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# Energy Contrast from Si Low Loss at 74 eV for Semiconductor Devices

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Use of a specific energy range in a energy filtered TEM (EFTEM) to enhance image contrast of specific features is increasingly being applied to speed up analytical and imaging experiments [1,2,3]. The improved contrast (energy contrast) can be compared with putting in an objective aperture to enhance amplitude contrast, or by going to a microscope with lower Cs to enhance phase contrast. For energy contrast, an energy filter is needed. The improved contrast provides a faster method to define the edge profiles of a structure. An energy range at 74 eV has been found to be very useful for polycrystalline silicon gate/gate oxide characterization in semiconductor industry. The $74\pm10$ eV energy range is at the tail of the silicon low loss peak. The intensity difference between crystalline silicon (Si) and amorphous silicon dioxide ($SiO_2$) at the low loss tail as shown in Fig. 1 is the main reason for the greatly beneficial contrast enhancement. Each example of this application is described in detail below. The images show the difference between zero-loss filtered and 74 eV energy contrast.

A. **Poly silicon gate profile and dimension measurement -** The first example is for samples with a curvature variation in the gate sidewall along the line. The zero loss image (Fig. 2a) show fuzziness at the edge whereas the 74 eV energy contrast image reveals two gray levels at the edge of the gate; the darker one has been established as representing the true gate outline. The second example is for sample that was totally amorpholized and contaminated with re-deposition in the FIB during sample preparation (fig. 2c). Nevertheless, the poly gate profile is well defined in the energy contrast image (fig. 2d).
B. **SiO2 gate oxide thickness measurement -** An elastic image (i.e. zero-loss filtered) is shown in fig 3a from a typical FIB prepared sample of a gate oxide over an isolation field. The oxide thickness, especially at the corner, is hard to measure accurately. If this image is compared to the energy contrast image shown in Fig 3b, it can be seen that the oxide layer is much more clearly defined. The thickness can be determined from intensity profiles across the oxide layer.
C. **Poly silicon residue defect -** Fig. 4a shows an image of a defect that causes the device to fail as open contact. The zero-loss filtered image shows a dome of oxide and nitride under the contact as the root cause. However, as shown in Fig. 4b from the energy contrast image, a stick with darker contrast as evidence of poly can be seen inside the dome.
D. **Poly silicon film surface roughness -** The roughness of the blanket poly film in this sample is very hard to tell in the zero loss filtered image (fig. 5a) but the phenomenon is clearly seen in the energy contrast image (fig. 5b).

References

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[2] L. Tsung et al., Proc. *Microsc. Microanal.* 8 (suppl. 2) (2002) 1194 cd
[3] J. Bow, et al., Proc. 28th ISTFA by ASM International (2002) 101- 105

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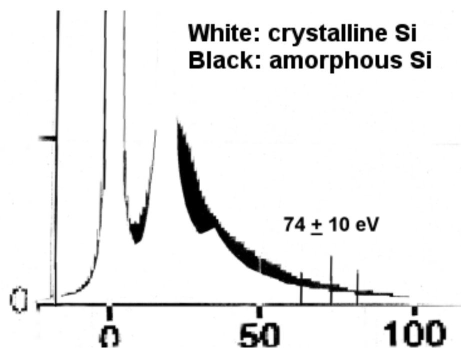


Fig. 1 – EELS from Si and SiO2

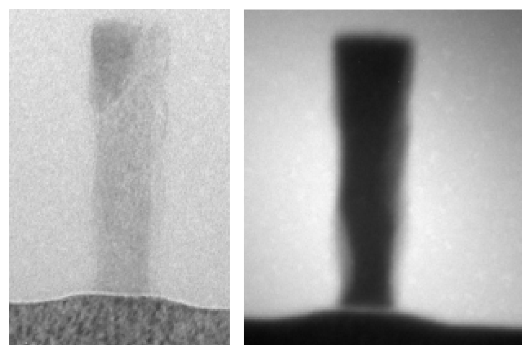

Fig. 2a – zero loss; 2b- 74 eV energy contrast

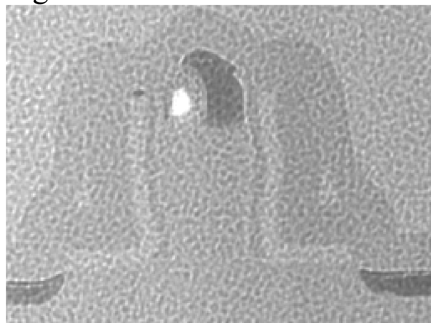

Fig. 2c– zero loss

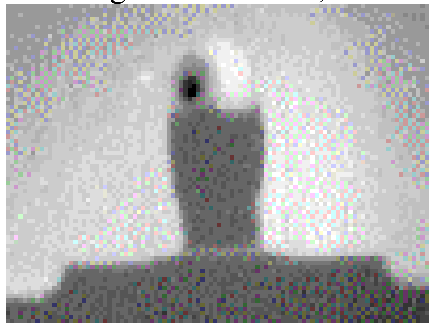

Fig. 2d- 74 eV energy contrast

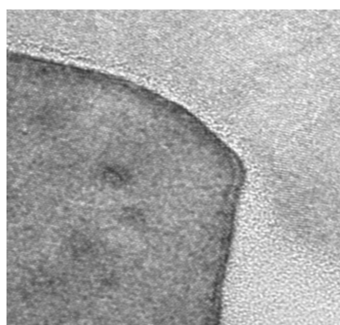

Fig. 3a – zero loss

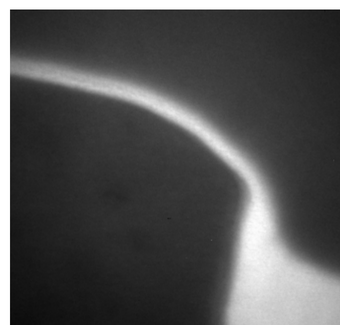

Fig. 3b- 74 eV energy contrast

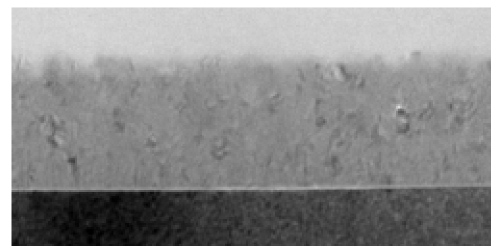

Fig. 5a- zero loss poly film

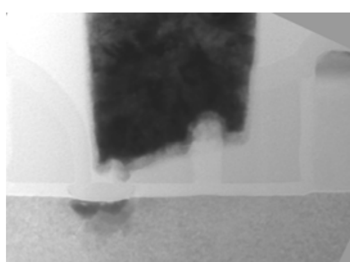

Fig. 4a – zero loss

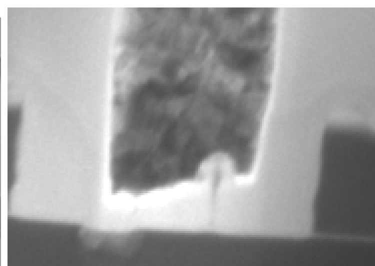

Fig. 4b- 74 eV energy contrast

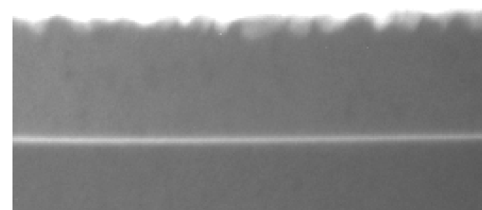

Fig. 5b- 74 eV energy contrast

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