Electronic interactions within Carbon nanodots-metal nanoparticles nanohybrids, and their applications in photocatalysis and photonics

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Carbon nanodots (CDs) have been emerging in the last 15 years as a family of zero-dimensional carbon nanomaterials displaying several interesting optical properties, such as a bright and tunable fluorescence and a strong tendency of behaving as photo-activated charge donors. CDs also display several key advantages with respect to other optical nanomaterials, such as non-toxicity, low-cost and ease of synthesis. Since their original discovery in 2006, CDs have been attracting a large and interdisciplinary research interest in nanoscience, and many groups are pursuing their application in multiple fields, such as optoelectronics, photocatalysis, bioimaging and sensing. In particular, the nature of CDs as efficient and tunable light harvesters or light emitters, combined with their chemical versatility and ease of functionalization, makes them ideal building blocks for a variety of functional nanocomposites.

Here we investigate the photo-physical and -chemical response of hybrid nanomaterials obtained by coupling Carbon Dots (CDs) to gold (AuNPs) or silver (AgNPs) nanoparticles. On one hand, we aimed to investigate whether the strong propensity of CDs to engage in photoinduced charge-transfer can cooperate with the carrier mobility in MNPs, to achieve a photocatalytic response in the newly constituted nanohybrids. On the other hand, we wanted to explore whether the plasmonic resonances in metal nanoparticles can be used to tailor the optical response of CDs.
We demonstrate easy strategies to produce CD-AuNP and CD-AgNP nanocomposites through electrostatic self-assembly in solution phase, facilitated by surface and charge engineering of the two components. After a detailed structural characterization, the optical response of these nanocomposites is studied in detail by combining methods from steady-state optical spectroscopy to femtosecond-resolved pump-probe measurements. We demonstrate various interaction pathways between CDs and metal NPs, leading to different consequences on the optical response of the nanocomposites. In CD-AuNP nanocomposites, we achieve an enhancement of the orange-red emission of CDs made possible by ultrafast energy transfer from photoexcited AuNPs. In CD-AgNP nanocomposites we observe instead an emergent photocatalytic activity stemming from the ultrafast electron transfer from photoexcited CDs to coupled AgNPs. The results are very promising and encourage further studies to develop a new generation of CD-based functional nanocomposites for a range of applications such as light emitters, pollutant degradation, and water splitting.