Plasmonic Nanostructures for Enhanced Light-Matter Interactions - DTU Orbit (12/08/2019)

Plasmonic Nanostructures for Enhanced Light-Matter Interactions: from Metal to Graphene

Plasmonics, a recent booming field, plays a major role in the fascinating research area of nanophotonics. Graphene, the newly rising star on the horizon of materials science and optoelectronics, exhibits exceptionally surprising properties. In optoelectronics, graphene (including other 2D materials) physics strongly overlaps with plasmonics. In this thesis, our pioneer works are mainly grounded on combining graphene with plasmonics. Several works of enhanced light-matter interactions (LMIs) in graphene-metal hybrid plasmonic structures and graphene plasmonic structures are demonstrated. Before diving into particular projects, an introduction is stated for understanding related topics and the latest progress. Then, the theoretical basis of plasmonics and graphene is concisely summarized. Afterwards, the experimental methods involved in this thesis are also introduced briefly.

Firstly, a metal-based plasmonic structure is introduced as a start point, which is a platform for enhanced LMIs. By introducing an elastic substrate, the lattice symmetry of the plasmonic structure can be reconfigured by strain, leading to a stretch-tunable and polarization-dependent optical response. The structure can strongly modify the spontaneous emission of emitters by exciting plasmonic modes. An enhancement of photoemission up to 30 times is observed, leading to a 4 times broader emission spectrum.

Next, we mainly discuss the LMIs in metal-graphene hybrid plasmonic structures. We introduce two novel hybrid systems for studying light-graphene interactions. Coupling of graphene to the plasmon modes within the metallic structures results in significant frequency shifts of the underlying plasmon resonances, enabling enhanced absolute light absorption in graphene layers and a large enhancement of the Raman fingerprints of graphene.

Finally, the attention is focused on the LMIs in graphene plasmonics. We experimentally demonstrate graphene-plasmon polariton excitation in a continuous graphene monolayer resting on a two-dimensional subwavelength silicon grating. Our grating-assisted coupling of the incident light to graphene-plasmon polaritons forms an important platform for optoelectronic applications. Then, unprecedented large-area graphene nanodot and antidot optical arrays are fabricated by nanosphere lithography, with structural control down to the sub-100 nm regime. The interaction between graphene plasmon modes and the substrate phonons is experimentally demonstrated, and structural control is used to map out the hybridization of plasmons and phonons.

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