

Comparison between EDS and EELS

INTRODUCTION

EDS (Energy Dispersive X-ray Spectroscopy) and EELS (Electron Energy Loss Spectroscopy) are elemental analysis techniques integrated with electron microscopes such as TEM (Transmission Electron Microscope). Both techniques provide nanometer-level or atomic-level direct observations and semi-quantitative analysis into materials elemental distribution and concentration, enabling accurate measurement of small complex structures such as FINFET or 3D NAND.

However, the analysis of EDS and EELS require different tool configurations, electron beam settings and analysis approaches. It is often not clear as for which technique is more appropriate for a certain analysis. In this application note we compare the respective strengths and limitations of EDS and EELS, by the case studies of a cross-section 3D NAND flash memory sample and a gate-cut FINFET sample. We also show our capability of performing simultaneous EELS and EDS that combines their respective advantages. All analyses were performed on a Cs Probe-Corrected ThermoFisher Titan.

RESULTS AND DISCUSSION

EDS spectrum has a wider energy range. As a result, EDS is able to detect most elements without any setting parameter adjustments. It is especially useful if one needs to know an unknown material's composition. Figure 1 shows EDS and EELS mapping of a cross-section 3D NAND sample. From EDS mapping, constituent elements including N, O, Al, Si, Ti and W are detected. However, in EELS, spectrum energy range is relatively limited, so is the number of detectable elements. For example, in the initial EELS mapping (fig.1b), Al, Si and W are not seen. To resolve this issue, some knowledge of the sample material is needed to adjust EELS acquisition setting parameters. Figure 1c shows another EELS mapping at the same region with the correct parameter set up, after the elements of constituent have been confirmed by EDS. Al/Si/W signals are clearly shown.

EDS is relatively not sensitive to light elements such as Nitrogen. Nitrogen in barrier TiN surrounding W wordline is clearly seen in EELS mapping, while such information is not available in EDS.

Once the elements of constituent are confirmed, EELS generally provides more accurate relative concentrations. Figure 2 shows semi-quantitative line scan analyses of the W-rich wordline and the SiO₂ spacer region, acquired by EDS and EELS respectively. In the spacer SiO₂ region, EDS line scan shows O:Si≈55:40, while EELS line scan shows O:Si≈65:35, much more close to

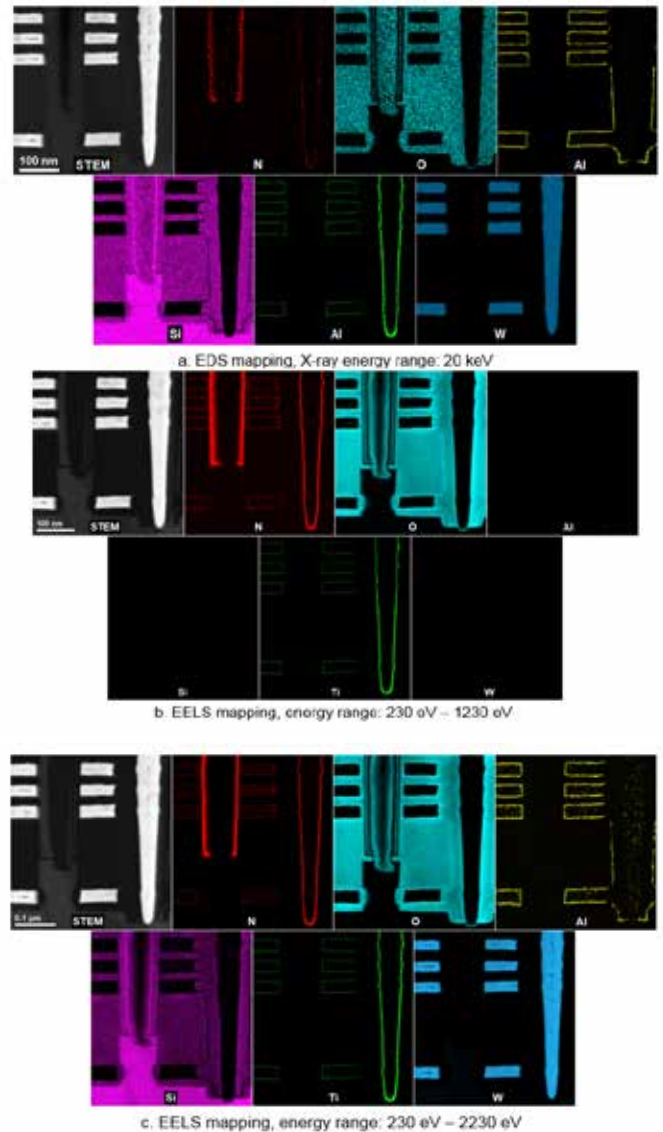


Figure 1: a. EDS mapping; b. Initial EELS mapping; c. EELS mapping with optimized setting to cover all elements.

theoretical value 2:1. In both SiO₂ and W region, EDS detects dilute amount of N and Ti. However, from EELS, it is evident that these elements are not real, but rather artifacts as a result of inaccurate background subtraction in EDS calculation. Such background subtraction is conducted automatically by EDS software and is unlikely to completely avoid.

One of the advantages of EELS over EDS is that EELS is able to help identify bonding information. Figure 3 shows different

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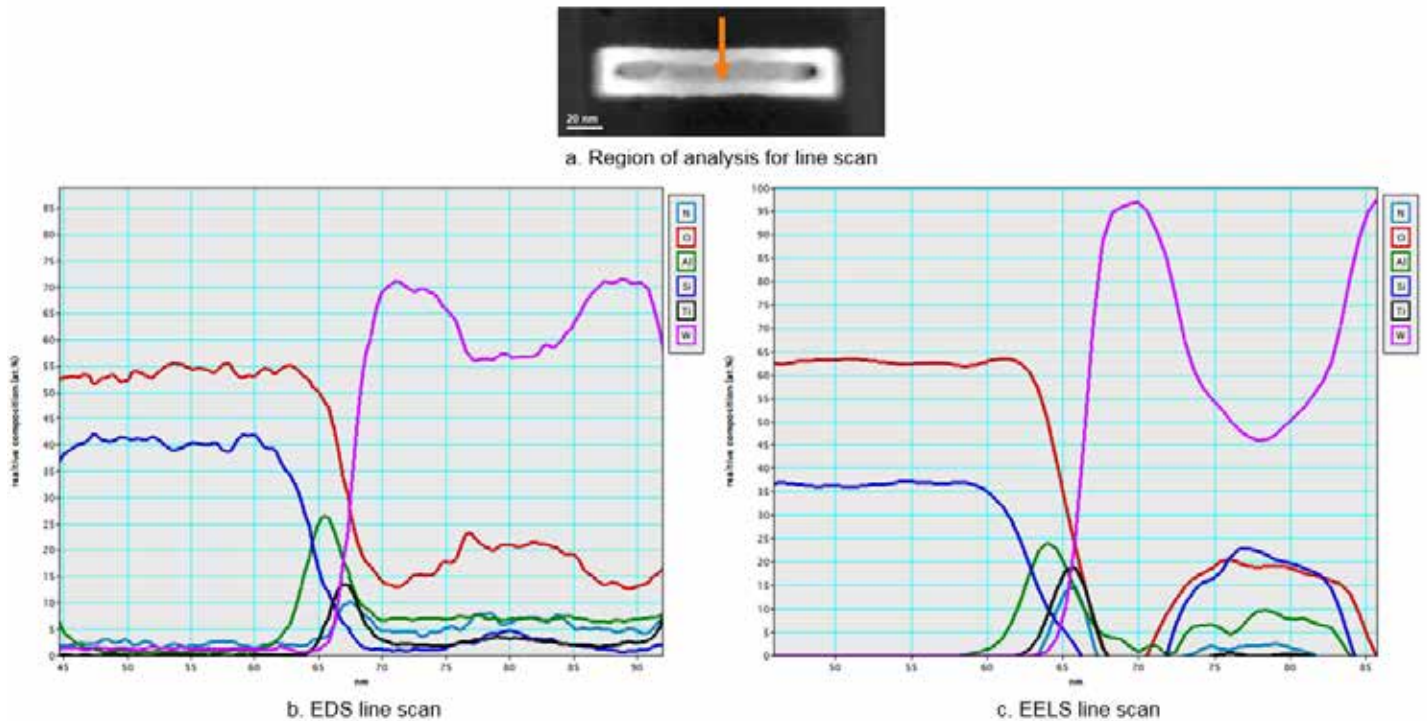


Figure 2: Semi-quantitative line scan analysis of NAND: a. Region of line scan; b. EDS; c. EELS

EELS spectra of Nitrogen bonded to Titanium and Silicon. Such spectrum shape difference can be used to differentiate N in SiN and N in TiN, and thus can be used to analyze either compound's distribution.

Nanolab Technologies provides simultaneous EELS/EDS that combines the advantages of EELS and EDS. This unique service enables accurate analysis of light elements with EELS and detection of elements that are not suitable for EELS at the same region within one scan. Figure 4 shows the EDS spectrum extracted from the EELS results in figure 1c near the etch bottom. Such capability is especially useful for detection of etch residuals such as Fluorine or Chlorine, when accurate analysis of C/N/O/Si is still needed.

SUMMARY

Below is a brief summary of the respective strengths and limitations of EDS and EELS. Due to the complexity of elemental analysis, it is highly recommended to have a discussion with an expert before moving forward to analysis.

EDS	EELS
Heavy Elements	Light elements (Li, B, C, N, O...)
Full element survey (except for H, Li, B...)	Selective element survey
Good for unknown	Good for detail
	Chemical bonding
	Less artifact (Cu, Zr, Mo...)
	Band gap, thickness...

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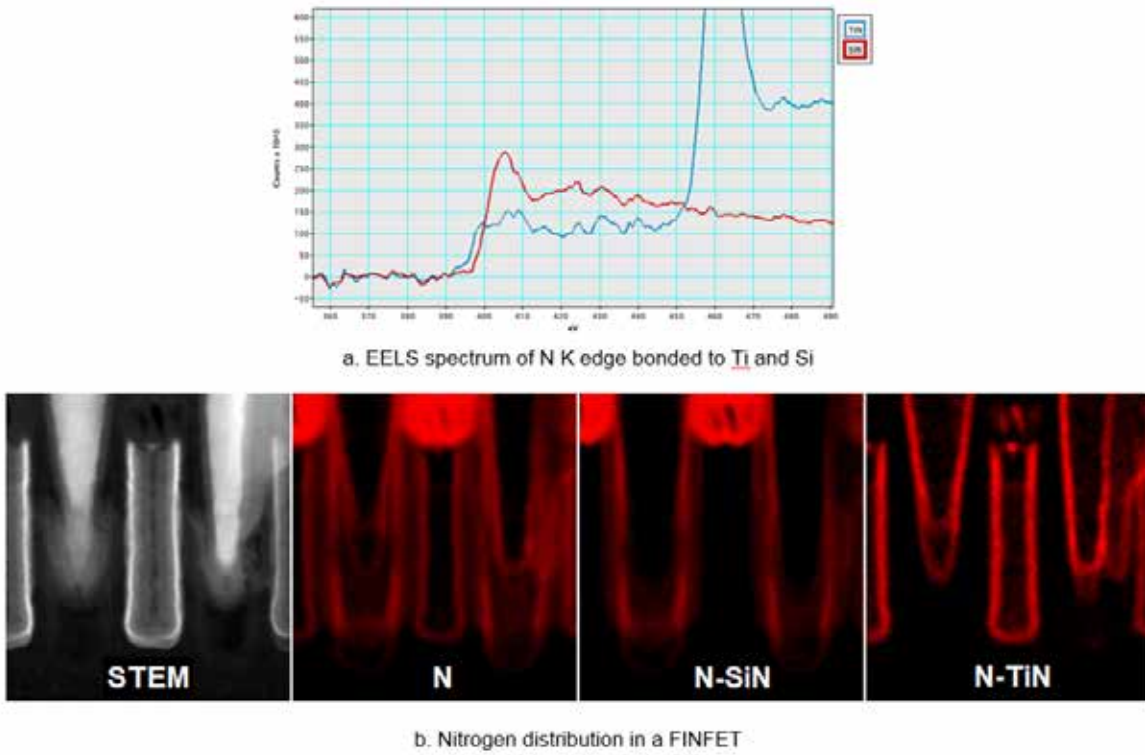


Figure 3: Nitride distribution in a gate cut FINFET: a. Comparison of EELS spectra of N bonded to different elements; b. Nitride distribution in a FINFET

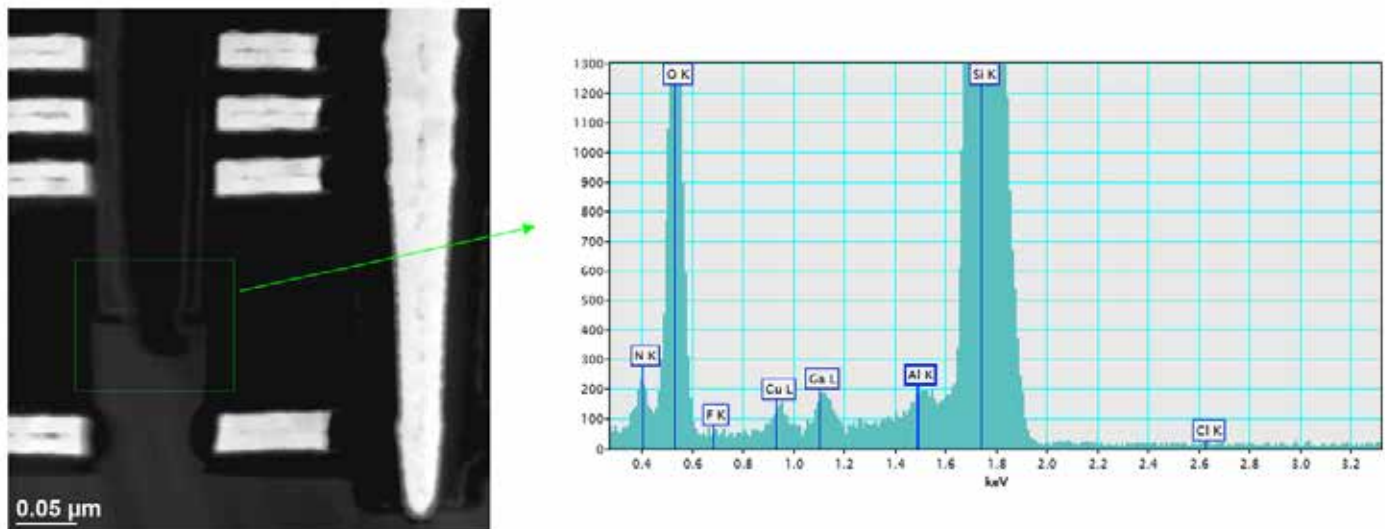


Figure 4: EDS spectrum extracted from a simultaneous EELS+EDS dataset