MATERION

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TECHNICALTIDBITS

MATERION PERFORMANCE ALLOYS

Scope creep! – Learn about several kinds of microscopy and spectroscopy in this temporary diversion from material properties.

- **Photoelectric Effect**
- **Thermionic Emission**
- **Scanning Electron Microscope (SEM)**
- **Secondary Electron Image (SEI)**
- **Back-Scattered Electron Image (BEI)**
- **Energy Dispersive X-ray Spectroscopy (EDS/EDX)**

The next issue of Technical Tidbits will begin a discussion of magnetic properties.

SCANNING ELECTRON MICROSCOPY (SEM) AND ENERGY DISPERSIVE X-RAY SPECTROSCOPY (EDS)

In last month's edition of Technical Tidbits, we discussed the work function of a material as a means of determining the minimum energy necessary to eject electrons from the surface. This energy can come from an incident light wave of sufficient frequency (the photoelectric effect), or by heating the material (thermionic emission.) We also discussed how a beam of such electrons liberated by heating a cathode ray tube can be used to make a microscope with much finer resolution than possible with visible light.

An optical microscope works by illuminating a small object with visible light, and by focusing the reflected light through a magnifying lens on a detector (usually the user's eye or a camera.) A scanning electron microscope (SEM) "illuminates" a specimen with an electron beam. Reflected and emitted electrons are focused by magnetic fields onto a detector, which is used to create a black and white, highly magnified, image of the surface. Note that I said, "reflected and emitted". (A beam of electrons can kick other electrons out of the surface more easily than a beam of light.) This is a key to the usefulness of the SEM.

Secondary electrons are valence electrons directly ejected (emitted) from the surface by the electron beam. When picked up by the detector, they form a very high-resolution image of the surface and its 3-dimensional features. This forms the basis of a **Secondary Electron Image (SEI)**. It tells you nothing about the composition of the material, but is excellent for examining pits, scratches, fracture surfaces, etc.

Back-scattered electrons are reflections of the incident beam. These are collected by the detector and translated into black and white image. Lighter elements reflect fewer electrons than heavier elements. Therefore, in a **Back-scattered Electron Image (BEI)**, lighter elements appear darker, and heavier elements appear brighter. The BEI gives you a good ideas of the relative distribution of elements in the image, but it does not provide as high a resolution of the surface features as the SEI does. Therefore, these two techniques are best used in tandem, by setting the detector first to capture the secondary electron image, then the back-scattered electron image, as shown in Figure 1.

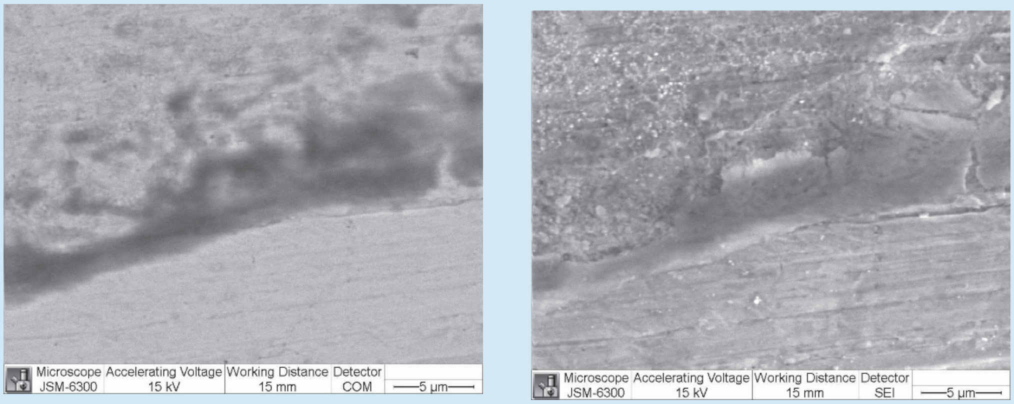

Figure 1 – Secondary Electron Image (SEI - Left Side) and Back-scattered Electron Image (BEI - Right Side) of a Contaminant on a Copper Alloy Part.
The SEI image on the left provides details of the morphology of the contaminant. The BEI image on the right shows that the primary components of the contaminant (dark) have a much lower atomic number than the copper alloy (light).

SCANNING ELECTRON MICROSCOPY (SEM)
AND ENERGY DISPERSIVE X-RAY SPECTROSCOPY (CONTINUED)

When an electron beam hits a surface, not all the electrons will be ejected from the surface. Some are just temporarily knocked into a higher energy state. When the electrons drop back down to the ground state, they will emit photons per the laws of quantum mechanics. Since the incident electrons have very short wavelengths and high energy, the emitted photons will also have high energy and short wavelengths, so they will typically fall into the X-ray spectrum.

Because each element on the periodic table has a unique electron configuration, every element will have its own set of characteristic X-ray spectra. This means that by analyzing the frequencies of the X-rays emitted from the sample, you can determine which elements are present in the sample. This is known as Energy Dispersive X-ray Spectroscopy, (EDS or EDX for short).

By plotting the energy detected vs frequency, you can even get an idea of the relative amounts of each element present, within a certain error limit. This is known as semi-quantitative EDS. Figure 2 shows just such an example

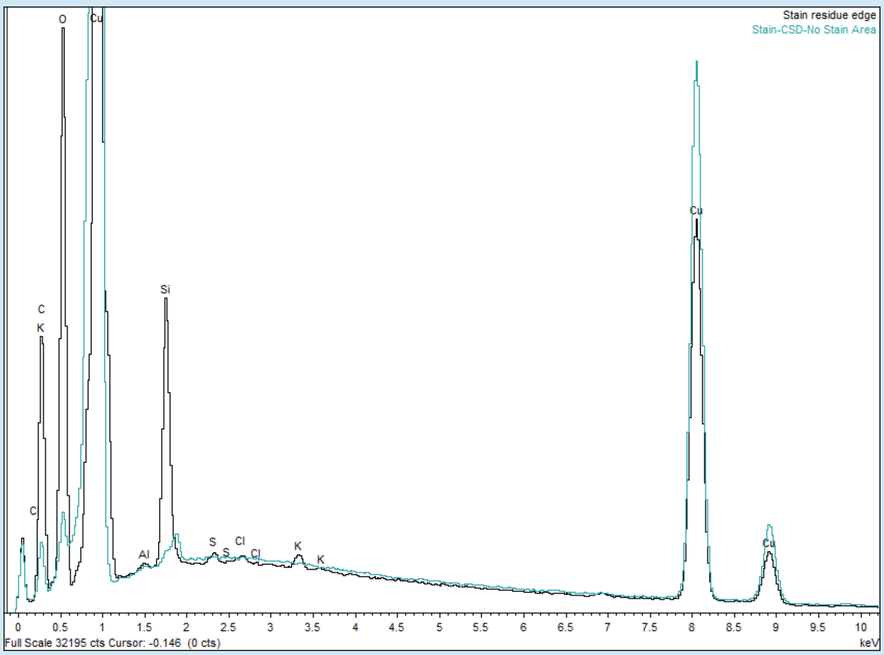

Figure 1 – EDS Scans of the Surface Shown in Figure 1.
By comparing the elements found in the stained area (black line) with the elements found in the unstained area (blue line), you can see that the contaminant consists mainly of carbon, potassium, silicon and oxygen, suggesting that some residual stamping lubricant became baked onto the part during heat treatment.

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References:

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Darrell D. Ebbing General Chemistry © 1990 Houghton Mifflin Company

David Halliday, Robert Resnick & Jearl Walker Fundamentals of Physics, 8th Edition © 2008, John Wiley & Sons.

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