Photo-induced force mapping of plasmonic nanostructures

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Plasmonic nanoparticles serve as efficient optical nanoantennae that interact with light with an effective cross section exceeding their geometric size. We have recently exploited this antenna effect to engineer photodevices for solar water splitting, optimizing for different plasmonic decay mechanisms such as near-field energy transfer to the surrounding semiconductor [1], plasmon-induced hot carrier generation and utilization [2], and broadband extreme light absorption within monolayer MoS2 [3]. However, often more than one plasmonic decay mechanism is at work, which makes it challenging to separate out the relative contributions and optimize them efficiently for solar water splitting. Novel characterization tools to study the heterogeneity of plasmonic photocatalysts both in terms of their morphology and optical near-field enhancements in-situ are therefore of widespread interest. Here we introduce a novel technique called photo-induced force microscopy that allows for simultaneous imaging of topographical features and spectroscopic characterization of near-field distributions with high spectral selectivity and temporal resolution. In this technique, a nanoscale tip is brought in the vicinity of the sample, which is optically excited. The photo-induced gradient forces between the tip and the sample can be detected with nanometer-scale spatial resolution, along with topographical information in atomic force microscopy tapping mode. I will show examples of our combined experimental-theoretical study [4] where we map force intensity enhancements in nanostructures and compare them to simulated force intensity enhancements in which a realistic tip-sample geometry is modeled using Maxwell-Stress tensor methods. Near-field inhomogeneities with a spatial resolution less than 10 nm are easily resolved. As such, photo-induced force microscopy will be a welcome addition to the toolbox of nanoscale characterization methods, and will find additional useful applications for the characterization of precisely manufactured nanostructures and surface-enhanced Raman scattering (SERS) substrates. Time permitting, I will discuss charge carrier dynamics in hybrid nanoparticles composed of plasmonic / two-dimensional materials, and applications of photo-induced force microscopy to these study photocatalytic processes.

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