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Compton Scattering in Electron Excited Energy Dispersive X-ray Spectra

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Trace element analysis using electron-excited energy dispersive x-ray spectrometry is always a challenge. Unless one is careful it is easy to mistake coincidence peaks, escape peaks, absorption edges and other artifacts for trace quantities of non-existent elements. When studying energetic x-rays from particulate samples there is an additional artifact which we believe we have identified and explained for the first time – Compton scattering. Compton scattering is a process which is familiar to practitioners of x-ray fluorescence spectrometry (XRF). In the Compton process, an x-ray loses energy when it scatters from an electron. XRF spectra often show a background resulting from Compton scattering of the incident x-ray flux. In a XRF spectrum collected with a rhodium source, it is common to see peaks resulting from the 20.2 keV Rh Kα characteristic lines but shifted by approximately a kilo-electron volt lower in energy. The magnitude of the Compton shift depends upon the x-ray energy and the scatter angle but increases with x-ray energy and can be 0.7 keV at 13.6 keV[1]. However, Compton scattering is not typically seen in electron excited energy dispersive spectra. We have discovered that under certain conditions it is possible to see a signal due to Compton scattering. Furthermore, we can predict the approximate magnitude and shape of the signal as a function of particle and substrate composition.

The key to understanding why we typically don't see Compton scattering and yet why under certain circumstances it is possible is the *relative cross sections for the photo-absorption and Compton processes* [2]. The cross section is proportional to the likelihood of certain process occurring as an x-ray traverses a distance in a material. If the photo-absorption cross section is much larger than the Compton cross section (as is typically the case) then almost all x-rays will be absorbed before they Compton scatter. Once absorbed the x-ray is essentially lost. Even when an x-ray does Compton scatter, the scattered x-ray is likely to be absorbed before it can reach the detector. Thus to observe Compton scattering we need a material in which the Compton cross section is of similar magnitude to the photo-absorption cross section. Higher Z materials (such as those which produce characteristic x-rays above 10 keV) tend to have larger photo-absorption cross sections but relatively small Compton cross sections. In general, materials which produce energetic x-rays are not suitable for observing Compton scattering. Neither are low Z materials suitable because they don't produce sufficiently energetic x-rays. However low Z materials do have a more favorable relationship between Compton scattering and photo-absorption. To observe Compton scattering we need a low Z material to produce the scatter and a high Z material to produce the x-rays. We can engineer this situation (or mistakenly fall into it) by placing a high Z particle on a low Z substrate. For example, a U_3O_8 (see FIG 1.) or a SrF_2 particle on a C substrate satisfy both requirements. In fact, the Compton peak from the uranium L line looks similar to a L line from trace Th. Since these elements are often found together it is easy to imagine a circumstance in which Compton scatter from the U L line is mistaken for Th at approximately the 0.8 weight percent level.

Fortunately, there are simple ways to avoid this artifact. One is to mount the particle on a higher Z substrate like Al or Si. Alternatively mount the particle on a thin film like a TEM grid or Mylar. Since the cross section for Compton is small, it takes a bulk substrate to produce sufficient scatter to observe.

[1] O. Klein & Y. Nishina, *Nature* 122 (1928) 398-399
[2] W.H. McMaster N.K. Del Grande, J.H. Mallett and J.H. Hubbell, *Lawrence Livermore National Laboratory Report UCRL-50174* (section I 1970, section II 1969, section III 1969 and section IV 1969).
[3] E. L. Garner, L. A. Machlan & W. R. Shields, *NBS Special Pub. 260-27* (1971)

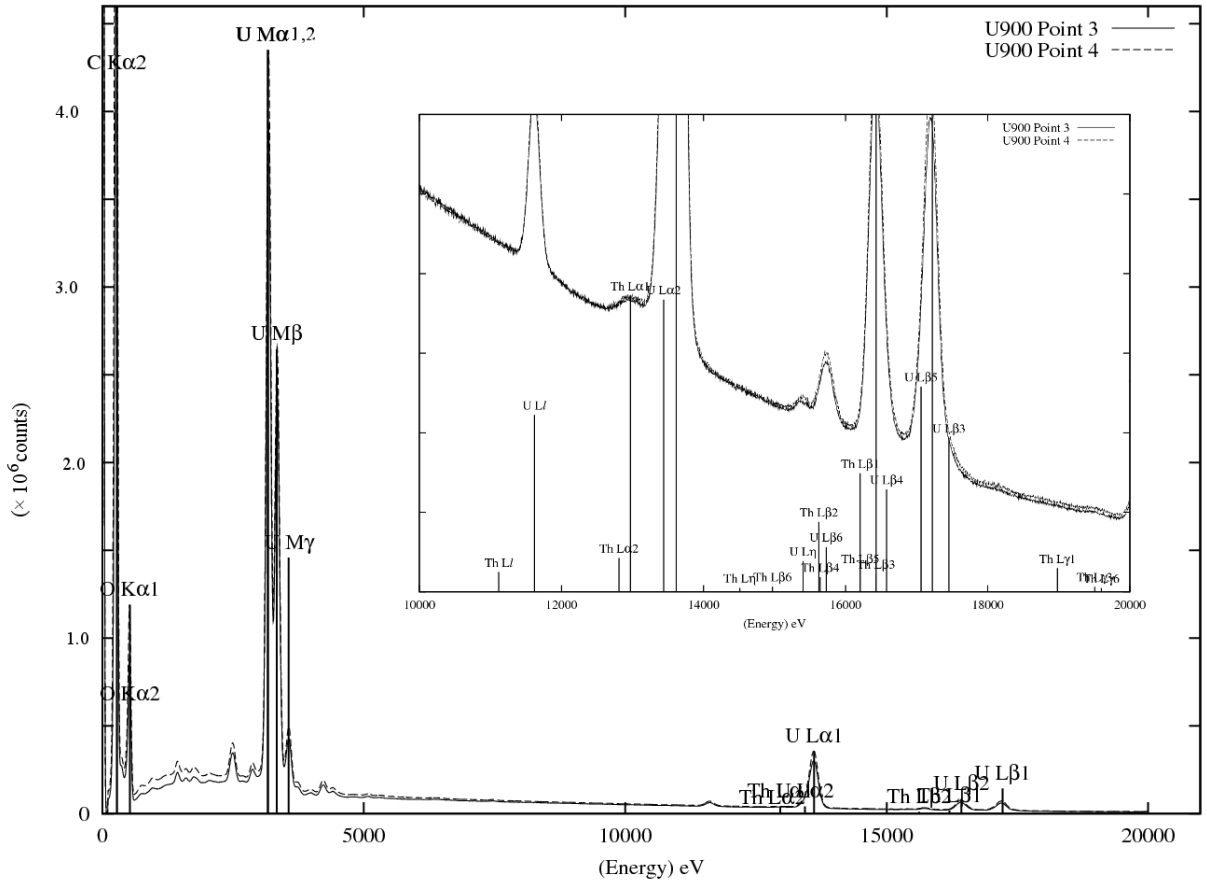

FIG 1: Spectra from two high purity uranium oxide particles (U900[3]). The spectra show a feature incorrectly labeled as Th Lα on the low energy side of the U Lα line. We attribute the artifact to Compton scattering of the U Lα by the bulk carbon substrate on which the particle rested.

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