Recent years have seen an acceleration in the pace of semiconductor development, driven by an ever increasing demand for high-performance, low-cost electronic devices. The ability to mass produce complex structures on a nanometre scale is critical to this process, requiring reliable characterisation techniques to measure and control key parameters of interest. The concentration and distribution of dopant atoms within semiconductors directly affects device performance, requiring analytical electron microscopes capable of accurate elemental quantification on a nanometre scale. This work focuses on the challenges in analysing advanced semiconductor structures, and the developments in microscope technology, EDS detectors and post-acquisition analysis routines which make this possible.

**Figure 1 left** shows a HAADF STEM image of an As/ P dopant distribution within a NMOS transistor, characterised using a JEM-2800 transmission electron microscope (TEM), a JEOL 100 mm2 (solid angle = 0.95 Sr) silicon drift detector (SDD) in conjunction with the NORAN System 7 microanalysis platform. The concentration of the dopant regions is low (<0.1%), within small regions (<5% area), as shown in the cumulative spectra in **Figure 1 right**. Whilst quantitative elemental mapping (peak deconvolution and background subtraction) eliminates many of the problems associated with traditional elemental analysis (**Figure 2**), such as overlapping peaks, many hours can be required to acquire statistically significant data. Furthermore, determining phases from such ‘Quant’ maps often results in end-user bias and the misidentification of chemically unique phases.

COMPASS is an ideal tool for EDS analysis under such extreme conditions, utilising multivariate statistical analysis (MSA) in order to extract the principle components of the spectra at each pixel and group statistically similar phases. **Figure 3 left** shows the composite phase map using COMPASS, **Figure 3 centre** shows the principle component map of As Doped Si and **figure 3 right** overlays spectra of each component. COMPASS extracts spectra relevant only to the specific phase of interest, enhancing the signal-to-noise ratio in comparison to the quant maps and assists in the detection of trace elements within a phase of interest. The end result is the significant reduction in acquisition time and the detection of physically significant phases **Figure 4**, otherwise missed by conventional spectrum-based phase approaches.

This work is set in the wider context of developments in analytical electron microscopy and the role this plays in improving advanced manufacturing processes.
Fig. 1: Figure 1 Left HAADF image of analysed area of a NMOS transistor. Right Cumulative spectrum for all pixels in the data set.

Fig. 2: Figure 2 Left Conventional peak count. Right quantitative elemental map of selected elements within the NMOS device. Ta is incorrectly displayed on a conventional elemental map due to overlaps with Ha.

Fig. 3: Figure 3 Left Composite COMPASS element map of Si regions. Centre Principle component map of As doped Si. Right selected area specta of Si phases.

Fig. 4: Figure 4 Left Composite map of non-Si phases. Right Spectra of principal components 10 and 12. Component 12 was not uniquely identified during spectrum based phase analysis.