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Secondary Electron Grain Contrast Induced by Incident Electrons in a Electroplated Copper Thin Film

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The difficulty in achieving desired grain structure for optimal copper interconnect line resistivity and reliability is a major concern for semiconductor industry. The characterization of the grain in narrow features is either difficult with the focus ion beam (FIB) because of the poor resolution or time consuming (sample preparation) with the transmission electron microscope (TEM). In this work, the secondary electron grain contrast obtained by incident electron is studied as possible characterization technique of small grains with good spatial resolution and easier sample preparation than TEM.

Figure 1 shows the same cross section area of an electroplated copper thin film obtained with incident electrons (eSE) and incident ions (iSE). Clearly, the same grain orientation information observed with either technique is similar, eSE image shows a better resolution and better signal to noise ratio than the iSE image, but iSE image shows a stronger contrast between adjacent grains. The better spatial resolution of eSE image gives a more detailed image and allows a higher magnification than the ion image. iSE images are more sensitive to surface topography, which can mask the grain contrast. Preliminary results have shown that grain size between 10 to 100 nm can be observed with eSE. However, the contrast between grain is weak and the instrument conditions (energy, current), sample preparation, and contamination are important factors that influence the quality of the image contrast. For example, carbon contamination will rapidly degrade the contrast of the eSE image [1].

Two different grain orientations do not always give a grain contrast with eSE image. Changing the incident electron angle can help show the boundary between two grains as shown in figure 2. Change of $\pm 5^\circ$ from the nominal specimen tilt of 52° show change in the grain contrast and even contrast reversal (bright/dark to dark/bright).

These sample tilt results suggest that the electron channeling can be the mechanism responsible for this grain contrast [2]. Comparison with the backscattered electron image, backscattered electron diffraction, focus ion beam, and helium ion microscopy will help to understand this contrast mechanism. Monte Carlo simulation with simple electron channeling models will be used to understand the effect of instrument conditions and grain orientations on the contrast observed experimentally.

References

[1] Hamed Parvaneh, Hendrix Demers, and Eric Lifshin. Efficiency of evactron for removing electron beam induced contaminations. 2009. In this proceeding.

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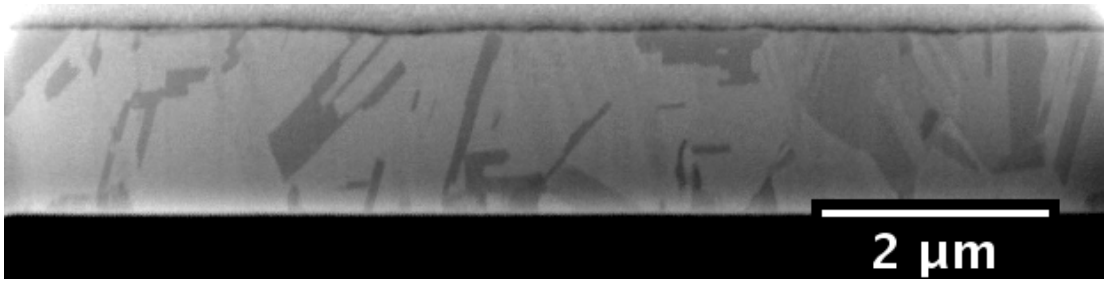
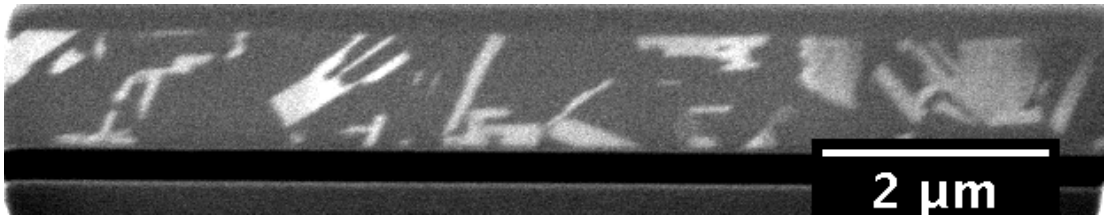
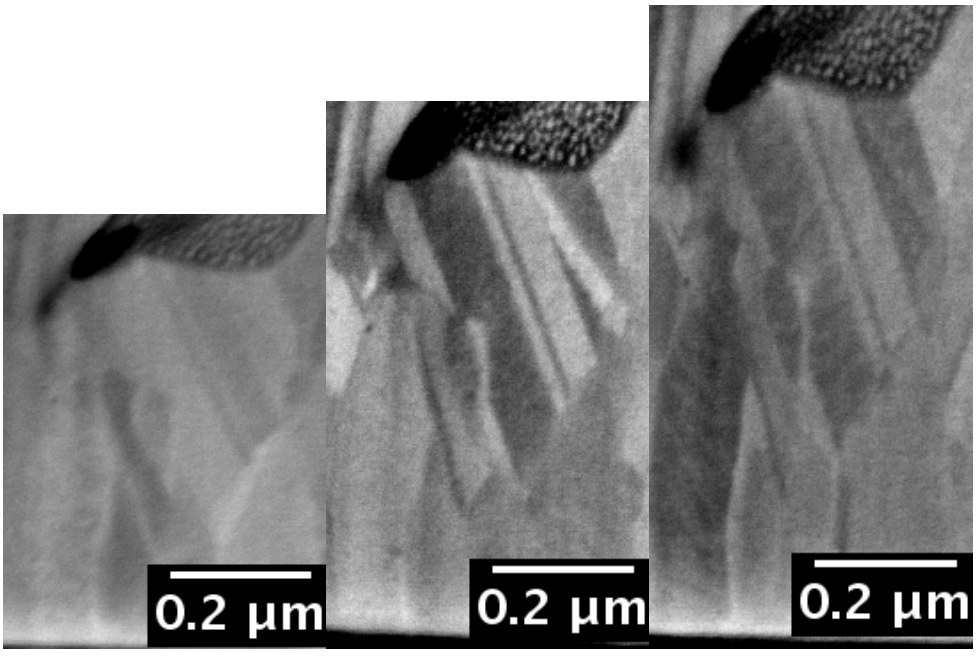


a) eSE



b) iSE

Figure 1: Grain contrast images of a cross section of an electroplated copper thin film obtained with a FEI Dual Beam 400 SEM/FIB. a) Secondary electron image induced by incident electron (SEM) with software tilt correction. b) Secondary electron image induced by incident ion (FIB) without software tilt correction.



47° 52° 57°

Figure 2: Grain contrast images variation with sample tilt of a cross section of an electroplated copper thin film obtained with a FEI Dual Beam 400 SEM/FIB. Software tilt correction was used for each images.

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