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Zero-Loss/Deflection Map Analysis

P. Fraundorf*, K. Pisane**, E. Mandell***, and R. Collins*

* Dept. of Physics & Astronomy and Center for NanoScience, University of Missouri – St. Louis MO, 63121
** now at Dept. of Physics, West Virginia University, Morgantown 25406
*** now at Dept. of Physics & Astronomy, Bowling Green State University, Bowling Green OH 43403

Outside of microscopy the relationship between energy lost, and momentum transferred, is a subject that has found considerable application in the past 2000 years. Only recently has it become possible for electron microscopes to routinely deliver quantitative information on energy lost as well as momentum transfer.

One simple and robust way to put this type of information to use is to group image-pixels according to the fraction of detected electrons removed from the zero-loss peak[1] versus the fraction of incident electrons scattered outside the objective aperture. These plots show new promise as a robust tool for quantitative analysis of intensities in transmission electron microscopes able to form energy-filtered images.

Figure 1 shows a map on which anyone can plot experimental observations of specimen brightness I/I_o in a brightfield transmitted electron image (x-axis), versus the fraction of *detected* electrons (y-axis) that did not lose appreciable energy (e.g. more than a few ppm).

Lateral coherence effects aside, both of these are simple to understand experimental quantities between 0 and 1 for a given scattering experiment. Holes in the specimen by definition plot at the (1,1) point in the upper right corner, while regions too thick to permit electrons through plot at (0,0) in the lower left. An electron energy filter or spectrometer is needed to characterize the y-position of a specimen region on the plot, but not to obtain data on the x-position.

Figure 2 shows a zero-loss/deflection map for pixels from a brightfield/zero-loss image pair taken of a bamboo-type multiwalled nanotube. This specimen allows one to examine cross-sections in specimens of known thickness and (002) orientation with respect to the electron beam. Figure 3 shows the inelastic cross-section (and perhaps density as well) of unlayered-graphene cores[2] to be about 80% that of the graphite rim in microtomed presolar core-rim graphite onions[3] from the Murchison meteorite[4]. Zero-loss/deflection maps of multiple onions support this conclusion[5].

References:
[1] R. F. Egerton (1996) *Electron energy-loss spectroscopy in the electron microscope* (Plenum,NY)
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[3] P. Fraundorf and Martin Wackenhut (2002) *Ap. J. Lett.* **578**(2) L153-156.
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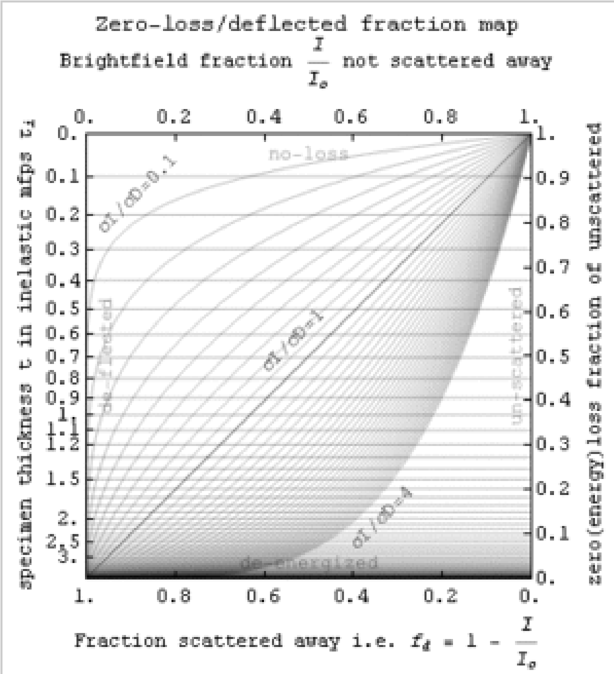

Fig. 1: Fraction of detected electrons with zero-loss versus the fraction of incident electrons undeflected.

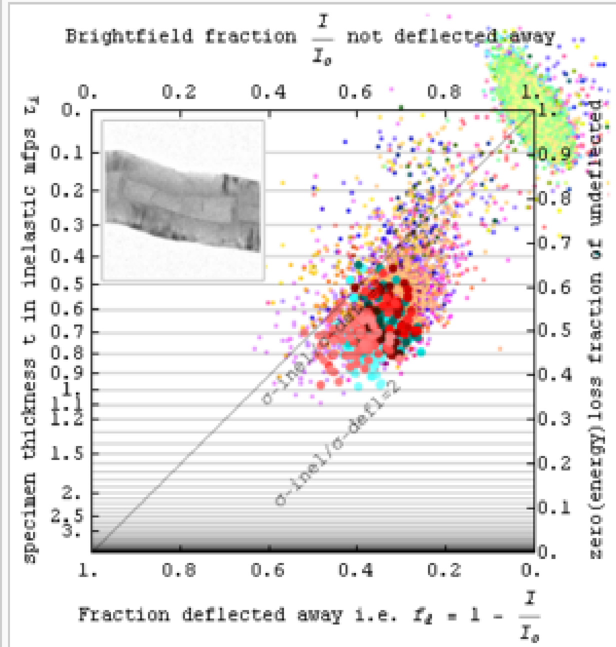

Fig. 2: Bamboo C-nanorod: Small dots cover whole image, Large dots cyan-red dots run left-right through center.

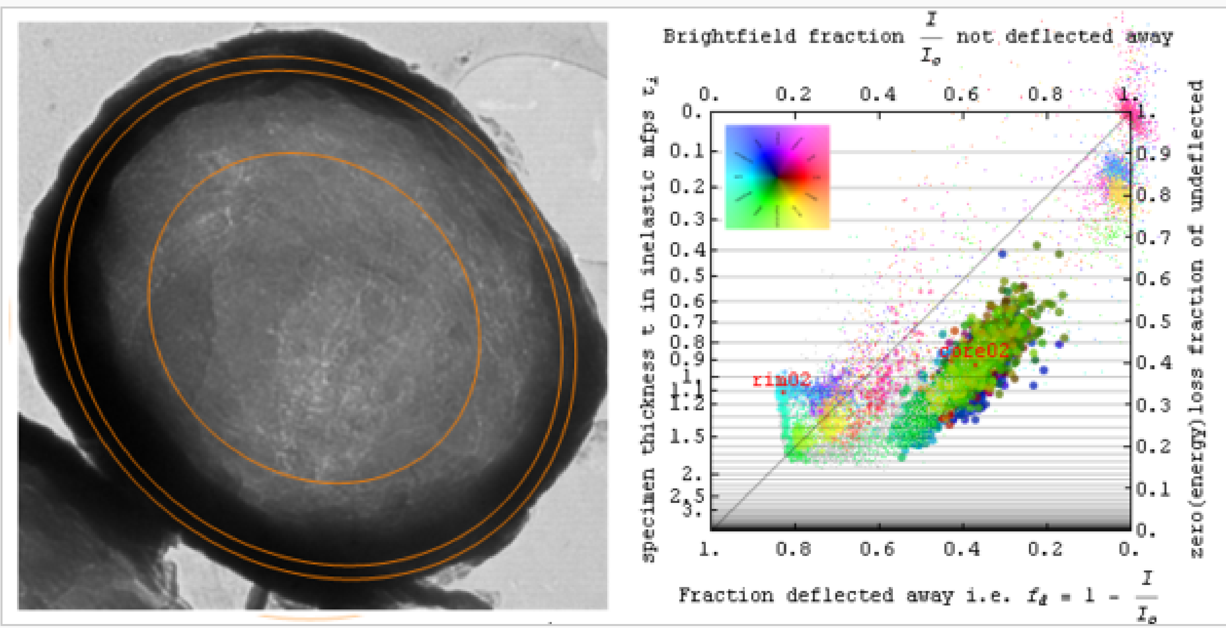

Fig. 3: Left panel - Brightfield image of presolar slice "Vivian". Right panel - core region dots are large, rim region dots are medium, transition region and support film dots are small. Except for the gray transition region dots, dot color denotes location in the image using the color template in the upper left.

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