BM 20	**Date of experiment**: from: 11.06.08 to: 16.06.08	**Date of report**: 25.11.08
Shifts:	**Local contact(s)**: Dr. Carsten Bähtz	*Received at ROBL:*

Names and affiliations of applicants (* indicates experimentalists):

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Report:

The experiment was focused on the influence of interlayer dielectric material (ILD) on the temperature dependence of the stress in copper interconnect structures. The continuous increase of transistor density on microelectronic devices requires a proportional shrinking of the on-chip interconnect structures. Modern copper interconnect structures have line widths of less than 200 nm and are build on more than 9 different levels. The complex structure and the small dimensions result in very strict requirements for the mechanical stability of the system.
Metal structures that are exposed to mechanical stress may show deformation if the stress increases above a certain level. Under normal production and operation conditions this level is globally not exceeded, however on a local level stress gradients may build up and copper migration phenomena can be observed. This migration can lead to void formation and in the case of thin lines to a complete interrupt and device failure.

Large arrays of parallel copper interconnect lines with different linewiths were measured at the copper (111) reflection in the side-inclination mode. This mode, where the diffraction geometry is keeped constant and the sample is tilted in Chi and Phi, enables the calculation of the full 3D-stress state. The measurement of higher angle reflections would yield better stress resolution and lower error bars, but diffraction intensity was not sufficient to utilize this setup.
The small structure sizes, especially the small structure height, lead to very low diffraction volumes, so that the highest possible beam intensity has to be focused on the sample. One sample with a slight overpolish, were the structure height was reduced below 100nm, was nearly unmeasurable in the current experimental setup. As heights below this range will become

common in the predictable future it was decided that a mayor upgrade of beam optics and and detector sensitivity is needed for project continuation.

Figure 1 shows a sample with a special ILD material. The stress temperature curve shows a completely different behaviour compared to normal low-k or ultra-low-k materials (Figure 2). The last process step for all samples is the addition of a capping layer at higher temperatures. The different coefficients of thermal expansions (CTE) lead to a tensile stress in the copper structures at room temperature after the cooling down. When the samples are heated up again, normally the stress decreases more or less linearly, whereas the rate of decrease depends on all the different materials CTEs and the geometry. The stress than reaches a zero level at a given temperature, that is not necessaryly the same as the capping layer deposition temperature. This due to irreversible processes like copper grain growth or chemical interlayer reactions that can take place. Further temperature increase leads to compressive stress, that reaches a constant level when copper yielding (plastic deformation) or ILD deformation begins.
The sample with the special ILD material shows a small increase of tensile stress in the first heating step, this may be due to the sample preparation. The sample cutout enables adsorbtion of water and other species from air which is prevented in the normal production process. The desorption changes the ILD volume and induces additional stress in the copper structures. Further heating decreases the stress, but with a much lower rate compared to the other samples. An explanation for this issue is even more speculative as further desorbtion, unusual thermal or thermo-elastic properties are possible.
With higher temperatures the stress decreases very fast and turns compressive. A stress plateau trough beginning yielding is not observed and maybe covered by different processes.
The examined ILD material shows much more complicated behaviour than expected and further analysis is going on for better understanding.

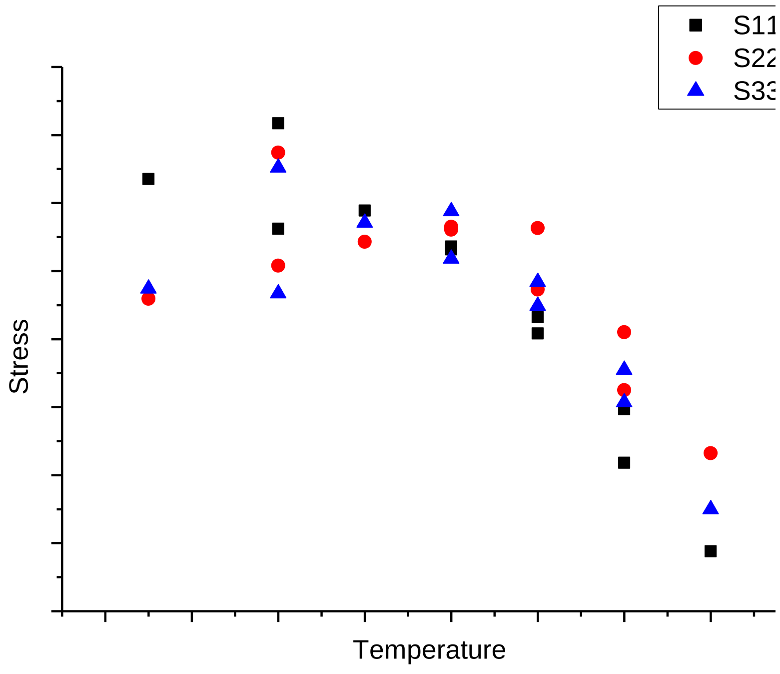

Figure 1: Stress-Temperature curve of a sample with special ILD material

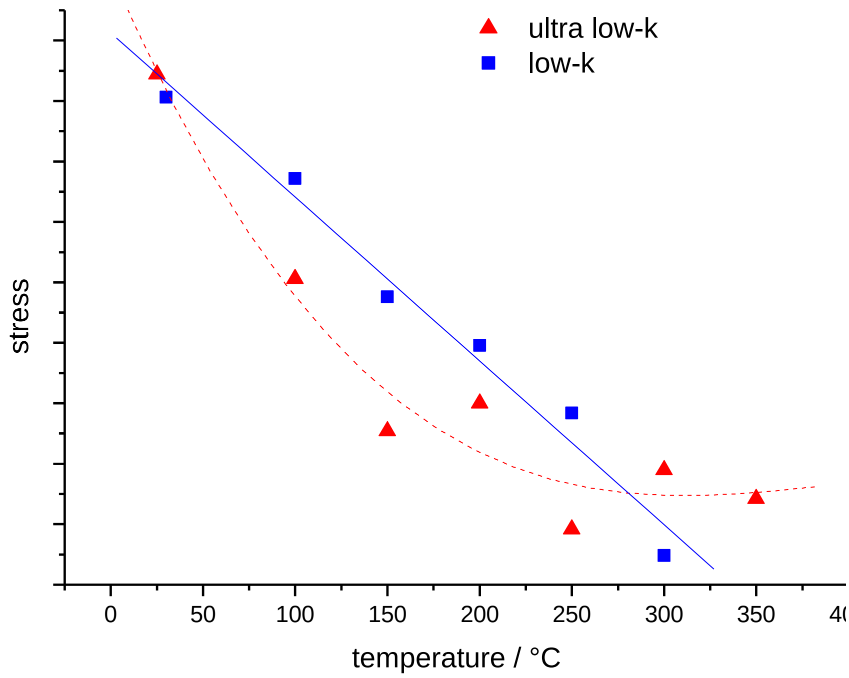

Figure 2: Stress-Temperature curve of samples with "common" low-k, ultra low-k ILD Material (taken for comparision from last report)