Plasmonic nanoparticles as energy converters for chemical reactions and for the launching of acoustic surface waves

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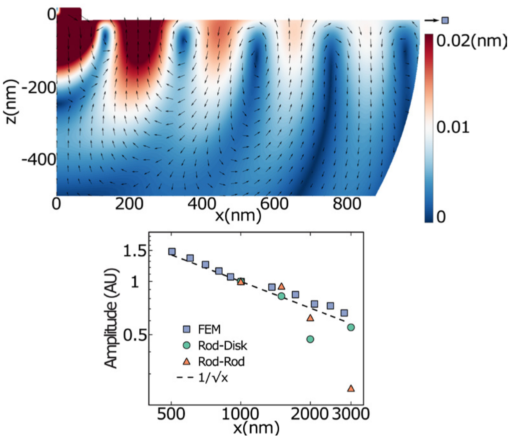
Abstract - In addition to the well-established electromagnetic hot spots of plasmonic nanostructures, metal nanoparticles can also act as nanoscale energy transformers from electromagnetic into chemical or acoustic energies. Energetic electron/hole pairs formed via plasmon decay enable control over chemical reactions on the nanoscale, and coherent acoustic vibrations of the nanostructures the controlled launching and detection of acoustic surface waves.

We present our recent efforts to unravel both the energetics and the spatial distribution of hot charge carriers generated in metallic nanostructures via the decay of localized surface plasmons. Using a combination of bulk electrochemistry and single-particle spectroscopy, we directly determine the energy of hot holes in Au nanocolloids and their energetic contribution to a polymerization reaction at the nanoparticle's surface [1]. Our results demonstrate that the energy contribution of the "hot" holes is maximized upon excitation at the localized plasmon resonance frequency of the particles.

Such plasmon-enhanced chemistry enables further control over nanoscale self-assembly [2] and also a novel super-resolution imaging scheme of optical absorption [3], based on the controlled cleaving of thiol-bonds via hot electrons excited in top-down fabricated gold nanoantennas. We use this scheme to bridge top-down nanofabrication with bottom-up self-assembly, and further show direct spatial imaging of near-field energy transfer in a Fano cavity.

In addition to hot electron effects, optical excitation of metallic nanoparticles also lead to coherent acoustic vibrations. Using spatially separated source and detector nanoparticles, we demonstrate the launching of acoustic surface waves in the underlying substrate via this scheme (Figure, [4]). This enables nanoscale interrogation of the properties of surface-acoustic waves.



Launching of surface-acoustic waves in the underlying substrate via coherent excitation of phonons in a metallic nanostructure [4].

[1] Pensa et al, Nano Letters 19, 1867 (2019)
[2] Simoncelli et al, ACS Nano 12, 2184 (2018)
[3] Simoncelli et al, Nano Letters 18, 3400 (2018)
[4] Berte et al, Physical Review Letters 121, 253902 (2018)