Microsc. Microanal. 8 (Suppl. 2), 2002
DOI 10.1017.S1431927602105927

COMBINING EELS AND ANGLE-RESOLVED AES TO MEASURE SHALLOW PROFILES OF THIN NITRIDED OXIDE FILMS ON SI.

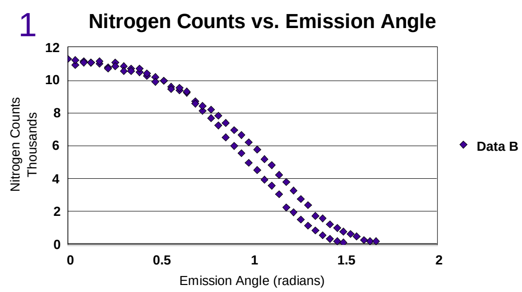
J. Bruley, H. Wildman, A. Paterson, IBM Microelectronics Division, Hopewell Junction, NY

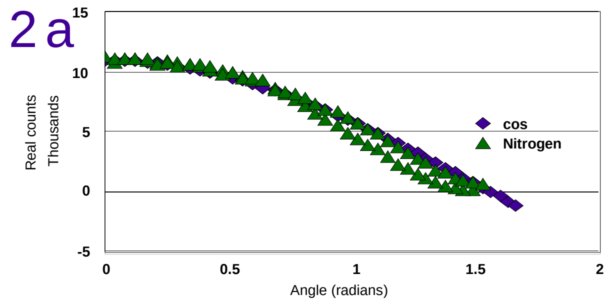
The use of thin oxynitride or nitrided-oxide films in advanced CMOS technology is motivated by the increase the dielectric constant, reduction in gate leakage relative to SiO2 and ability to block dopant diffusion out of the polysilicon p-FET gate material [1]. Since the properties of the dielectric depend critically upon the details of N distribution, methods are sought that can characterize the nitrogen profiles of 1-2nm thick films in small areas. In this study we explore the application of angle-resolved Auger Electron spectroscopy (AES), comparing the results with high resolution phase contrast TEM images and elemental line profiles measured with EELS in STEM.

Since Auger yield is very sensitive to the distance from the sample surface, a depth profile can be extracted from a series of angle-resolved AES. High energy-resolution provides chemical state information. Whilst a benefit of this approach over the conventional sputter depth profiling is the absence of cascade ion-mixing, damage from the electron beam precludes high lateral spatial resolution. For a uniform distribution of N or O with depth, the intensity of the appropriate signal should scale simply with the cosine of the detector angle. Model elemental distributions are used to simulate the angular intensity distribution of the Auger signals using a Simpson's integral and a minimization technique is used to optimize the resultant profiles. An angle resolved data set is shown in figure 1. Note that as the emission angle increases the counts decrease as expected. Figure 2 compares the distribution of the O and N with the cosine function. The small deviations from this cosine seen in the figure reflect non-uniform variations in the elemental concentration profile. Qualitatively, the excess oxygen signal, and deficit N at high angle indicates a O rich film near the oxynitride surface.

A HREM image of the oxynitride film is shown in figure 3. In this case, the amorphous film was coated in Cr to enable sample preparation by mechanical polishing. This image suggests that the Si surface is atomically sharp with a dielectric film of 1.7nm thick. Compositional variations such as might be evident with a nitride rich layer at the Si interface are not visible in such phase contrast images. Atomic resolution STEM was carried out in a Jeol 2010F FE-TEM using the 0.3nm probe size. An elemental profile was measured by EELS spectrum profiling. Figure 4 shows a series of the data taken at 0.2nm spacing. The integrated counts within the N and O K-edges are shown in figure 5 and confirm that there is a 0.7nm outer layer of oxide which is denuded in nitrogen.

References
[1]E.P. Gusev et al. IBM J. Res. Devp. **43** 265-286 (1999)





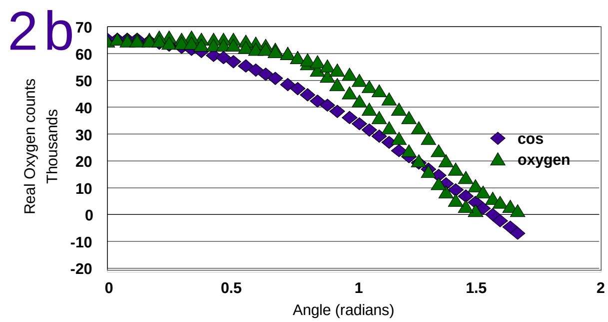


FIG 1: Angle resolved Nitrogen signal

Figure 2a: Comparison of N Signal with cosine function

Figure 2b: Comparison of O Signal with cosine function

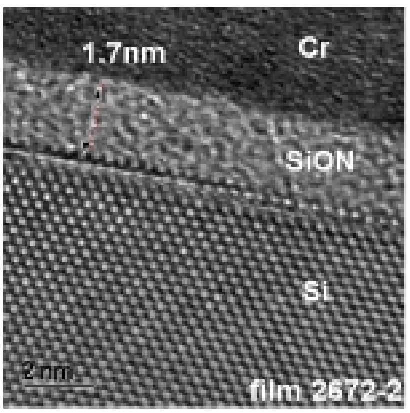


Figure 3: HREM image of oxynitride film

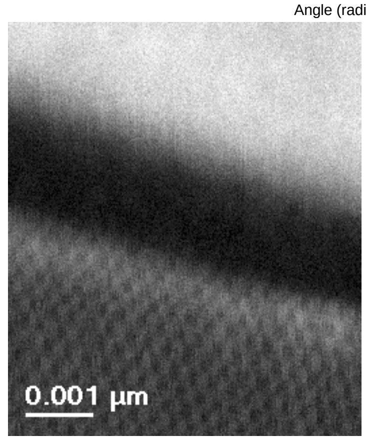


Figure: ADF image using 0.3nm probe size

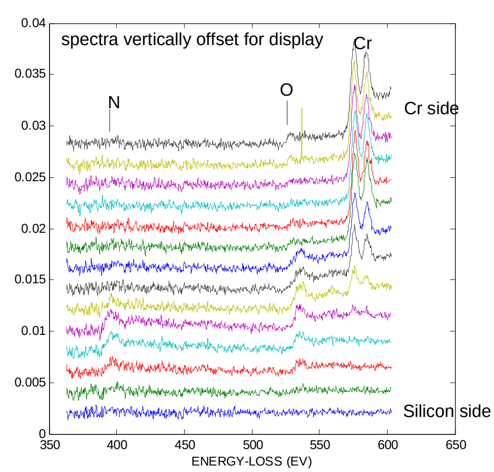


Figure5: Spectrum line series

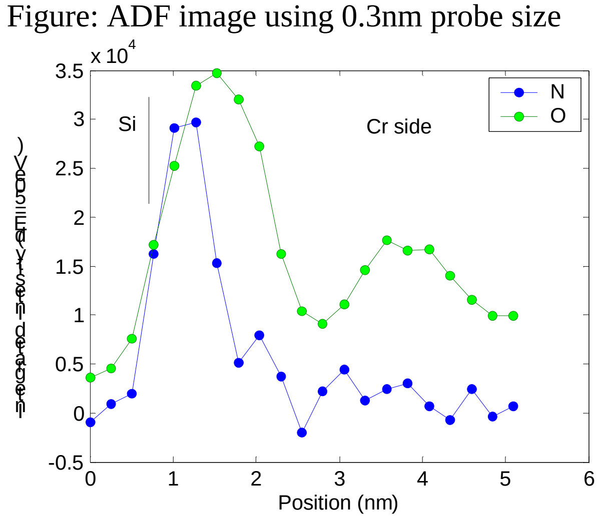


Figure 6: Elemental profile extracted by EELS.

https://doi.org/10.1017/S1431927602105927 Published online by Cambridge University Press