Highlights

Activity B - Superconducting and correlated low dimensional materials and devices for quantum electronics and spintronics - 2021

Quantitative Ultrafast Electron-Temperature Dynamics in Photo-Excited Au Nanoparticles

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The dynamic processes and the redistribution of the charges following the photoexcitation of metallic nanoparticles (NPs) lie at the very heart of some highly-appealing light-induced physical phenomena, with applications in nanophotonics, hyperthermia, and photocatalysis to name a few. In order to investigate the mechanisms of electromagnetic-energy conversion, we need to study the fundamental processes occurring after the interaction of light with matter. In this work, we report for the first time a direct measurement of the ultrafast electron-temperature dynamics in plasmonic gold NPs in the first femtoseconds after impulsive photoexcitation. We measured the ultrafast electron-temperature dynamics in NPs deposited onto a transparent conductive oxide; we excited the NPs by means of an ultrashort pulse with wavelength at 650 nm, and collected ultrafast time-resolved photoemission spectra as a function of the elapsed time by means of extreme-ultraviolet ultrashort pulses (photon energy 16.9 eV, Figure 1).
Tiny variations on the Fermi edge of gold NPs, ascribed to the ultrafast heating and relaxation of the electron gas, were observed. Fitting the Fermi edge, we directly extracted the temperature of the electron gas as a function of the delay time elapsed from the moment of excitation (Figure 2). After excitation, the electronic temperature quickly increased and reached the maximum value after several hundreds of femtoseconds (~800 fs) and then gradually relaxed towards the environment temperature, in agreement with theoretical simulations. These results represent a significant progress for future investigation in the field, opening exciting perspectives for direct and quantitatively accurate studies of the electrodynamics of metallic bulk and nanostructured systems.

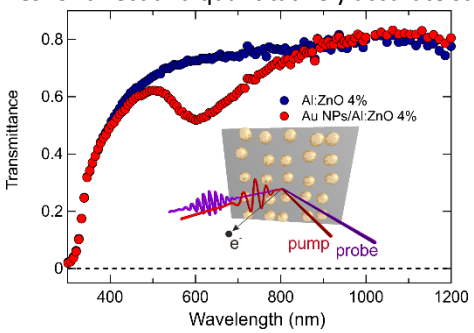

Fig. 1: Transmission spectra of 4 at% AZO film on MgO substrate with (red markers) and without (blue markers) Au NPs. Inset: Schematic diagram of the experimental setup.

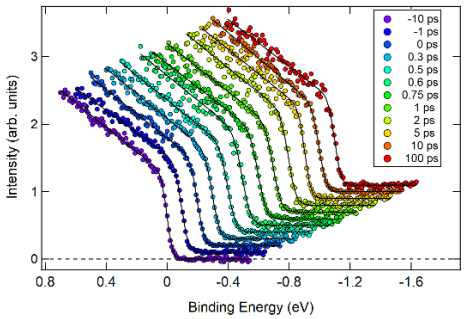

Fig. 2: Time-resolved pump-probe spectra of Au NPs at the Fermi edge (markers). Best fits according to Equation (1) (solid lines). The curves have been offset in energy and intensity for the sake of clarity.