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Characterization of Metallic and Bimetallic Nanoparticles by Off-Axis Electron Holography

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It is well known that at nanoscale, parameters such as size, shape and surface morphology play a fundamental role on the properties that materials exhibit. In metallic nanoparticles, an increase in reactivity is obtained when size is reduced. In the case of bimetallic nanoparticles, unique physical and chemical properties can be achieved when composition and shape are controlled [1]. Aberration corrected electron microscopy is an ideal technique to study nanoparticles, however the images obtained correspond to two dimensional projections of three dimensional objects, which correspond to a partial characterization.

Electron holography is a powerful tool that can provide surface information from a single image, this makes it a useful technique to study highly faceted nanoparticles. Electron holography is an interferometric technique that has been used to extract quantitative information such as electro and magneto static fields, impurities in solids, determination of the thickness and strain measurements in nanostructured materials and devices. An electron hologram is a fringe-modulated image containing the complete information, amplitude and phase, of an electron transparent object. Since the electrons have a high spatial coherence, electron holography has a significant potential in the determination of morphology and physical properties at high spatial resolution and sensitivity [2].

In this work, we use a variable magnification method for off-axis electron holography using a dual-lens imaging system that achieves high spatial resolution and phase sensitivity [3]. We have applied this technique to compute thickness and morphology in metallic and bimetallic nanoparticles. The reliability of the technique performance was validated with the reconstructed phase of the hologram in gold decahedral nanoparticles in which the topographic shape and 3D visualization have been extracted as shown in Fig. 1, nanometric surface irregularities can be quantify due to the high phase sensitivity. In addition, the reconstructed phase images of Au/Pd core-shell nanocubes, Fig. 2, show information of the nature at the core and shell interface. The phase reconstructions in different zone axes and the contrast contribution of the truncated octahedron core planes (111) and (100) for Au/Pd core-shell nanocubes is correlated with the strain field map obtained by analyzing Cs-STEM HAADF images by geometrical phase analysis.

These results show the strength of electron holography to study nanoparticles morphology and composition. The capabilities of this technique lead to the precise determination of the morphological surface of nanoparticles obtained from the reconstructed phase images.

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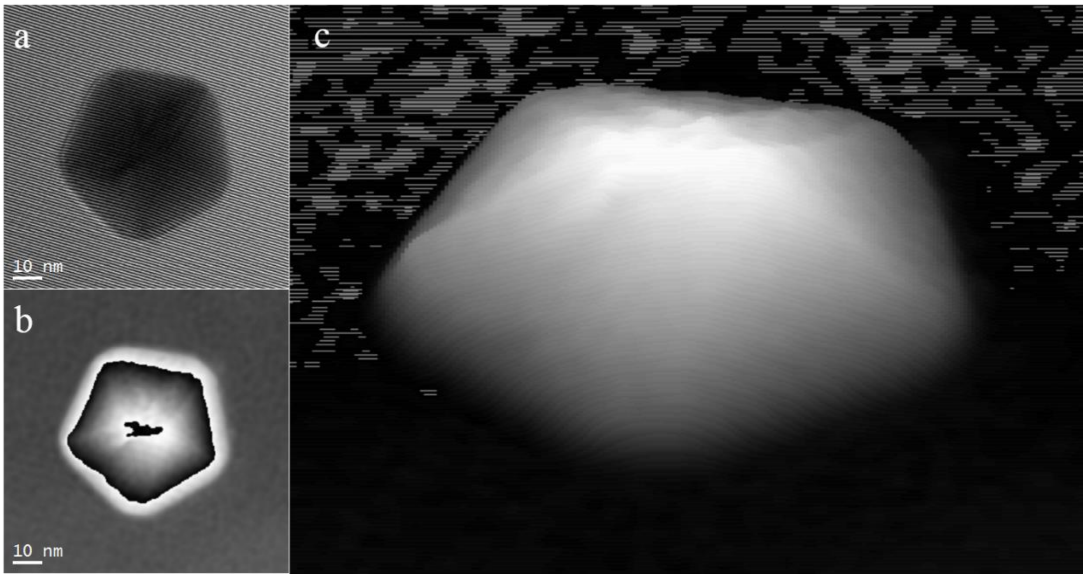

Figure 1. Au decahedral nanoparticle: (a) object hologram, (b) reconstructed phase image and (c) surface plot from the unwrapped phase image.

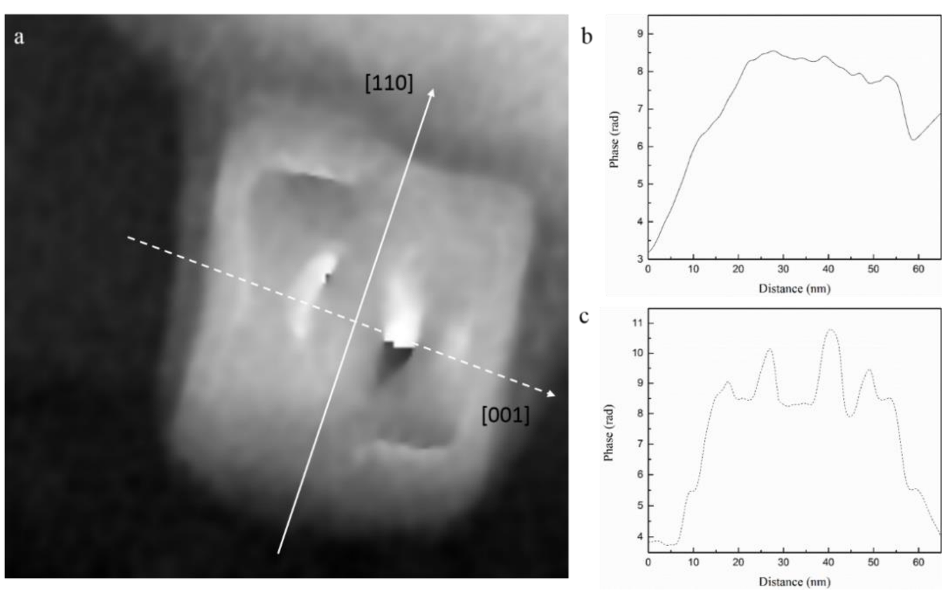

Figure 2. Au-Pd core-shell nanoparticle (a) Unwrapped phase image, (b) Line profile across the core in [110] direction, showing smooth contour (c) Line profile across the nanocube in the direction [001], showing abrupt phase shift at the core edges.

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