Evaluating plasmonic heating and hot-charge carrier effects in plasmon-driven syntheses

Metal nanoparticles are used in a wide range of applications, from catalysis, to advanced solar cells, photo-thermal cancer therapy, and medical imaging. One of the most striking features of metal nanoparticles is their unique interaction with light, leading to strong absorption and scattering in the UV, visible, and IR ranges. These resonances, commonly called plasmon resonances, are responsible for a variety of interesting effects, from the activation of sub-wavelength electromagnetic field hot spots, to the generation of non-equilibrium charge carriers and high temperature gradients at the surface of the nanostructures[1]. In our group of Nanomaterials for Energy Applications (NEA) at DIFFER we explore such light-induced phenomena to actively control a variety of chemical reactions at the surface of metal nanostructures, from catalytic conversions, to sol-gel and colloidal syntheses.

Although the field of plasmon-driven chemistry has gained significant attention in the recent years, it has been challenging so far to understand the role of light and the exact mechanism accelerating these chemical reactions. Recently, recently developed a new synthesis of Au@Ag core@shell nanoparticles that allows us to study these activation mechanisms. We found that the growth of a Ag shell on top of Au nanoparticles can be triggered by both photothermal heating and hot-charge carrier ejection. Using a controlled illumination geometry and careful numerical calculations involving Monte-Carlo and COMSOL simulations, we were able to identify the light propagation and heat-generation inside the nanoparticle suspension, thereby allowing us to discriminate the effects of hot-charge carriers and photothermal heating on the Ag shell synthesis. Despite these understandings, there are still several open questions regarding the influence on the reaction rate of the size of nanoparticles, the volume of nanoparticle suspensions, the optical density of the solution and the illumination wavelength and intensity.

In this project, we intend to tackle this challenge by carefully studying the various parameters listed above, in order to understand the contributions of photothermal heating and hot-charge carriers. In this internship (5 – 9 months), the student will be involved in the synthesis of metal nanoparticles using colloidal techniques, characterization of nanostructures using UV-Vis spectroscopy and electron microscopy, performing plasmon-driven synthesis in our home-built photo-chemical setup and in performing numerical calculations.

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