OSE SPECIAL SEMINAR

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New frontiers for Plasmonics: From UV to Ultrafast Spectroscopy

The proper exploitation of the plasmon resonance typical of metallic nanoparticles can allow for the confinement of the electromagnetic field in nanometric volumes, thus creating the so called “hot spots”. These nanometric volumes are characterized by high field, remarkably useful characteristic for a huge variety of applications in photonics and optics such as the quite new field of UV sensing and ultrafast spectroscopy.

With regard to UV, the most commonly employed plasmonic metals, Au and Ag, yield resonances only reaching up to the near-UV electromagnetic range, in fact stretching upwards the energy of plasmon resonances requires the use of different materials. Deep-ultraviolet plasmon resonances were indeed predicted exploiting one of the cheapest and most abundant materials available on earth. Aluminium holds the promise of a broadly-tuneable plasmonic response, theoretically extending far into the deep-ultraviolet (DUV). Complex fabrication issues, including the strong Al reactivity, have however stood in the way of achieving this ultimate DUV response. We report the successful realization of 2-dimensional arrays of ultrafine aluminium nanoparticles that exhibit a remarkable plasmonic response up to the DUV electromagnetic range. Careful nanofabrication allowed to maintain the mean NP size below 20 nm, preserving a purely-metallic core. These systems exhibit a striking high-energy plasmon resonance up to 6.8 eV photon energy, and preserve their DUV plasmon response when exposed to atmosphere. These observations pave the way to the full exploitation of aluminium plasmonic tunability, hence extending the numerous applications of plasmonics to the high-energy side of the spectral range.

Similarly to UV plasmonics, another domain where SPPs have found new youth is ultrafast spectroscopy in strongly coupled systems. This regime is reached when SPPs and matter exchange energy coherently and reversibly before losses take place, resulting in the formation of new hybrid exciton-plasmon states formed by lower and upper energy bands. In this field most of the works focus on steady-state observations, indeed experiments on the dynamics of such hybrid systems are relatively scarce and their intrinsic photophysics is still far from being understood. Here, in order to improve our understanding of the dynamics of hybrid exciton-plasmon states, we have studied through ultrafast pump-probe approach, a hybrid system composed by gold hole arrays and J-aggregate molecules while modifying the lattice constant of the metallic array. Under upper hybrid band resonant excitation, transient absorption spectra provide the evidence that exciton-plasmon hybrid states are formed. Meanwhile, kinetics analysis led to the discovery of a remarkably long-lived upper band, at least one order of magnitude at 1/e than bare J-aggregate molecules. This result was explained with the identification, in the transient absorption spectra, of a trap state combined with the negligible relaxation effect from vibrational modes. The intrinsic long lifetime of hybrid states is of crucial importance both from a fundamental and applicative point of view, having implications in the use of exciton-plasmon states for technological purposes. The understanding of the dynamics on strong coupling systems can provide indeed a promising route towards novel ultrafast plasmonic devices with coherent functionalities.

Biography:
Remo Proietti Zaccaria is group leader of the Multiphysics laboratory at the Italian Institute of Technology and Professor at the Cixi Institute of Biomedical Engineering, Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences. His work mainly aims in modelling and experimentally validate complex systems at
the micro/nano-scale with strong emphasis on the final device. In particular, his research themes focus on the integration of different physics (i.e. interdisciplinary) such as photonics, heat diffusion, electric charge/mass diffusion and mechanical-deformation towards the development of innovative devices for energy manipulation (harvesting, storage and sensing).