Tuning Plasmon Resonances by Electrochemical Potential Control

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Recently considerable attention has turned towards the relationship between plasmon excitation and the electrochemical potential associated with the electron gas in a conductor. In this paper, we explore this relationship in three contexts: 1) the plasmoelectric effect, a new physical phenomenon that relates resonant excitations in conductors to their electrochemical potentials and 2) field effect tuning of the electrochemical potential and plasmon resonances of graphene nanoresonators and 3) transport of plasmon-excited hot carriers across metal-semiconductor interfaces.

The plasmoelectric potential is an electrochemical potential induced by resonant optical absorption in plasmonic nanostructures. This electrochemical potential results from the dependence of the plasmon resonance frequency on electron density. Electrically connecting two metallic nanostructures with resonant absorption maxima at distinct frequencies, and irradiating both structures with an intermediate frequency, induces electron transport from the high frequency plasmonic resonator to the low frequency resonator. This process is entropically driven by an increase of the absorbed incident radiation, which results from the shifted plasmon resonances induced by the new charge density configuration. We demonstrate experimentally the relationship between plasmoelectric potential and resonant optical absorption via three independent experimental methods: 1) electrochemical potential measurements made by Kelvin probe force microscopy observations of Au nanoparticles on conducting substrates 2) potential measurements between two photoelectrochemical cells connected by a salt bridge and 3) comparison of extinction spectra take under broadband 'white' illumination and scanned monochromatic excitation.

We report the gate-tunable resonant absorption in lithographically fabricated arrays of graphene ribbon plasmonic nanoresonators with cavity lengths in the 10-100 nm range. Resonant mid-infrared absorption features due to transverse and longitudinal plasmonic cavity resonances are observable, as are plasmonic features that couple to localized phonon modes in the underlying silicon dioxide substrate. The plasmonic dispersion relations for these resonators can be developed by variation of resonant energy with cavity length as a function of gate voltage. The relationship between cavity edge roughness and resonance linewidth will be discussed.

Recently considerable attention has turned towards finding a silver lining in the cloud of plasmonics by extracting energy from the inevitable optical losses resulting from plasmon decay. We assess the prospects energy conversion via hot electron injection from localized plasmon decay across a rectifying metal-semiconductor Schottky barrier junction. Of particular interest is the relationship between the injection current across the Schottky barrier and the polarization of the electric field used to excite the plasmon. We analyze the current injection in Au/Si Schottky barrier nanoantennas excited with fields polarized transverse and parallel to the heterojunction interface.