GATAN

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Application Note

High-Speed Composition and Chemical Analysis of Nanoelectronic Materials with GIF Continuum

Introduction to the GIF Continuum

The GIF Continuum® series represents the next generation of electron energy-loss spectroscopy (EELS) and energy-filtered transmission electron microscopy (EFTEM) systems from Gatan. In these systems, Gatan's exclusive detector technology, advanced software, and electron optics are combined into a single acquisition platform capable of delivering spectral acquisition rates as high as 9,000 spectra per second with near 100% collection efficiency and low noise over an energy range of over 3,000 eV per spectrum. As shown in Figure 1, this has considerable advantages for chemical mapping and analysis of nanoelectronic materials and devices. The GIF Continuum delivers high quality, and superior signal-to-noise ratio (SNR) maps across the full energy-loss range due to the system's exceptional sensitivity and collection efficiency.

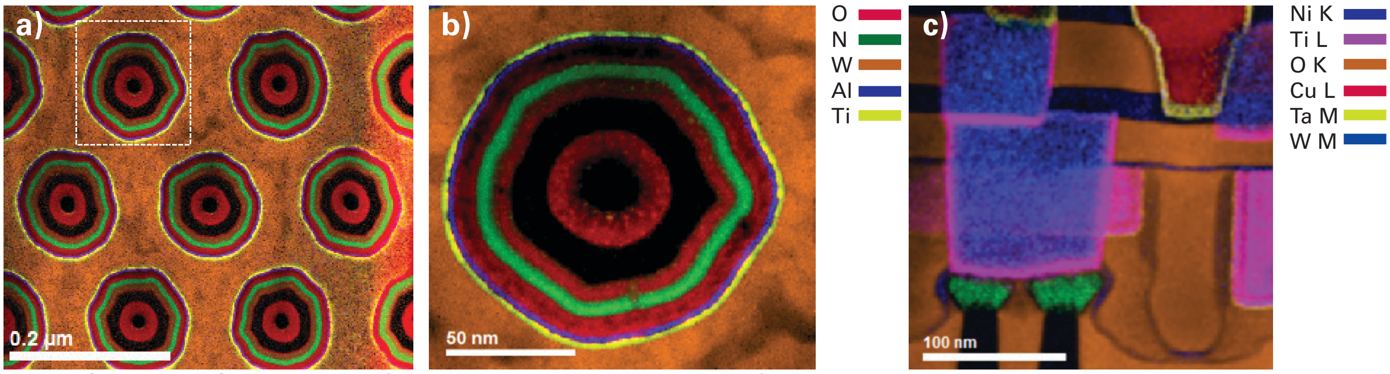
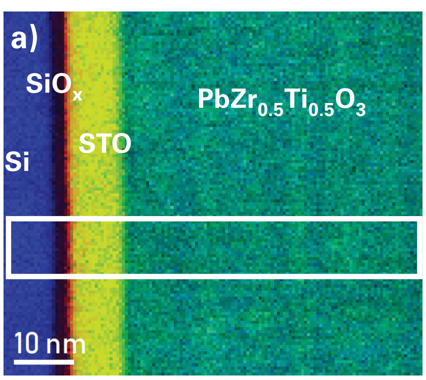


Figure 1. Composite EELS elemental maps of a) 3D NAND device, b) single memory cell from the highlighted area in Figure a, and c) FinFET device.

Core-loss EELS Analysis of Piezoelectric Ceramics with GIF Continuum

Nanoelectronic materials typically have high surface-to-volume ratios due to their low dimensionality. As a result, local changes in chemistry at interfaces, such as oxidation state or atomic coordination environment, significantly affect their functional properties. Energy-loss near-edge fine structure (ELNES) analysis of core-loss ionization edges gives access to this information. To perform reliable ELNES analysis, higher quality EELS data must be captured than is typically required for simple elemental mapping, as the whole edge shape must be recorded.

EELS spectra and elemental maps acquired from a piezoelectric multilayer stack ($Si/SrTiO_3/PbZr_xTi_{1-x}O_3$ (PZT)) are shown in Figure 2. PZT represents a challenging system due to the presence of low and high Z elements in a single material. The Ti L and O K edges at 456 eV and 532 eV are separated from the Zr L and Pb M edges at 2,222 eV and 2,484 eV, by almost 2,000 eV. The large energy field of view of the GIF Continuum allows all four ionization edges to be collected in a single spectrum, with short pixel dwell time (5 ms) while also maintaining high SNR due to the detector sensitivity. The improved spectral quality from these detectors also allows for good ELNES analysis. Figure 2b shows Si K spectra extracted from the Si substrate and $SrTiO_3$/Si interfacial layer. There is a clear change in ELNES shape and energy shift from one spectrum to the other, indicating Si oxidation at the $SrTiO_3$ interface.



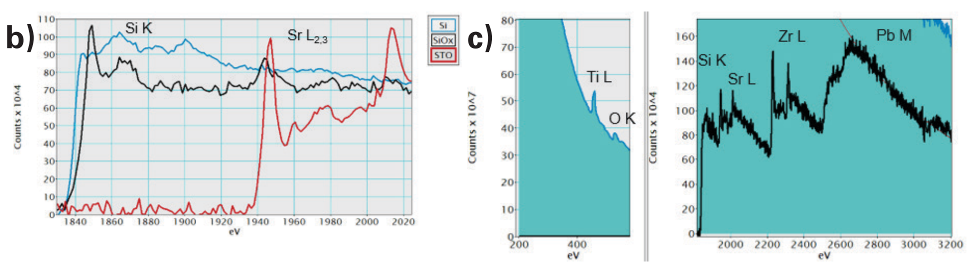


Figure 2. a) Composite EELS elemental map of Si/STO/PZT. b) Extracted spectra showing Si K and Sr $L_{2,3}$ edges in the Si substrate and $Si/SrTiO_3$ interface. Note the change in Si K ELNES shape and chemical shift c) EELS spectrum integrated from the highlighted region in Figure 2a. The Ti L and O K edges shown separately from the background subtracted high energy-loss edges for clarity.

Summary

The GIF Continuum significantly extends the analytical possibilities with EELS, as seen here in the spectrum imaging of 3D NAND and FinFET devices, in addition to multilayer composites such as Si/STO/PZT. The advantages of the GIF Continuum extend to all current samples of interest for EELS characterization and samples where EELS analysis was not possible using previous spectrometer technology.

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