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 dual damascene inlaid copper inter-connect structures at temperatures between RT and 500°C	**Experiment number**: 20-02-648
Beamline: BM 20	**Date of experiment**: from: 19-SEP-07 to: 25-SEP-07	**Date of report**:
Shifts: 18	**Local contact(s)**: Dr. Carsten Baehtz	*Received at ROBL:*

Names and affiliations of applicants (*,[1] indicate experimentalists):

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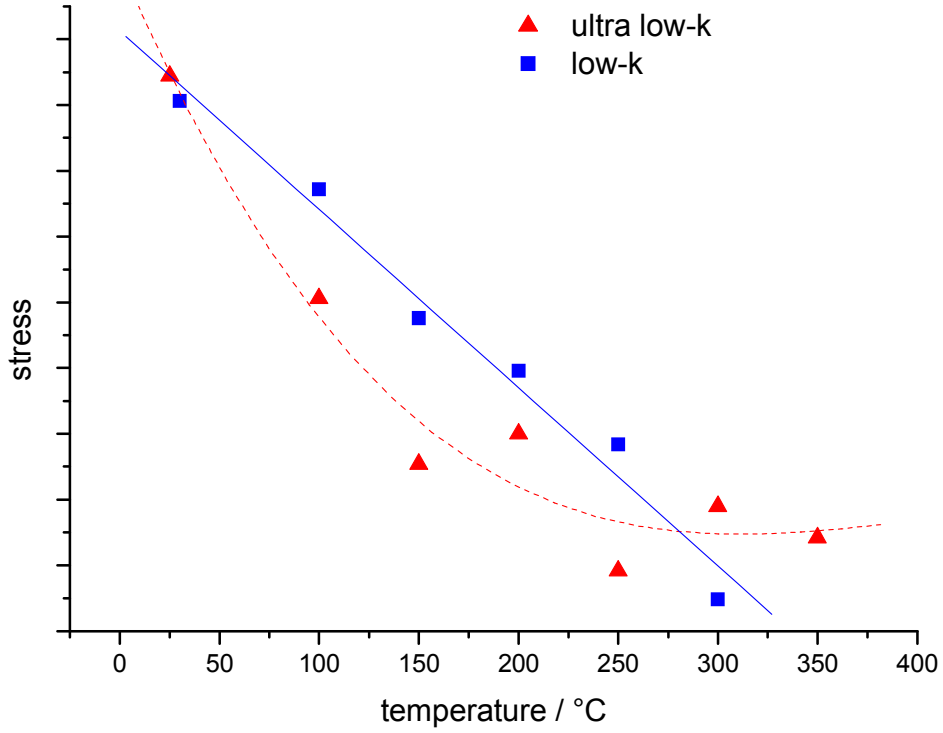
Report:

Following the previous projects, the stress state of copper interconnect structures at temperatures between 25 and 350 °C has been examined. The samples contained the newest generation of metal stacks with ultra low-k material as dielectric. For all experiments in the past the high angle (311) reflection was used as the accuracy of XRD stress measurement directly depends on the diffraction angle. It showed up that on the newest samples the intesity of this reflection was not high enough to enable a correct data evaluation and the (111) reflection had to been chossen. The final data evaluation showed that the measurement of the (111) is not suitable for further measurements as the error of the stress data rises above the temperature dependant signal in some cases. As a consequence only a rough characterization of the stress temperature relation was possible.
The low intesity is a consequence of continous down scaling of interconnect structures. For XRD measurements the decreasing structure height leads to a much lower diffracting volume. Unfortunately the height reduction is strictly necessary to keep the structures within a manufacturable aspect ratio.
The only possible solution is the enlargement of the structure array. The new litho masks are already available and will be used in sample production for the next experiments.
Even though the data quality only enables a rough comparison, some interesting, new aspects and possible risks of the new materials could be derived from the last experiments.

The room temperature stress state is very similar to low-k interconnect structures. With rising temperature the tensile stress decreases faster in the ultra low-k dielectric, although the exact slope cannot be determined. The zero stress temperature is lower. At temperatures above 200-300°C, the stress starts to level in the compressive region.
For low-k and conventional dielectrics the stress leveling at high temperatures is connected with the start of copper yielding. In the case of the ultra low-k samples the temperature and the stress is in fact too low for copper yielding, so it is supposed, that other mechanisms for stress relieve like plastic deformation of the dielectric are important.
For device testing, there are several possible consequences.
For stress testing (temperature cycles) the higher slope of the stress means higher mechanical load per cycle. Plastic deformation of the dielectric even more encourages the formation of dielectric voids and interface delamination. Voids and delamination cracks can form copper diffusion paths and may lead to electrical shortage failures.
For electromigration (EM) testing, the stress leveling observed at test temperatures means that the maximum back stress, which is an important counterforce to electromigration, is much lower. EM may be less retarded and in the worst case copper extrusions and voids could be formed much more easily.



[1] Geisler, H., Prinz, H., Zienert, I. Rinderknecht, J., Kiene, M., and Zschech, E. Temperature-Dependent Stress Measurements at Inlaid Copper Interconnect Lines, Eigth International Workshop on Stress-Induced Phenomena in Metallization, AIP conference Proceedings **Vol. 817** (2006), p.277-287

[2] Prinz, H., Zienert, I., Rinderknecht, J., Geisler, H., Kiene, M., and Zschech, E. Effect of capping layer on temperature-stress relation in copper/low-k dual inlaid interconnect structures, Materials Research Society, AMC Conference Proceedings **Vol. 21** (2005), ISBN: 1-55899-865-9