Exciton - phonon-plasmon polariton interaction in quantum dot and graphene nanocomposite deposited on polar crystals

Mahi Singh,[1] Boris Fainberg,[2] Marek Brzozowski[1] and Boris Apter[2]

[1]Department of Physics and Astronomy, Western University, Canada,
[2] Department of Physics, Holon Institute of Technology, Israel
Corresponding Authors: fainberg@hit.ac.il and msingh@uwo.ca

Recent progress in nanofabrication techniques and advances in laser technologies opened new directions in research of plasmonic materials at nanoscale. Plasmon coupling to excitons is studied by a field of research named plexcitonics [1]. There is a considerable interest in developing nanoscale plasmonic devices by combining graphene with quantum dots (QDs) and metallic nanoparticles into hybrid nanostructures called nanocomposites. The aim of this paper is to study a new type of interaction between exciton of QD and phonon-plasmon polariton (PPP) in QD-graphene (a graphene flake) hybrid material deposited on a polar crystal such as SiC or SiO_2. When an electromagnetic field acts on the graphene flake, surface plasmon (SP) polaritons are created due to coupling between SPs and photons. The surface optical phonons of a polar crystal couple with SPs of the graphene via long-range Fröhlich coupling, leading to a modified plasmonic dispersion, PPPs, as was measured in Ref. [2]. Whereas exciton-SP and SP-phonon interactions have been studied in the past, we study here a new type of interaction, namely *exciton-PPP interaction*. Using the density matrix method, we have calculated the absorption coefficient of a three-level QD in a V-configuration in the presence of both exciton-SP polariton and exciton-PPP coupling. Our calculations show the enhancement of the absorption in the QD in the terahertz range that is very sensitive to the detuning of both exciton-SP polariton and exciton-PPP coupling resonances. This sensitivity can be used to fabricate switches and sensors in the THz energy range. We also compare the case when only one coupling (exciton-SP polariton or exciton-PPP coupling) is resonant with that when both couplings (exciton-SP polariton and exciton-PPP coupling) are resonant. Our calculations show that the enhancement of the absorption peak corresponding to exciton-SP polariton coupling is larger than that corresponding to exciton-PPP coupling. This means smaller energy transfer from graphene to QD due to exciton-PPP coupling.

1. N. T. Fofang, T.-H. Park, O. Neumann, N. A. Mirin, P. Nordlander, N. J. Halas, *Nano Lett.* **8**, 3481, 2008.

2. H. Yan, T. Low, W. Zhu, Y. Wu, M. Freitag, X. Li, F. Guinea, P. Avouris, and F. Xia, *Nature Photonics*, **7**, 394, 2013.