From Catalysis and Plasmonics: Probing the Structure of Nanoscale Materials with the TEM and EELS

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Electron energy loss spectroscopy is an invaluable technique to study the detailed structure and the chemical state of materials at unprecedented spatial resolution. In today's modern electron microscopes, it is possible to tackle problems requiring the highest energy resolution, down to 60meV, and highest spatial resolution, down to the angstrom level, so that atomic resolved spectroscopy with high spectroscopic sensitivity and resolution can be obtained. This leads to the potential of covering excitation phenomena from the mid-infrared, soft-X-rays and even hard-X-ray regime.
In this presentation, various examples of applications of electron microscopy will be given. First of all, the detection of low-loss features in plasmonic nanostructures and nanoantennas, down to the mid-infrared part of the electron energy loss spectrum will be given, and this by directly imaging resonances down to 0.17eV, the lowest plasmonic features detected with EELS [1,2] and hybridization effects demonstrating strong field enhancements between nanostructures. I will then demonstrate examples of detailed structural and analytical work in a number of alloy nanoparticles systems ranging from fundamentals of phase stability and surface segregation to catalysts used for fuel cells. I will present test cases where one monolayer segregation is observed and confirmed from EELS. Examples will cover overview of the imaging conditions used to detect core-shell ordering changes in PtFe, PtRu, PtAu alloy nanoparticles [3] and graphene [4] used for fuel cell catalyst application, using a combination of high-angle annular dark-field STEM imaging, EELS elemental mapping and simulations. I will also show how to detect bonding state changes in surfaces [5]. This powerful technique can also be used to study of the structure and substitutional effects from single atom dopants in phosphors [6], metallic alloys [7] and high-temperature superconductors [8].

[1] D. Rossouw, et al., *Nano Letters* 11, 1499-1504 (2011),
[2] D. Rossouw, G.A. Botton, *Phys. Rev. Letters* 110, 066801 (2013), and S. J. Barrow et al, , Nano Letters 14, 3799-3808. (2014); Y. Liang; Rossouw, D.; et al, Journal of the American Chemical Society 135, 9616-9619. (2013)
[3] S. Prabhudev et al., *ACS Nano* 7, 6103-6110, (2013), and recently submitted work.
[4] S. Stambula et al., *Journal of Physical Chemistry* C, (2014), C 118, 3890-3900. (2014)
[5] G.-Z. Zhu, G. Radtke, G.A. Botton, *Nature*, 490, 384, (2012) 51.
[6] G. -Z. Zhu, et al. *Phys. Chem. Chem. Phys.* 15, 11420-11426. (2013);
[7] M. Bugnet, A. Kula, M. Niewczas, Botton, G. A., *Acta Materialia* 79, 66-73. (2014)
[8] N. Gauquelin, et al, *Nature Communications* 5, 4275. (2014)