GLH
GRAPHENE-BASED LIGHT HARVESTING

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Thin metal films and metallic nano-structures exhibit the capability to confine optical fields far below the diffraction limit (surface plasmons: SP). Strongly driven by the recent developments in nanoscale device fabrication, SP-based devices have resulted in a wide variety of applications including light harvesting devices and methods to improve the efficiency of solar cells and biosensors, as well as a medium to tailor the long-range energy transfer between emitters and tailor strongly enhanced interactions between optical emitters and SPs.

Although several fabrication methods are now available for structuring metals at the nanoscale, an extremely high level of control is required to provide reproducible devices with a high level of control over strongly confined optical fields. Moreover the intrinsic properties of the metal are not in-situ tuneable, and the losses associated to strong scattering in metals are detrimental to the device efficiency and capabilities.

Here, we incorporate an atomic-layer of carbon (graphene) as an alternative material for carrying surface plasmon modes and as a medium for extremely efficient light harvesting and to tailor energy transfer between optical emitters. These significant advantages make graphene an excellent candidate for light manipulation and harvesting devices, which can be directly integrated with electronic circuits and PV cells. This project aims at making the first steps towards graphene nano-plasmonics, by studying the interactions between graphene and fluorescent emitters (quantum dots).

The goals of this project are two-fold:

1. We studied the transfer efficiency from the optical energy from quantum dots to graphene (Figure 1)
2. We studied novel type of device integration based on substrate induced doping of graphene

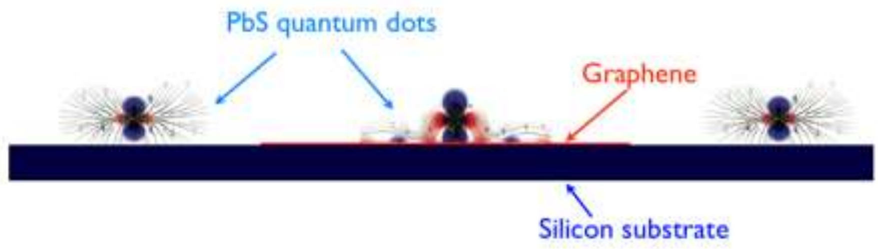

Figure 1: schematic representation of energy transfer from emitters to graphene. The gray lines represent the Poynting vectors. Strong energy transfer to graphene is expected due to the unique properties of graphene.

Objectives and results

WP1. Fabrication of high quality graphene devices with nanoscale electronic contacts and gates (Figure 2).

The graphene flakes were prepared by the standard mechanical exfoliation technique of highly ordered pyrolytic graphite with tape and deposited on a SiO2 (285nm)/Si wafer. Contacts to graphene were defined by conventional electron beam lithography followed by evaporation of titanium and gold (5 nm / 100 nm). The mobility of the devices was about 1000-3000 cm^2/Vs.

WP2. The synthesis of high quality quantum dots and tuning of their optical properties to match optimal conditions for energy transfer (Figure 2).

PbS quantum dots have synthesized and thin films have been deposited on graphene. The quantum dots on graphene reveal a strong modification of the lifetime, elucidating energy transfer processes between quantum dots and graphene.

WP3. Integrating graphene devices with ferroelectric materials in order to boost the doping to extremely high levels and suppress plasmonic losses.

We successfully deposited graphene on transparent substrates which show modification of the intrinsic doping of graphene, revealed by transport measurements. Future experiments will elucidate the effects of doping on the near-field interactions between quantum dots and graphene.

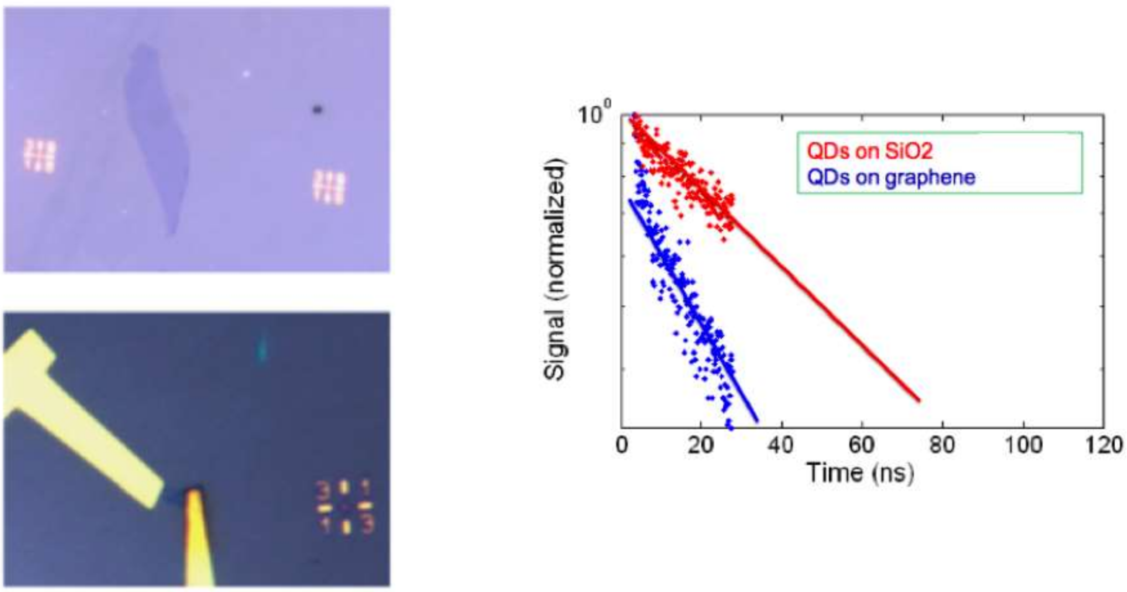

Figure 2: (left) Contacted graphene flakes. (right) Emission lifetime of PbS quantum dots on graphene and silicon

Integration

We have performed lifetime and fluorescence measurements (performed by partner 1) revealing the non-radiative energy processes from quantum dots (synthesized by partner 2) to graphene (Figure 2). Theoretical work (by partner 4) elucidated the very rich physics due to the massless character of the charge carriers, the two-dimensionality, and the ability to tune in-situ the properties of the system. This system is therefore an ideal and test bed for studying novel regimes of energy transfer processes to a two-dimensional conductor.