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THE ENERGY SPECTRA OF SECONDARY ELECTRONS

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It has been estimated that more than 90% of all scanning electron microscope (SEM) images ever published have been obtained using secondary electrons (SE) which are defined as those electrons emitted with energies between 0 and 50 eV. The properties of these secondary electrons are therefore of considerable interest and importance. However, although secondary electrons have been intensively studied since their discovery by Starke in 1901, the majority of the work has been aimed at determining the SE yield coefficient and its variation with energy for elements and compounds. The energy spectrum of secondary electrons has received far less attention although it is evident that the form of the spectrum must have an effect on the image contrast observed in the SEM because SE detectors are energy selective devices. The few studies that have been made have mostly concentrated on spectra obtained from clean samples observed under ultra-high vacuum conditions. This is understandable because it is certain that the presence of a surface layer of contamination will change the SE spectrum to some degree or other, but it is unfortunate because all specimens in real SEMs are dirty and it is information about this situation that is required.

We have studied the secondary electron spectra of a number of pure elements and simple compounds in a Perkin Elmer 680 Scanning Auger Microprobe, under vacuum conditions closely resembling those in a modem SEM. The samples were handled in a manner consistent with good laboratory practice for scanning microscopy but without any additional *in situ* sputtering or thermal cleaning. Spectra were generated at an incident energy of 2 keV over the energy range of 0 to 50 eV, the energy resolution was 1 eV and the spectrum was digitally recorded at 1 eV increments. Figure (1) shows representative spectra from four different materials plotting N(E) vs E, where N is the number of secondary electrons in the 1 eV step at energy E. The relative height of the profiles is proportional to their respective secondary yields. The zero of the energy scale is the vacuum energy level of the material rather than earth potential since this choice makes it easier to compare spectra. If the emission energy E is referenced to ground potential then the onset of secondary emission occurs at a different energy for each material because of the variations in work function and the effects of sample charging.

It can be seen that all of the spectra have the same general form in which the profile starts at zero, rises rapidly to a maximum value and then decays away up to the maximum energy of 50 eV. For the majority of materials so far examined, the peak occurs at an energy between 4 and 6 eV. After correcting for the choice of energy zero these values are typically 1 to 2 eV higher than the peak energy values reported for spectra taken from clean samples of these materials under ultrahigh vacuum conditions. In some materials there are also minor peaks present on one side or other of the main maximum. For example, three of the materials shown here have a small shoulder at about 2 eV while the compound semiconductor InP also has an additional peak at about 24 eV. There are also clear variations in the width of the spectral distribution. For example the aluminum profile is relatively narrow while the InP profile is very broad. In general, there are significant differences between all the experimental spectra and the form of the spectrum profile predicted by the classic theory of Chung and Everhart.[1]

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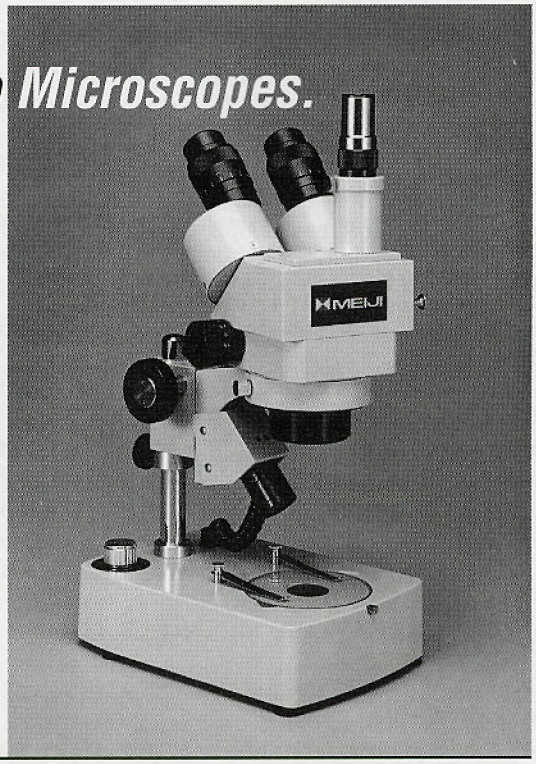

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Because secondary electrons only have a small escape range (3-5 nm) inside a solid, the SE spectrum will become less characteristic of the real sample and tend towards a generic carbon spectrum if the surface becomes too dirty. Thinner contamination layers tend to reduce the total secondary yield and to shift the peak energy position upwards (because the layer charges positively and so retards the SE as they leave) but otherwise causes only minor changes in the shape of the spectrum. ■

1. M S Chung and T E Everhart, J.Appl.Phys. **45**,707-709, (1974)

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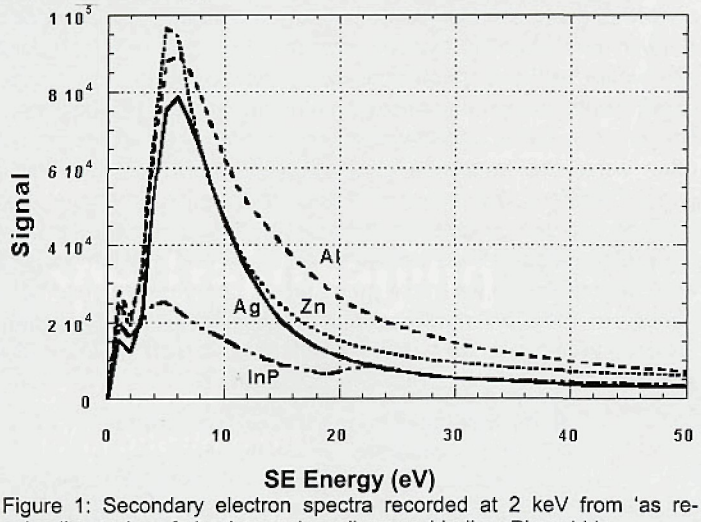

Figure 1: Secondary electron spectra recorded at 2 keV from 'as received' samples of aluminum, zinc, silver, and Indium Phosphide

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