Potential Of The EsB Detector In The Low Voltage Scanning Electron Microscopy (LVSEM): Application In Microelectronics

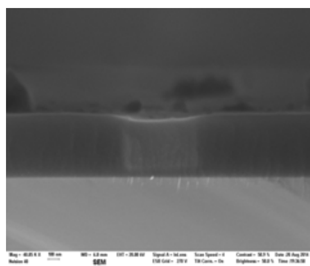
Aránzazu Garitagoitia Cid[1,2], Rüdiger Rosenkranz[1], Martin Gall[1], Ehrenfried Zschech[1,2]

1) Fraunhofer Institute for Ceramic Technologies and Systems - Materials Diagnostics (IKTS-MD), 01109 Dresden, Germany
2) Technical University Dresden, Dresden Center for Nanoanalysis, 01069 Dresden, German

Motivation: Strong degradation of OSG during observation in SEM

Organosilicate glass (OSG) thin films are **low – k materials** which are needed to reduce signal delay time and cross-talk in on-chip interconnects systems. The differentiation between OSG and etch stop layers, with different chemical compositions, and the exact determination of geometrical data of the Cu/low-k structures at cross-sectioned samples are important tasks for analytical labs in semiconductor industry, for both process control and physical failure analysis. However, during the electron beam application to the sample with Scanning Electron Microscopy (SEM), the OSG network is densified, which phenomenologically causes a significant **shrinkage** of the material. Low voltage SEM in combination with the use of the Energy selective Backscattered (EsB) electron detector improves the compositional contrast and mitigates the shrinkage of the OSG caused by electron beam-induced material damage.

Shrinkage in OSG thin films



OSG thin film

Si-substrate

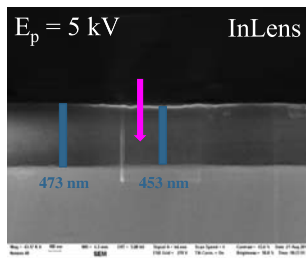
κ = 2,27

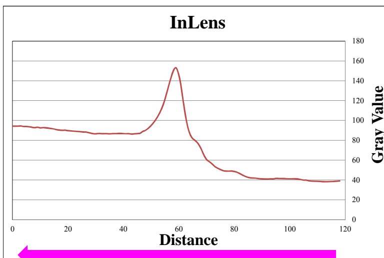
Film thickness = 468 nm

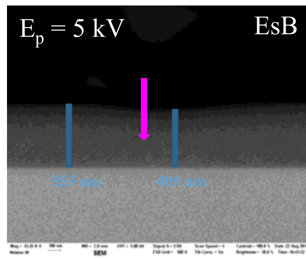
Porosity ≈30%

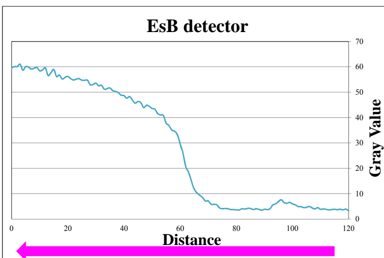
Shrinkage effect in an OSG thin film (low – k material) after 3 min. scan, high primary beam energy (E_p = 20 kV) and high magnification.

Imaging advantages of EsB detector



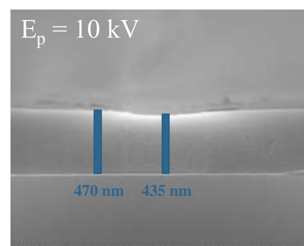


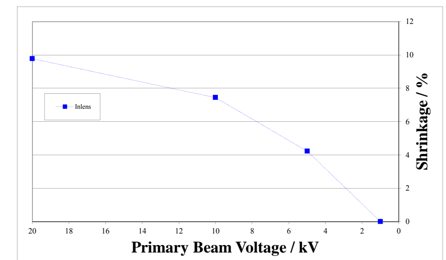


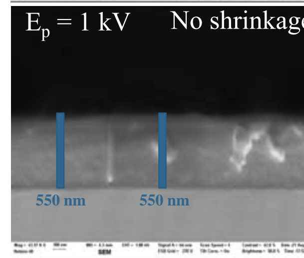


The EsB detector offers material contrast between the OSG film and the Si. Additionally, it avoids the edge effect which is present on the InLens image using secondary electrons. It can be demonstrated on the intensity profile of both images across the phase boundary (right).

Influence of the primary beam energy (E_p) on the shrinkage

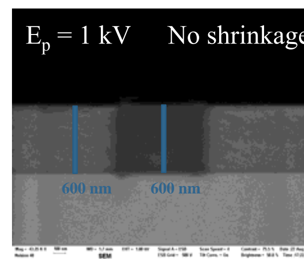






At higher values of accelerating voltage the shrinkage effect increases, but it can be avoided by working with lower values of primary beam energy. It disappears completely at Ep ≤ 1 kV.

EsB detector at low voltage: No evidence of shrinkage



No shrinkage effect in an OSG thin film at Ep ≤ 1 kV.

Due to the carbon content of the low - k material, contamination during longer exposition times occurs. This effect can be reduced by optimizing the image at a location, which is adjacent to the region of interest (ROI), and then moving to ROI for final image only.

Conclusions

- By decreasing the accelerating voltage, the severe shrinkage in the OSG thin films can be dramatically reduced, and it can be even avoided by working with Ep ≤ 1 kV .
- Working with a shorter value of working distance (WD ≤ 2 mm) is an essential requirement to image with low E_p, in order to improve the resolution.
- The energy selective backscattered-detector (EsB) can be used at lower values of E_p to obtain a good compromise between avoiding shrinkage and offering a fine resolution.

Acknowledgments

We kindly thank Carl Zeiss Microscopy GmbH for funding the investigations in the framework of the project “Untersuchungen zur Charakteristik und Applikation des EsB Detektors”.

References

[1] H. Jaksch, Carl Zeiss Microscopy, 2008.
[2] J. Cazaux, Journal of Applied Physics, 2012, 11, 1-8.
[3] H. Schatten, J. B. Pawley, Biological Low-Voltage Scanning Electron Microscopy, 2008, Springer.
[4] H. Geisler, D. Chumakov, E. Zschech, Nanomechanical Probing Techniques, NanoS 01.08, 2008, 27–33.
[5] F. Goethals, Periodic Mesoporous Organosilicas for Application as low-k Dielectric Materials, Department of Inorganic and Physical Chemistry, Faculty of Sciences, University of Ghent, 1-27.
[6] Chang et al., Thin Solid Films, 2004, 469– 470, 383–387.
[7] David C. Bell, Natasha Erdman, Low Voltage Electron Microscopy: Principles and Applications, 2013, John Wiley & Sons, 1, 1-30.