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Mahi R Singh

University of Western Ontario, Canada

Study of plasmonics and phononics in nano-hybrids made of graphene and polar crystals and their applications to nano-switches and nano-sensors

There is a considerable interest in developing nano-scale plasmonic devices by combining graphene with Quantum Emitters (QEs) and metallic nanoparticles into hybrid nanostructures. Graphene was invented theoretically by Wallace in 1947 and he found that graphene is a gapless material. 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 band gap materials than indirect band materials. Most of research on nano plasmonics has focused mainly on noble metals. The problem with the noble metals is that they are hardly tunable and exhibit large Ohmic losses which limit their applicability to plasmonic and optoelectronic devices. On the other hand, graphene plasmons provide an attractive alternative to noble metal plasmons. It is because they exhibit much tighter confinement, small Ohmic losses and have relatively long propagation distances. The SPPs in graphene can also be tunable via electrostatic gating technique. Graphene has also emerged as a very promising candidate for THz to visible frequency applications since its plasmonic resonance frequency lies in this range. Here we investigate the effect of phonon-plasmon and surface plasmon polaritons on photoluminescence in graphene deposited on polar crystals. Other zero-band-gap nanostructures will be also included in the present study. Using the second quantized formulation for SPPs and PPs interaction and density matrix method we have calculated photoluminescence of the quantum emitters. It is found that when the exciton energy of the quantum emitter is in resonant with the SPP and PPP energies the absorption and photoluminescence in the quantum emitter are enhanced in the terahertz range. The enhancement is due to the transfer of SPP and PPP energies from the graphene flake to the quantum emitter. We have also compared our theory with photoluminescence experiments of ZnO-MGF hybrid system deposited on SiO_2 polar crystals and a good agreement between theory and experiments has been found. The present theory is also able to explain the change in enhancement due to SiO_2 spacer thickness in this hybrid system. The energy transfer from the graphene to the quantum emitter can be controlled by applying external pump lasers or stress and strain fields. This means that the energy transfer from the QDs to the graphene can be switched ON and OFF by external ultrafast laser. These are interesting findings and they can be used to fabricate switches and sensors.

Biography

Mahi R. Singh received both M.Sc. (1970) and PhD (1976) degrees from Banaras Hindu University, Varanasi in condensed matter physics. After that he was awarded an Alenxander von Humbold Fellow in Stuttgart University, Germany from 1979 to 1981. Between 1981 and 1985 he was a Research Associate and Lecture at McGill University, Montreal, Canada. From 1982 to 1983 he worked in INSA, Toulouse, France as a vesting scientist. He also worked as Research Associate at University of North Carolina, Chapel Hill, USA. After that he joined the University of Western Ontario as associate professor in 1985. Currently he is professor in this university. He was a visting professor at University of Houston, USA from June till November in 1992. He also worked as a chief researcher at CRL HITACHI, Tokyo between November 1992 and May 1993. In summer 1993 and 1994, he was a visiting professor and Royal Society Professor at University of Oxford, UK.

msingh@uwo.ca