Research Topic for the ParisTech/CSC PhD Program

Subfield: Applied Physics, Material Science and Engineering
ParisTech School: ESPCI Paris, 10 Rue Vauquelin, 75005 Paris
Title**: **Plasmonic Nanocrystals for Optoelectronics
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Web site: http://www.espci.fr/recherche/labos/lpem/mnc/index.html
http://optoelec.lpem.espci.fr

Short description of possible research topics for a PhD:
Surface plasmon resonance (SPR) is an important physical phenomenon that has aroused extensive fundamental and practical interest since their first observation. When an incident light is shone onto a conductive nanostructure, the confined free electrons oscillate collectively with respect to the positively charged nuclei with the same frequency as the radiation. The resonance of such oscillation (termed "localized surface plasmon resonance", LSPR) produces intense and well-defined spectral absorption as well as strong localized electromagnetic near fields. LSPR subsequently decays either radiatively by re-emitting a photon or non-radiatively through Landau damping generating hot carriers on a time scale ranging from 1 to 100 fs after LSPR excitation. Hot carriers, if not extracted through a specific device structure, will then quickly redistribute their energy towards lower energy electrons via electron-electron scattering followed by thermalisation with the lattice and heat transferred to the surroundings on a time scale ranging from 100 ps to 10 ns. Plasmonic nanostructures are therefore both hot carrier generators and efficient mediums to convert photons to thermal energy [C. Clavero, *Nat. Photonics*, 8, 95-103 (2014); H. Chen et al. *Chem. Soc. Rev.*, 42, 2679-2724 (2013)].
In this thesis, we aim to study a series of solution-processed plasmonic nanocrystals for optoelectronic applications such as photovoltaic devices and optical sensors. This project will start with learning the colloidal synthesis for plasmonic nanocrystals from published protocols and subsequent structural and optical characterizations on the obtained nanocrystals. The student will then focus on (1) the application of plasmonic nanocrystals in a composite structure (e.g. together with a thermoelectric device) for solar light harvest based on the plasmonic-induced photothermal effect; (2) the design and fabrication of plasmonic photodetector structures based on the extraction of plasmonic-induced hot carriers; (3) the characterization of the fabricated devices by nano-optical means (fluorescence and near-field optical microscope). These latter techniques will also provide a direct microscopic view of the optical effects involved (nano-antenna and light confinement effects).

Required background of the student: Applied Physics, Materials Science, or Chemistry. Motivated for experiments and good language skills in English.

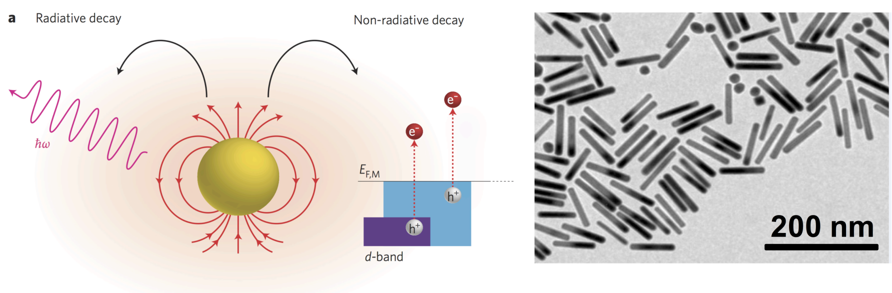

Figure 1. (Left) Schematic describing LSPR decay, hot electron generation and injection (C. Clavero, Nat. Photonics, 8, 95-103 (2014)). (Right) Plasmonic gold nanorods with LSPR tunable from the visible to the near-IR wavelength range synthesized in our laboratory.

2-3 representative publications of the group:

- "Parallel Collective Resonances in Arrays of Gold Nanorods", A. Vitrey, L. Aigouy, P. Prieto, J. Garcia-Martin, M.U. Gonzalez, Nano Letters, **14**, 2079-2085 (2014).
- "Plasmonic-Enhanced Perovskite-Graphene Hybrid Photodetectors", Z. Sun, L. Aigouy, Z. Chen, Nanoscale, **8**, 7377-7383 (2016)
- "Reduced Carrier Recombination in PbS - $CuInS_2$ Quantum Dot Solar Cells", Z. Sun, G. Sitbon, T. Pons, A. A. Bakulin, Z. Chen, Scientific Reports, 5, 10626 (2015)