Excitation and strong electrical modulation of plasmons in Graphene with the use of a 2-dimensional inverted pyramid array diffraction grating

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The peculiar band structure of graphene results in an electrically tunable optical spectrum rendering it an ideal material for plasmonic applications. In this work an inverted pyramid array diffraction grating is used to couple plasmons in graphene. Due to the multi-interface nature of the device a high frequency plasmon mode of odd vector parity is excited achieving higher plasmon excitation frequencies than those in single interface systems. Additionally, thanks to the symmetry of the diffraction structure both s and p polarization of light can equally excite plasmons.

Gate modulated plasmon absorption was mapped over the near infrared spectral range as a function of chemical potential with the use of theoretical calculations as well as Rigorous Coupled-Wave Analysis method. Strong shift of plasmon absorption was demonstrated over the near infrared spectrum with plasmon energy increasing by ~0.05eV for 0.04eV increase of chemical potential in Graphene. Most importantly the ability to dynamically switch off plasmon excitations by lowering the chemical potential and moving from the intraband to the interband transition region was observed, with promise in the field of high density photonic logic circuits. Furthermore, optimization of structure parameters was performed for achieving higher coupling efficiency. Optimizing diffraction efficiency lead to significant enhancement of plasmon absorption in the monolayer. Finally, plasmon excitation was found to be effectively unaffected from angle of incidence of photons thus allowing the excitation of plasmons with the use of high numerical aperture lenses.

This findings of this work have promise in several commercial fields since providing strong control over the plasmon energy and strength as well as shifting plasmon excitations to the near infrared and visible optical wavelengths can lead to on-chip light modulation, photonic logic gates as well as sensing applications.

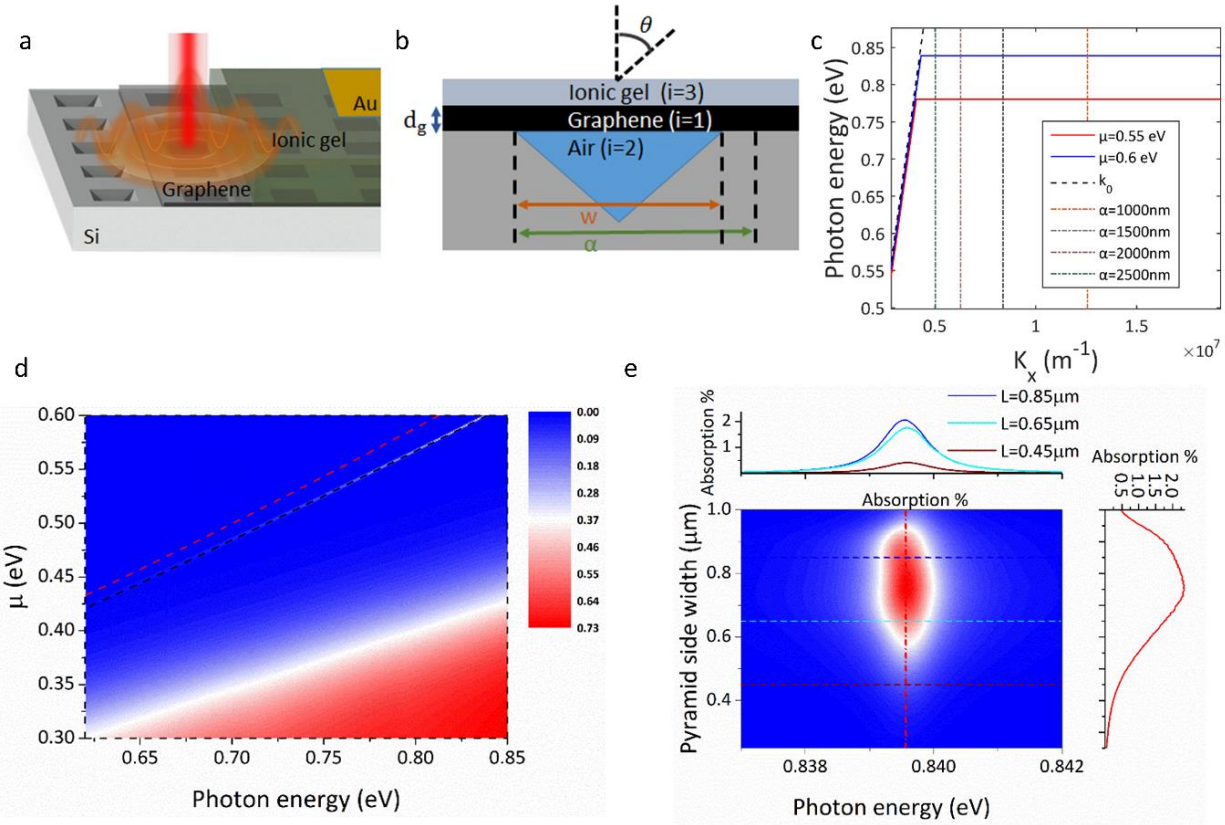

Fig. 1. (a) 3D model of the device. (b) Schematic of the device used for theoretical calculations. (c) Tunable plasmon dispersion of graphene. (d) Electrostatically tunable plasmon absorption. (e) Plasmon absorption enhancement by optimization of diffraction grating.