Development and applications of backscattered electron and X-ray detector

Dr Katherine Macarthur[1], Haithem Mansour[1], John Zhang[1], Anthony Hyde[1], Simon Burgess[1], Philippe Pinard[1]
[1]Oxford Instruments NanoAnalysis, High Wycombe, United Kingdom

Electron microscopical analysis frequently suffers from the criticism that we're only investigating a small region, a small percentage, of the whole material. When we only investigate minute regions of the sample, how can we make sure we're not biased by what we find or haven't found? How can we make sure that we're achieving a realistic overview of the sample? One strategy to increase the sampling is to acquire a large area mapping, where secondary electron (SE), backscattered electron (BSE) and X-ray signals are collected over 100 to 10,000's of fields by moving the stage to cover the entire sample. The rate limiting factor is usually the throughput and sensitivity of the energy dispersive spectrometry (EDS) detector(s) to collect enough X-rays to achieve an acceptable signal-to-noise ratio (SNR) for all elements in the sample.

One solution is to increase the solid angle of the EDS detector, by moving it under the pole piece of the scanning electron microscope (SEM), while keeping the ability to acquire SE and BSE signals simultaneously. In 2023, we introduced a detector which combines both X-ray and BSE sensors into one device (Unity, Oxford Instruments, UK). The head features two circular silicon drift detector X-ray sensors, two custom shaped BSE sensors and two cutouts to give unobstructed line-of-sight to conventional EDS detectors. Here, we will lift the lid on some of the important developments required to bring together the backscattered electron and X-ray (BEX) detector system. Figure 1 shows the type of data which achievable with this detector.

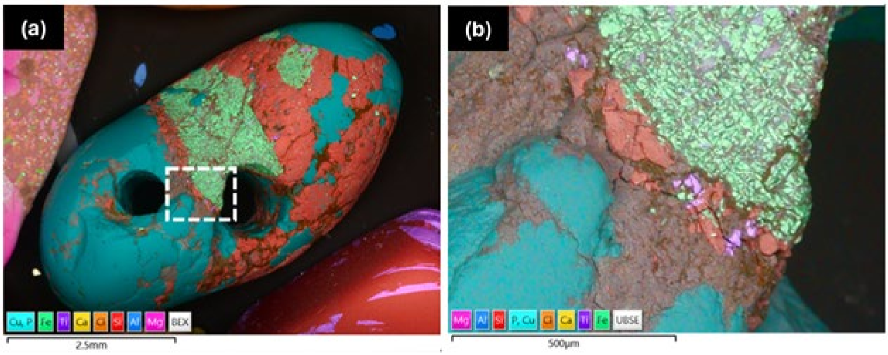
Firstly, the integrated BSE. Having two distinct sensors means both Z-contrast and topography can be produced. The unusual shape of the detectors maximises the collection area of the detector and therefore SNR, whilst still maintaining compatibility with additional standard EDS detectors. The Z-contrast is possible because the sensors are symmetrically positioned around the pole piece and cover a large solid angle. Combined experiments with a BSE signal is important because this has a much higher signal to noise and better resolution than x-ray elemental maps. In the overlaid results, Figure 1, the BSE is providing a sharpness to the image that wouldn't be present in the x-ray maps alone.

Secondly, the Unity detector is designed to work in parallel with a standard EDS. The Unity detector has a protective membrane over each of the X-ray sensors to help extend their life and cope with the high count rates an under pole piece detector is exposed to. Due to this membrane, there is limited detection of light elements, combining with a traditional EDS detector resolves this. Counterintuitively, having a second detector with a lower count rate is much better for mapping light elements, as it allows for the use of a longer process time, leading to improved energy resolution and therefore by association improved deconvolution of the lower energy X-ray lines. The BEX detector does not need to process low energy signals which means it can run faster and be optimised for the higher energies. This set up is technologically slightly tricky as it means the combination of two X-ray sensors which differ in size, shape, and sensitivity, in addition to the simultaneously acquired BSE signal. Unity is designed to maximise the throughput and achieve the optimal mapping resolution, whilst the ideal process time for the conventional EDS detector can be selected based on the relative solid angle, detector sensitivity and geometry. A similar ratio and comparison of the variance optimizes the selection of the optimum X-ray map for each element. Map selection has also been optimized for a multidetector system, making sure the best results are being displayed, for each element.

BSE experiments are typically run with a constant dwell time where are EDS experiments are run with a variable dwell time but maintaining and constant live time. This must be taken into account when designing a synchronized experiment. We will present on the technology behind an improved workflow for synchronized multi-sensor and multi-signal experiments, including the importance of acquisition synchronization, combined processing and displaying of the final data.

Figure 1: Showing example results taken with a BEX detector, with a combined overlay of the BSE and several elemental maps (a). A larger view of (a) is shown in (b) emphasizing the sharpness of contrast which is achievable by this technique.

Graphic:



Keywords:

BSE, EDS, Multi-signal, Synchronization, hyperspectroscopy