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Quenching of photoluminescence in graphene hybrids

Mahi R Singh
The University of Western Ontario, Canada

Recently there is a considerable interest to study the plasmonic properties of graphene hybrids. Graphene was invented theoretically by Wallace in 1947. He predicted that graphene is a gapless NS and has an indirect band gap. Later, Wallace and I found more gapless materials such as Cd3AS2, HgTe which have direct band gaps. We showed that the optical energy absorption/emission is stronger in the direct bandgap materials than indirect band materials. Recently graphene-like nanostructures such as germanene and silicanes have been invented. Here, we investigate the quenching of photoluminescence in a quantum dot (QD)-metallic nanoparticles and metallic graphene film (QD-MN-G) hybrid system deposited on a dielectric material such as Si. The surface plasmon polaritons (SPPs) are calculated solving the Maxwell equations for the graphene and the dielectric heterostructure in the quasi-static approximation. QDs have excitons which interact with SPPs of the graphene-dielectric heterostructure. Photoluminescence (PL) of QD is found by using the quantum density matrix method in the presence of exciton-SPP coupling. Numerical simulations for the PL spectrum in the QD is performed for (QD-MN-G) hybrid system. It is found that when the exciton energy of the QD is in resonant with the SPP energy the intensity of the photoluminescence is quenched. The PL quenching occurs is due to the transfer of photon energy from the QD to the graphene film and MNP due to the exciton-SPP coupling. Furthermore, when the exciton energy is non-resonant with the SPP energy the PL quenching disappears. The energy transfer from the QDs to the graphene film can be switched ON and OFF by mismatching the resonant energies of excitons and polaritons. The mismatching of energies can be achieved by applying external pump lasers or stress and strain fields. Recently Dong et al. and Zeng et al. have measured the PL spectrum of QDs in QD-G hybrid and QD-MN-G hybrid, respectively. In both experiments, they have observed the PL quenching. We have compared our theory with these experiments and found a good agreement between theory and experiments. These are interesting findings and they can be used to fabricate switches and sensors by using graphene nanocomposites.

msingh@uwo.ca