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Unveiling nanometric plasmons optical properties with advanced electron spectroscopy in the Scanning Transmission Electron Microscope

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Since the pioneering work of Yamamoto[1], the use of electron spectroscopy such as Cathodoluminescence (CL) and Electron Energy Loss Spectroscopy (EELS) in a Scanning (Transmission) Electron Microscope (STEM) has considerably helped improving our understanding of the optical properties of metallic nanoparticles. The resemblance of spectroscopic signals from electron and pure optical techniques leads to the intuition that both types of techniques are very close, an idea theoretically discussed by F.J. Garcia de Abajo and coworkers[2]. However, it is also quite intuitive that CL and EELS should be different. For example, EELS helps detecting any sort of modes while CL can only detect radiative ones. On the other hand, even between optical spectroscopy techniques, clear differences such as energy shifts or spectral shapes changes are expected in the case of plasmons. The lack of adapted instrumentation capable of performing combined EELS and CL, as well as theoretical developments allowing to account for the generic difference between EELS and CL and their optical counterparts impeached a comprehensive understanding of plasmons physics with the otherwise amazing electron spectroscopies. In this talk, I will present recent experimental results showing combined EELS and CL spectral mapping of plasmonic properties for nanoparticles with several shapes (triangles [3], cubes, stars) and composition (gold, silver, aluminum). Helped with different theoretical tools [3,4], I will try to show how these results can be related to their optical counterparts (extinction, scattering), and what type of physical insights can be gained from these combined measurements. Finally, if time allows, pointing the weaknesses of state-of-the-art CL and EELS (in terms of spectral range and/or spectral resolution), I will present EELS results obtained on highly monochromated electron beams that could cope with these limitations. [1] N. Yamamoto, K. Araya, and F. Garca de Abajo, Phys. Rev. B 64, (2001). [2] F. Garca de Abajo and M. Kociak, Phys. Rev. Lett. 100, (2008). [3] A. Losquin, L. F. Zagonel, V. Myroshnychenko, B. Rodrguez-Gonzlez, M. Tenc, L. Scarabelli, J. Frstner, L. M. Liz-Marzn, F. J. G. de Abajo, O. Stphan, and M. Kociak, Nano Lett. 15, 1229 (2015). [4] A. Losquin and M. Kociak, ACS Photonics 2, 1619 (2015).