GATAN

Experiment Brief

Monarc Cathodoluminescence Detector

Title

Investigating the optical properties of nanophotonic materials far below the diffraction limit.

Gatan instrument used

The Monarc™ Pro system offers the most complete analysis of cathodoluminescence (CL) emissions and empowers all users to capture the highest quality data whether novice or expert.

Background

Plasmonic metal-based nanoparticles have attracted significant attention due to a plethora of novel optical device designs that take advantage of enhanced light emissions and absorptions that may be controlled by a nanostructure's size, shape, and composition. The interaction of light causes resonance of the free electrons leading to greatly enhanced electromagnetic fields, particularly in noble metal structures. Identification of the plasmon resonance modes and hot spot locations is critical but presents a significant experimental challenge due to weak light emission levels and the particle size begin smaller than the diffraction limit.

Materials and Methods

The structures investigated were chemically-synthesized gold-palladium (Au-Pd) nanostars of about 120 nm nominal side length. Nanostars were suspended in fluid, deposited on a silicon substrate, and dried to the surface. CL measurements were performed in a conventional FE-SEM using a Monarc Pro (model 450.P.WAR) with an optional filter housing and a linear polarizer. Traditionally, nanophotonic materials have been considered difficult to analyze due to the low flux of emitted photons and complexity in co-aligning the optical collection system and SEM. However, the Monarc system's auto-alignment capability and optimized optical design enable the polarization-filtered spectrum images of Figure b to be collected in just 120 s.

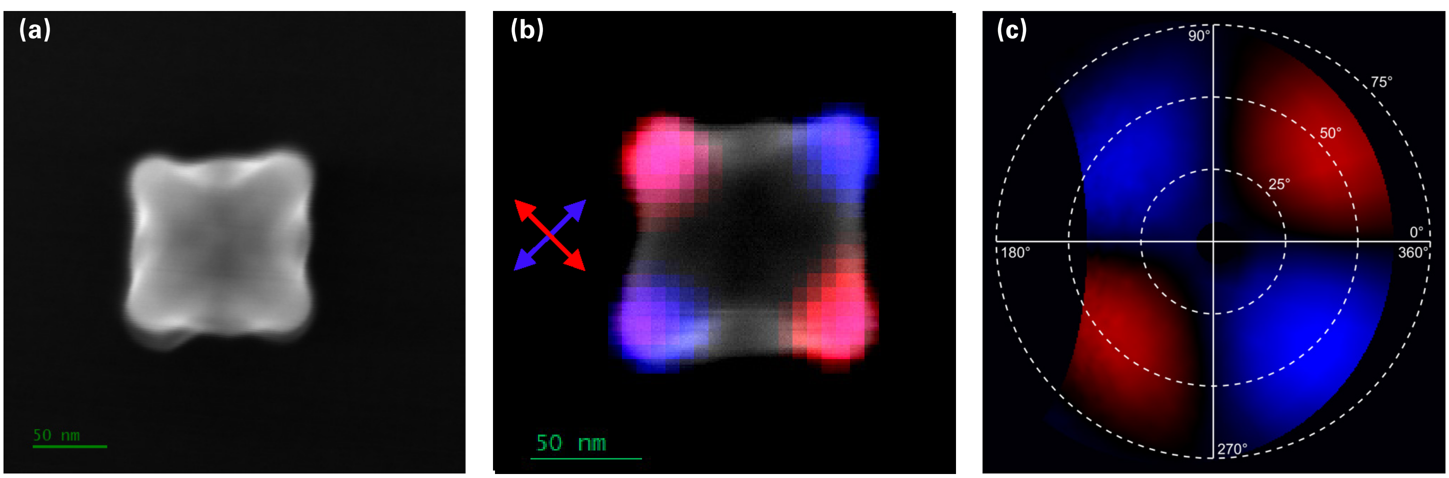

Figure 1. (a) In-lens secondary electron image of a typical Au-Pd nanostar, (b) colorized polarization-filtered CL spectrum image with opposing polarizations displayed in blue and red (acquired in 120 s) overlaid on the (simultaneously collected) in lens secondary electron image, and (c) the difference of averaged angle-resolved (AR) CL patterns for excitations at the tips of the isolated nanostar using the same colorization as in Figure b. The CL intensity of the isolated nanostar shows spatial variation consistent with the highest local density of optical states (LDOS) enhancement at the tips; filtering the CL intensity by polarization suggests that the most intense plasmonic modes generated by the electron beam are dipolar and resonant at opposing tips. The AR-CL patterns reveal that the emission patterns lie orthogonal to their respective dipole axes.

Summary

CL in an SEM was used to reveal the local density of optical states in a metallic nanostar far below the optical diffraction limit. Polarization-filtered emission of an isolated nanostar demonstrated the selectivity of excitation while angle-resolved CL revealed the emission direction from plasmonic modes activated at the nanostar tips and confirmed they are dipolar resonances with broad isotropy along the polar direction.

Credit(s)

Special thanks to Dr. Emilie Ringe, Rice University for generously providing the specimen.

Rice University is a multidisciplinary research institute specializing in high-level characterization & analysis of a wide spectrum of materials. By fostering an interdisciplinary philosophy, it serves as a hub to the broader university community, encompassing bioengineering and biosciences, the environment, and an extensive range of engineering.

Gatan is the world's leading manufacturer of instrumentation and software used to enhance and extend electron microscopes—from specimen preparation and manipulation to imaging and analysis.

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