

Comparison of SCEM and STEM-HAADF Imaging in Thick Specimens

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The Scanning Confocal Electron Microscope has been shown to have significant advantages during imaging of thick specimens in both Materials and Biological applications. [1-4]. Since the electron optical configuration of STEM is a subset of the more general SCEM configuration, it is of interest to compare the performance of these two imaging modes. In the limit of infinitely thin specimens SCEM and STEM performance should be essentially be identical, this is born out by the "3D STEM" imaging of the ORNL group[5]. In this work we compare imaging at the other extreme.

A test specimen for analysis was fabricated by Focused Ion Beam (FIB) milling of a semiconductor device in a Zeiss 1500XB system. A periodic structure on the device was chosen so that resolution measurements could be made on nearly identical features as a function of thickness. Using the FIB, six flat neighboring parallel slabs were machined into the device having total thicknesses of 890, 1950, 2630, 3050, 3230 and 3870 nm (Fig. 1) measured by SEM imaging. After fabrication the specimen was mounted on a 3mm Cu slot grid and transferred to the ANL SCEM, which was operated at 300 kV in both the SCEM and STEM-HAADF mode [2]. Adjustment between imaging modes was done by changing the currents in the C1, C2, C3, Objective and P1 lenses, the P2-P4 lenses of the instruments where not utilized in these experiments. In SCEM mode only C3 and P1 lenses were employed while in STEM-HAADF C1, C2, Obj, and P1 were employed. The specimen was oriented perpendicular to the incident probe and with the features of interest on the electron exit surface of the sample to maximize deleterious thickness effects.

Figure 2 presents unprocessed images from the thinnest (890 nm) and thickest (3.87 μm) regions of this test specimen in both SCEM and STEM-HAADF modes. Identical regions of a flat Cu interconnect of width 0.8 μm were imaged in each mode. In each case the dark level of the detector was always set to zero, however the gain was adjusted to 90% of saturation on the most electron transparent area of the specimen within the field of view. Figure 3 compares the normalized intensity profiles measured across the vertically oriented interconnect for the two extreme thicknesses. In all four profiles the average background intensity was subtracted and maximum intensity normalized. For display purposes the plot uses inverted contrast, and shows only the leading edge onset. The horizontal arrow in Fig 2C indicates the nominal position at which the profile was measured in each image. In the thinner region of the test specimen the resolution difference as measured by the signal rise profile width between SCEM (~44nm) and STEM-HAADF (~49nm) is small, however we note that there is significantly more contrast available in the SCEM image due to the inclusion of diffraction contrast which is nearly absent in the STEM-HAADF image. In the 3.87 μm thick area, the profile resolution is clearly superior in SCEM (~125 nm) vs. STEM-HAADF (~275 nm) and is expected to be even greater in an aberration corrected SCEM.

References

- [1] Frigo et al. , *Applied Physics Letters Vol 81 #11, 2112, (2002)*
- [2] Zaluzec N.J., *Microscopy-Today Vol 6, 8 (2003)*. US. Patent # 6,548,810 (2003)
- [3] Hallegot P. and Zaluzec N.J., *Microsc. Microanal. 7 Suppl. 2, 679 (2004)*.
- [4] Gazda J. and Zaluzec N.J., *Proceedings of ISSM 2004, Tokyo Japan, Oct. 2004* in press.
- [5] Peng Y. et al *Microsc. Microanal. 7 Suppl. 2 , 197 (2004)*.

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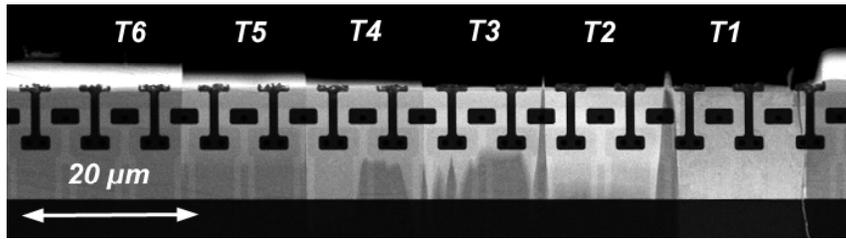


Figure 1:
Low Magnification image showing the test specimen and the 6 thickness zones. T1-T6 = 890, 1950, 2630, 3050, 3230 and 3870 nm

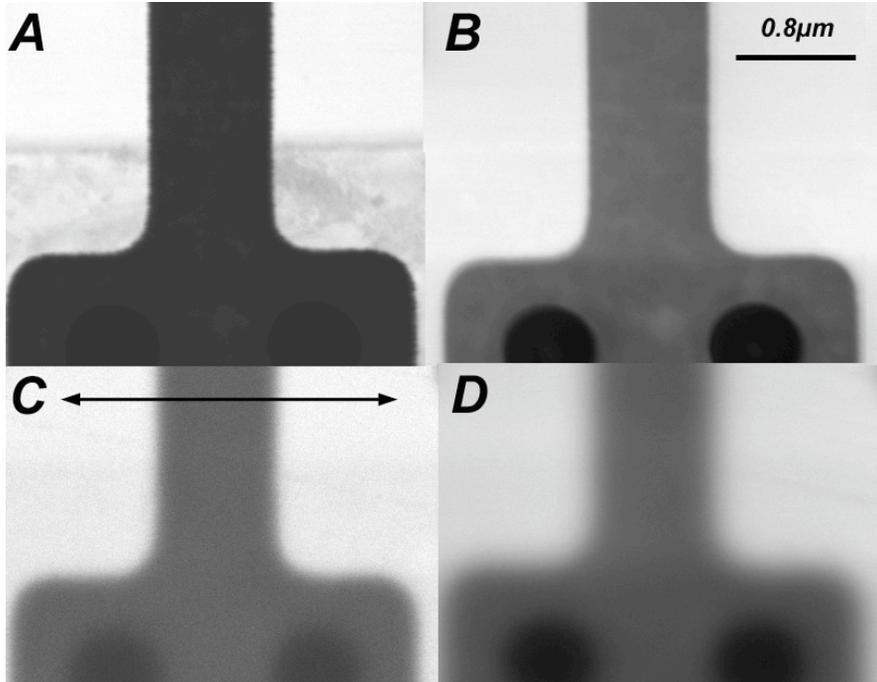


Figure 2. Comparisons of SCEM(A,C) and STEM-HAADF (B,D) images in 890 nm (A,B) and 3870 nm (C,D) thick sections of a Cu interconnect in semiconductor device. The horizontal arrow in C, indicates the position in all images where the edge profile measurements were performed.

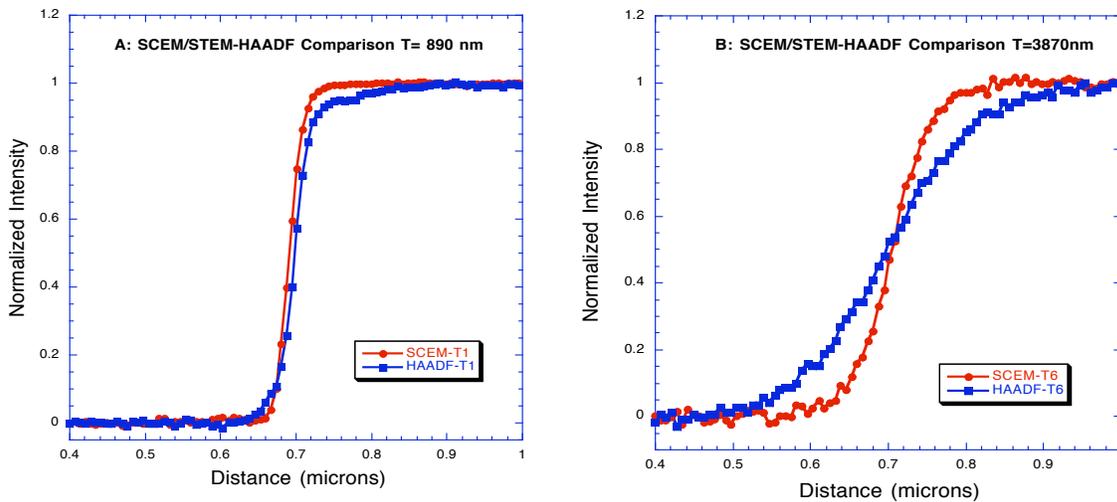


Figure 3. Comparison of normalized intensity profiles for SCEM and STEM-HAADF data of Fig 2. The location of the profile measurement shown corresponds to the horizontal arrow at the top of Fig. 2C, Note: profiles are shown with inverted contrast (light=0, dark=1) and for clarity only the leading edge across the Cu interconnect is shown.