Quantitative Hyperspectral X-ray Map (QMap)

When a sample is exposed to the electron beam in a scanning electron microscope a variety of signals are generated. X-rays being one of those signals that can provide valuable insight into a materials chemical makeup. The collected X-ray signal includes background X-ray radiation and more importantly, X-rays of specific energies, that are characteristic of the elements present in the sample. For this reason, an energy dispersive X-ray detector (EDS) is one of the most common detectors that is added to a scanning electron microscope (SEM). It is used to not only determine the elements present in a sample but in many instances can give insight to the quantity as well as the spatial distribution of these elements over very small volumes.

Most EDS systems today have the capability of hyperspectral imaging. An EDS spectrum is collected at each pixel in the map data set is stored as a large data cube (Figure 1). The data set can be reprocessed at any time. New element maps can be created and spectra can be extracted from different regions within the map. JEOL EDS systems include not only hyper spectral imaging but also can construct quantitative maps (QMap). A QMap can be instructive when characterizing your sample if you are experiencing high background or faced with peak overlaps. In QMap, a quantitative analysis is performed at each point in the map data set. This subtracts the background, and in many instances, can successfully deconvolute overlapping X-ray peaks. Some common peak overlaps with EDS systems are shown in Table 1 below.

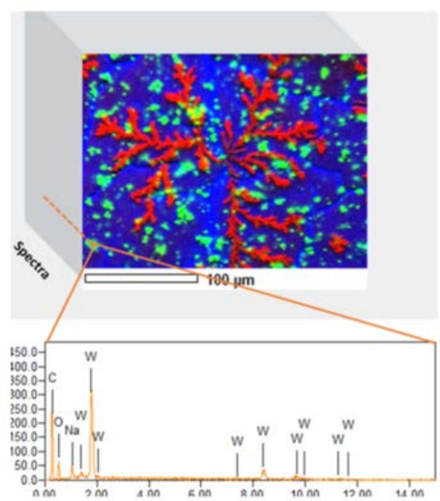

Figure 1: Data Cube – Hyperspectral Imaging with EDS

To show the benefit of QMap in Hyperspectral Imaging, consider an example of a ceramic automotive brake pad. These pads are a complex mixture of many components where a major challenge in their manufacturing process is controlling the quantity and distribution of the individual ingredients. An SEM can play a key role in examining this distribution as well as investigating failures or wear.

Figure 2 shows the EDS sum spectrum from a map data set. From the EDS sum spectrum, it is obvious that there are many components present. In this instance amongst the components both barium and titanium are detected.

Element X-ray Line	**Interferes With**
S Kα & Kβ	Mo Lα, Pb Mα
Ti Kα	Ba Lα
Mn Kβ	Fe Kα
As Kα	Pb Lα
W Mα and Mβ	Si Kα and Kβ
Zr Lα	P Kα

Table 2: Common X-ray Peak Overlaps with EDS

Since the X-ray lines for these elements overlap each other in an EDS system, the X-ray intensity maps for these elements appear to be the same. That is, the spatial distribution of the barium versus titanium components are not resolved (Figure 3)

By processing the data to create a QMap, we can successfully de-convolute the barium and titanium X-ray lines to give a clear indication of the spatial distribution of these elements in this brake pad (Figure 4).

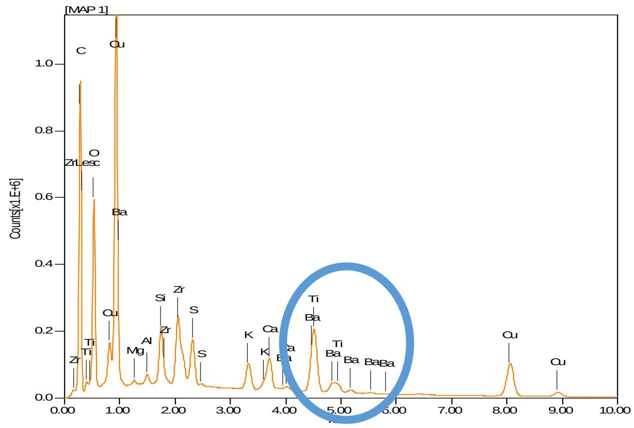

Figure 3: Ceramic Brake Pad - Sum Spectrum from EDS Hyperspectral Imaging Data Set

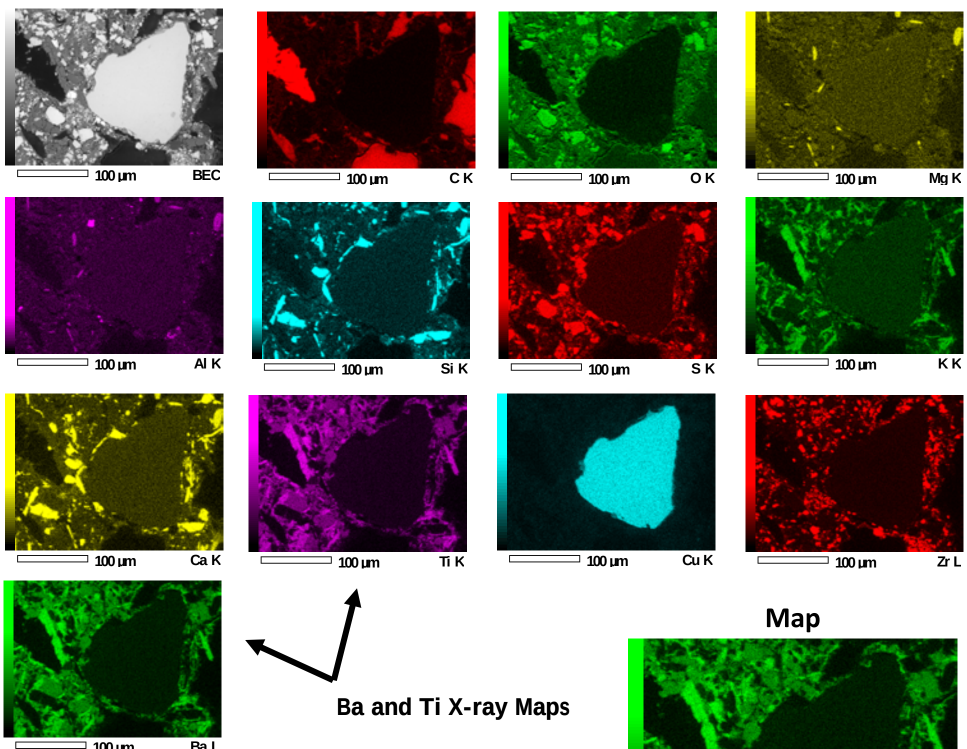

Figure 4: Ceramic Brake Pad - X-ray Maps (Barium and Titanium X-ray Maps and Overall)

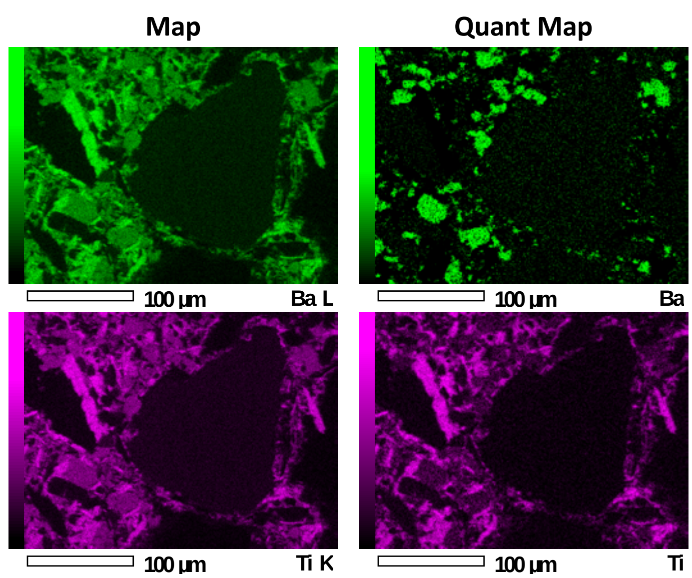

Figure 5: Ceramic Brake Pad Showing Barium and Titanium X-ray Maps Before and after QMap