POST-DOC

Time-resolved spectroscopy of charge transfer in plasmon-assisted photoreactions

Funding: 18 months project funded by the PEPR LUMA
Start date: Any time between 01/03/2025 and 01/10/2025

Position summary

We are seeking a highly motivated postdoctoral researcher to conduct mechanistic investigations of charge transfer between plasmonic metal nanoparticles and organic molecules using advanced time-resolved spectroscopic techniques. The project aims to disentangle electronic and photothermal effects in plasmon-assisted photoreactions, including photopolymerization and out-of-equilibrium self-assembly.

The postdoctoral researcher will employ ultrafast pump-probe spectroscopy and microscopy techniques to elucidate the mechanisms of hot-electron generation, transfer, and reaction dynamics in these hybrid systems. The insights gained will provide a blueprint for designing plasmon-enhanced photoreactions for applications in photocatalysis and nanofabrication.

The study is part of the SUNRISE project in the PEPR LUMA[1] financed for 6 years by France 2030. The work will be carried out in the Optics, Photonics and Surfaces Department of the Hubert Curien Laboratory (LabHC) located in Saint-Etienne, France, in collaboration with the Laboratoire de Chimie of the ENS Lyon, the Institut des Sciences Moléculaires in Bordeaux and the Université de Haute Alsace in Mulhouse.

Scientific context, objectives and methodology

The localized surface plasmon resonances (LSPRs) of plasmonic nanoparticles result in strong light absorption and lead to the generation of hot electrons through Landau damping and nonradiative plasmon decay.[2] Once generated, these hot electrons can be transferred to adjacent materials, including adsorbed molecules, semiconductors, or polymeric matrices, where they drive chemical transformations.[3] In plasmon-driven photochemistry, hot electrons can be directly injected into the lowest unoccupied molecular orbital (LUMO) states of nearby molecules, facilitating chemical reactions that are otherwise thermodynamically unfavorable. Two primary charge transfer mechanisms have been identified: Direct injection via chemical interface damping (CID), where electron transfer occurs within femtoseconds, mediated by orbital hybridization at the nanoparticle-molecule interface; Indirect injection, in which electrons must first thermalize before diffusing toward acceptor states. This process is often limited by recombination losses, reducing the efficiency of charge separation.[2] A particularly intriguing application of these processes lies in plasmon-assisted polymerization. Recent studies have demonstrated that hot electrons can initiate polymerization reactions without the need for conventional radical initiators, enabling localized polymer growth on metal surfaces.[4] Despite these advances, a major limitation in the field is the reliance on steady-state measurements, which fail to capture the ultrafast dynamics of hot-electron transfer and polymerization. A more precise understanding requires time-resolved spectroscopic techniques to track charge transfer rates from metal nanoparticles into polymer LUMO states and distinguish between electronic and photothermal contributions to reaction kinetics.

To elucidate the fundamental mechanisms of charge transfer in plasmon-assisted photoreactions, the study will address key research questions. The postdoctoral researcher will utilize state-of-the-art ultrafast spectroscopy and advanced materials characterization techniques to characterize hot-electron injection dynamics from metal nanoparticles into organic molecules, determine the role of hybridization in CID-mediated charge transfer, assess the impact of nanoparticle morphology on charge separation efficiency, differentiate signatures of hot-electron transfer and photothermal effects, and investigate plasmon-induced polymerization across different monomers. The researcher will also collaborate with theoretical physicists implementing DFT calculation to provide quantitative insights into hot-electron transfer dynamics.

Required qualifications

The candidate should have:

- A PhD in photonics a related field,
- Expertise in ultrafast spectroscopy,
- Experience with plasmonics,
- Knowledge of surface science techniques (XPS, SERS, electron microscopy),
- Strong analytical and computational skills to interpret spectroscopic data
- Ability to work independently and collaboratively in an interdisciplinary environment
- Good writing and communication skills in English

Applicants must send their CV to the contact persons, with a motivation letter, and reference names. Applications will be reviewed on a rolling basis, so we encourage you to submit your documents as soon as possible.

Contact: Prof. Nathalie DESTOUCHES, Dr Tatiana Itina
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References :

[1] https://www.pepr-luma.fr/;

[2] J. Khurgin et al., "Hot-electron dynamics in plasmonic nanostructures: fundamentals, applications and overlooked aspects" eLight, 4 :15 (2024);

[3] Y. Zhang, et al., "Surface-Plasmon-Driven Hot Electron Photochemistry" Chem. Rev. 118, 2927 (2018);

[4] Y. Wang et al., "Plasmon-directed polymerization: Regulating polymer growth with light" Nano Research, 11(12): 6384 (2018).