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This Week's Citation Classic ®

Seah M P. Quantitative Auger electron spectroscopy and electron ranges.
Surface Sci. 32:703-28, 1972.
[Div. Inorganic and Metallic Structure, National Physical Lab., Teddington, Middlesex, England]

This study is one of the earliest works to define electron attenuation lengths for Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS). The data are measured by the overlayer technique, in situ, on a quartz crystal oscillator of high stability and sensitivity, for several systems. Data of this type are vital for the quantification of AES and XPS and still, today, represent major sources of uncertainty. The 1979 paper is a compilation of all published measurements of electron inelastic mean free path lengths in solids for energies in the range 0-10,000 eV above the Fermi level. [The *SCI*® indicates that this paper has been cited in more than 290 publications.]

While Apollo Was Away

M.P. Seah
Division of Materials Metrology
National Physical Laboratory
Teddington, Middlesex TW11 0LW
England*

The reason for this work was our requirement to use Auger electron spectroscopy (AES) to measure sub-monolayer levels of segregants at grain boundaries. In order to quantify the spectra, we needed the attenuation lengths (ALs) of the Auger electrons involved.[1] Of course, at that time, the term *attenuation length* had not been used in this context and, to give a handle to the parameter we were measuring, the term *inelastic mean free path* (IMFP) was coined. The IMFP was the measured parameter characterising the exponential increases and decreases of the observed overlayer and substrate Auger electron intensities in a classical layer-on-substrate deposition experiment. Today, this definition is reserved for the AL, whereas the IMFP is now taken to be the equivalent characteristic in the absence of elastic scattering.

Since neither of the above terms was in use at the time of this work, the phrase *electron range* was used in the title to attract the relevant readership. But, on the first page, the reader is told clearly that the paper is not about "ranges" at all but about the IMFP or, as we now call it, the AL. If you are confused, the bad news is that various workers have redefined these terms to suit their own purposes over the years and only now are internationally valid definitions being formulated.

At the time of this work, we were studying the grain boundary segregation of tin in iron. Later we were to publish the measures of ALs in that system[2] and both the grain boundary[3] and surface[4] segregations. However, the discerning reader will notice that there is no mention of tin, iron, or segregation in this study at all. The reason for this is that the other party (code name Apollo) was at a conference in Australia during the period of this work and also during the preparation of the manuscript (he used to travel by boat to Australia in those days and that, unfortunately, meant that for a period of many weeks staff had to rely on their own imagination to decide what research to undertake).

Against the above background, the paper established several points: (i) ESCA was as surface sensitive as AES; (ii) the quartz crystal oscillator could be used, in situ, to measure sub-monolayer deposits of metals in overlayer experiments; (iii) direct or differential AES measurements could be used; and (iv) the geometry of the analyser could be taken into account to deduce the ALs according to a simple algorithm. Unfortunately, the accuracy of these experiments is limited by the quality of the layer-by-layer system deposited. Very few materials systems adopt such a simple structure and, if they do not, the data then become very hard to interpret with any accuracy.

Over the years there have been a number of compilations of experimental data from such overlayer experiments, and that approach has led to some simple predictive relations for the electron energy and material dependence of the AL. The accuracy of these predictions is not high. So, theoretical predictions have been made of IMFPs[5] and the elastic scattering[1] necessary to convert these data to ALs. At the present time, this is a sector of serious activity since the problem has not been accurately solved and is central to the quantification of atoms on surfaces using AES or X-ray photoelectron spectroscopy.

1. **Seah M P.** Quantification of AES and XPS. (Briggs D & Seah M P, eds.) *Practical surface analysis. Volume 1: Auger and X-ray photoelectron spectroscopy.* Chichester, England: Wiley, 1990. p. 201-55.
2. ----------. Quantitative Auger electron spectroscopy: a comparison of techniques for adsorbed tin or iron. *Surface Sci.* 40:595-608, 1973. (Cited 50 times.)
3. **Seah M P & Hondros E D.** Grain boundary segregation. *Proc. Roy. Soc. London Ser. A* 335:191-212, 1973. (Cited 180 times.) [See also: **Seah M P & Hondros E D.** Citation Classic. *Current Contents/Engineering, Technology & Applied Sciences* and *CC/Physical, Chemical & Earth Sciences* 11 March 1991. p. 10.]
4. **Seah M P & Lea C.** Surface segregation and its relation to grain boundary segregation. *Phil. Mag.* 31:627-45, 1975. (Cited 95 times.)
5. **Tanuma S, Powell C J & Penn D R.** Calculations of electron inelastic mean free paths for 31 materials. *Surf. Interface Anal.* 11:577-89, 1988. (Cited 25 times.)

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