Plasmonic Hot Electrons in Metal-Semiconductor Assemblies: Fundamental Aspects and Application in Photocatalysis

The photosensitization of large bandgap semiconductors at the nanoscale with plasmonic materials such as Au or Ag has proven to be a reliable means to activate them with visible and NIR photons, leading to the formation of nanohybrids with efficient photocatalytic activities in a broader range of the solar spectrum. In this process, the population of hot electrons created at the metal component upon electromagnetic excitation can be subsequently transferred to the nearby semiconductor, hence creating an efficient separation of charges with prolonged lifetimes that can be used to drive chemical reactions. Our previous studies in this field have allowed us to obtain a better insight on the role played by the morphology,[1] composition[2] and inter-particle coupling[3] of the plasmonic component on the final photocatalytic activity of the hybrid. Interestingly, these results show that exciton-driven reactive oxygen species (ROS) generated under irradiation play an important role in the activity of such hybrid photocatalysts in aqueous solutions.[4]

In this Thesis we will study the mechanisms behind the efficient separation of charges in nanostructured macroscopic hybrids formed by the self-assembly of plasmonic and semiconductor nanocrystals. In this manner, long-range order will allow us to form devices with homogeneous optical and photocatalytic features that can be then implemented to study the fundamental aspects of hot electron injection at the macroscopic scale. We will pay special attention to the detection and quantification of ROS while the role played by thermal effects in plasmon-induced photocatalysis will also be investigated. Moreover, these structures will be applied as catalysts in processes with industrial relevance such as the photocatalytic dehydrogenation of alcohols at low temperature.[5]

The PhD student will be in charge of the synthesis and assembly of the hybrids by means of colloidal chemistry protocols. Techniques such as transmission and scanning electron microscopy or X-ray diffraction will be routinely used for the characterization of the materials. Moreover, he/she will study in detail the optical and photocatalytic features of such hybrids by means of absorption spectroscopies and different photocatalytic set-ups that are available at our institute.

Competences

MSc in Chemistry, Nanotechnology or Materials Science. Previous experience in colloidal chemistry, synthesis of inorganic nanocrystals and/or plasmonics will be valuable.

Starting date: October 2021

References

[1] Sousa-Castillo et al., Journal Physical Chemistry C, 2016, 120, 11690.
[2] Negrín-Montecelo et al., ACS Energy Letters, 2020, 5, 395.
[3] Negrín-Montecelo et al., ChemCatChem, 2018, 10, 1561.
[4] Sousa-Castillo et al., Nano Letters, 2020, 20, 7068.
[5] Viola et al., Catalysis Today, 2019, 333, 97.

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