

Photodetection: ionic glass at play to control the carrier density fo nanocrystal array

Thanks to large progresses relative to their synthesis, nanocrystal now appaer as possible alternative to epitaxially grown semiconductors. However the doping of such nanoparticle remains chalenging and thus method to tune their carrier density still have to be develloped. The physical chemistry team from INSP in partnership with IPCMS (U. Strasbourg) has develloped a new type of gate based on ionic glass to design field-effect transistor.

Over the past decade, colloidal nanocrystals have become a very interesting alternativ eto epitaxially grown semiconductor for the design of infrared optoelectronic devices. Among possible device geometry, the field effect transistor (FET) appears of utmost interest. In this configuration, the nanocrystal film is absorbing the incident light and the transistor gate tunes the carrier density to minimize the dark current.
The conventional way to build an FET relies on SiO_2 as dielectric. Here, we explored the potential of the LaF_3 ionic glass. In this glass, the fluorine vacancies move under the application of a voltage, which generates a polarization and therefore a field-effect. This strategy leads to gate capacitance almost as high as the obtained using electrolytes while ensuring a fast operation. In addition, this method is compatible with sub room temperature operation corresponding to the operating temperatures of infrared sensors used to reduce their internal noise. Ionic glass gating is a very general method that we have applied to both narrow bandgap nanocrystals [1-2] and 2D materials like $MoSe_2$ [3].
We then demonstrated that replacing the metal electrodes with graphene electrodes, which were manufactured at IPCMS (Jean Francois Dayen's team), induces a new mode of operation. Here, Graphene is not used for its large mobility, but rather for its transparency to electric fields. Unlike metal electrodes, graphene does not screen the gate induced field. It then becomes possible to generate a p-n junction in the film of nanocrystals. The latter is used to enhance the charge dissociation when the film is under infrared illumination [4], see the figure below.

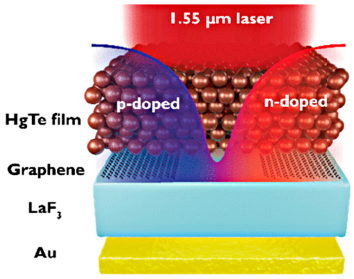


Figure 1
Sketch of field effect transistor combining a LaF3 ionic glass as gate ; graphene as electrodes with HgTe nanocrystal array as channel.

Now that this new type of gate is developed, the next challenge is to couple the FET with plasmonic resonators in order to obtain an exalted light-matter coupling. This project is being conducted in the framework of the ANR Copin and the ERC BlackQD project.

References

[1] Field-Effect Transistor and Photo-Transistor of Narrow-Band-Gap Nanocrystal Arrays Using Ionic Glasses
C Gréboval, U Noumbe, N Goubet, C Livache, J Ramade, J Qu, A Chu, ...
Nano letters 19, 3981-3986 (2019)
[2] Pushing absorption of perovskite nanocrystals into the infrared
P Rastogi, A Chu, C Gréboval, J Qu, UN Noumbé, SS Chee, M Goyal, ...
Nano Letters 20, 3999-4006 (2020)
[3] Ionic Glass–Gated 2D Material–Based Phototransistor: $MoSe_2$ over LaF_3 as Case Study
UN Noumbé, C Gréboval, C Livache, T Brulé, B Doudin, A Ouerghi, ...
Advanced Functional Materials 29, 1902723 (2019)
[4] Reconfigurable 2D/0D p–n Graphene/HgTe Nanocrystal Heterostructure for Infrared Detection
UN Noumbé, C Gréboval, C Livache, A Chu, H Majjad, LE Parra López, ...
ACS nano 14, 4567-4576 (2020)
https://pubs.acs.org/doi/abs/10.1021/acsnano.0c00103

Contact

Emmanuel Lhuillier - el@insp.upmc.fr