HAJIM SCHOOL OF ENGINEERING & APPLIED SCIENCES
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The Department of Chemical Engineering Presents:

Catalysis on plasmonic metal nanoparticles: Opportunities for highly selective chemical conversion

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Metal nanoparticles are used as commercial catalysts for many chemical reactions, including ammonia synthesis, hydrocarbon reforming, oxidation and hydrogenation reactions. In commercial systems, these reactions are triggered by the thermal heating of catalyst nanoparticles. This process excites the phonon modes of the nanoparticles, which couple with the reaction coordinate (for example, vibrational modes of the reacting adsorbates). This coupling results in the evolution of the adsorbate from the reactant to the product state on the ground-state potential energy surface. These reactions usually require relatively high temperatures, and the distribution of the products is governed by the ground-state free-energy landscape. They offer limited opportunities to tune the product selectivity.

We recently made an important breakthrough by showing that relatively small plasmonic metal nanoparticles, illuminated with visible light, can activate chemical reactions on their surfaces in an alternative mechanism. We showed that these chemical transformations are driven by the energetic charge carriers that are formed on the surface of the nanostructures upon their interaction with resonant light and transferred from plasmonic nanoparticles to the reacting adsorbates. This has led to an entirely new field of chemical conversion, often referred to as plasmonic catalysis. Unlike in the case of phonon-driven reactions, it is in principle possible to change (and improve, through targeted design of nanostructures) the product selectivity compared with phonon-driven thermal reactions.

I will discuss: (i) the physical features of plasmonic nanoparticles that make them ideal for the charge transfer mediated reactions, (ii) the mechanism of charge-carrier driven chemical transformations on metals, (iii) the mechanisms behind the plasmon-induced charge injection processes, (iv) the approaches to engineer these nanostructures so that they can support specific chemical transformations to make value-added products with high selectivity and at lower temperatures.

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