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Full Wafer Particle Analysis of sub-50nm Defects by Auger Electron Spectroscopy (AES)

In the competitive semiconductor marketplace, rapid development of new semiconductor designs and shrinking design rules drive the need for continuous yield enhancement. As design rules shrink, the critical defect size becomes smaller and the identification of defects becomes more challenging. Correct compositional identification of wafer defects has become vital for optimizing tool performance and can have significant financial impact.

Defects are usually first discovered in an optical detect mapping tool, which typically provides location and sizing information for the defects (Fig. 1a). A map is generated that shows the location of the defects on the wafer (Fig. 1b). Individual defects are then located using the coordinates provided by the particle scanner and an SEM image of the defect is obtained (Fig. 1c). Finally, a compositional analysis is performed (Fig. 1d)

Historically, defects have been analyzed by Energy Dispersive X-Ray Spectroscopy (EDS); however, only a small fraction of the X-rays collected in a standard EDS analysis originate from the defect due to the large sampling volume of the technique. This situation becomes increasingly worse as defects become smaller, which often can lead to inconclusive results. This problem can be mitigated to some extent by using low accelerating voltages and windowless detectors but still leaves only the less reliable low energy spectral lines for analysis.

In contrast, the high surface sensitivity and small analysis volume of Auger Electron Spectroscopy (AES or Auger) makes Auger the ideal technique for the analysis of sub-50nm defects. Since the sampling depth is independent of acceleration voltage, high beam energies can be used to excite all available transitions in the spectrum. The Auger signal is collected mainly from the surface of the defect (Fig. 2) and as a result, the signal contribution from the defect stays nearly constant with shrinking defect size. Auger spectra do also contain some contribution from the substrate due to beam scattering, which can be minimized but not eliminated.

Figure 3 shows some examples of Auger spectra collected from small defects of various sizes. Excellent sensitivity, as documented by the strong signal intensity, is maintained down to a defect size of only 20nm, with some signal drop-off below this size.

The high surface sensitivity of the technique can be a useful tool for identifying contaminants on the surface of the defects that might be related to their root cause. In combination with ion sputtering, the composition of the defects can also be analyzed as a function of depth to determine: the thickness of the surface oxide; whether contaminants are really only present on the surface; or whether the defect is buried or has an outer layer that is different from the bulk. In the examples in Fig. 3, spectra were acquired as received and after sputter cleaning. C and O detected on the surface of the defects were mostly related to environmental contamination and surface oxidation. Sputtering exposed the particles actual composition: Cu, Al, Cu, AlO_x, respectively.

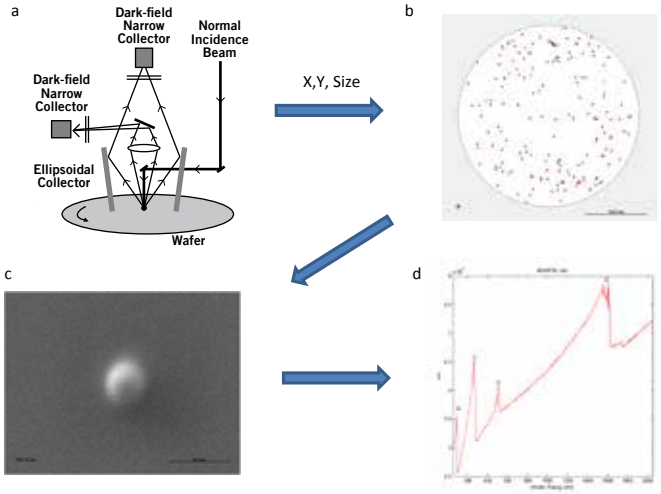

Figure 1: Particle analysis workflow: (a) Particle Scanner, (b) Defect Map (c) SEM image (d) Spectrum

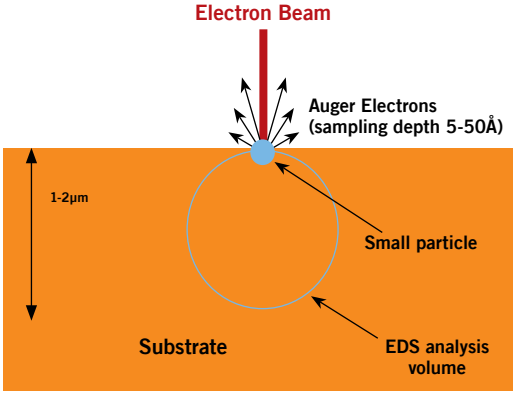

Figure 2: Comparison of detection volumes, AES vs. conventional EDS

Compositional analysis by Auger can be performed on bare, coated or patterned wafers with a wafer diameter of up to 300mm. Photomasks can be analyzed as well, as long as a conductive layer is present on the surface of the reticle. EAG's full wafer Auger tools are compatible with defect coordinates provided by industry standard optical inspection tools and can accept a variety of file formats. Analysis of defects on wafers can provide valuable compositional information that can lead to enhanced yields for semiconductor production.

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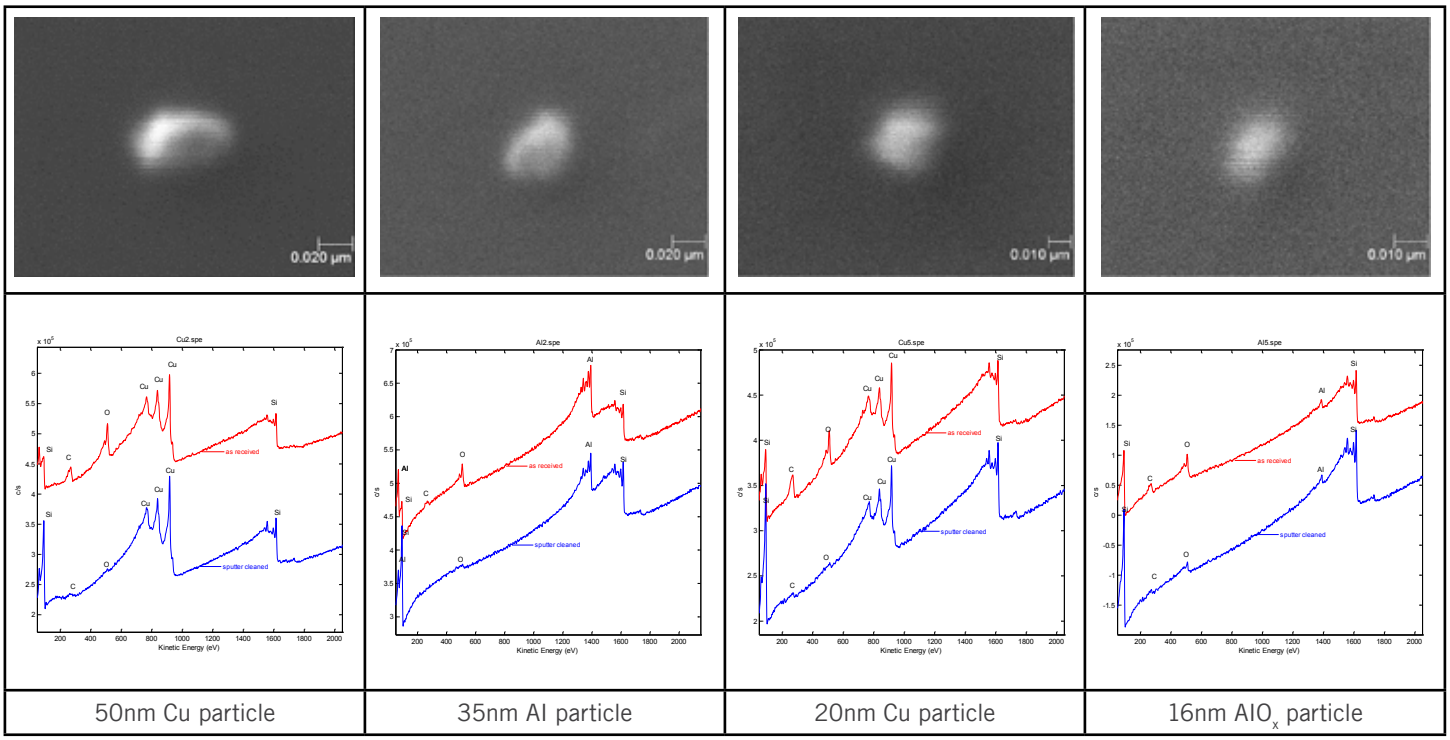

Figure 3: SEM images and Auger data collected on defects of various sizes from 50nm down to 16nm. Spectra were acquired before and after sputtering.