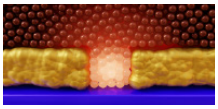

Photoconduction at the diffusion length limit

Nanocrystals became an essential building blocks of modern optoelectronics. In the infrared, HgTe nanocrystals are used for the fabricate cameras and LEDs. In these polycrystalline materials, hopping has often been seen as a bottleneck to their performance. Members of the team of physical chemistry of the INSP have shown that by adapting the geometry of the device, it is possible to obtain photoconduction properties as high as bulk materials.

HgTe is a zero band gap semiconductor. When it is synthesized as nanoparticles, it becomes possible to induce a tunable gap between 20 meV (THz range) and 1.5 eV (near infrared). This tunability makes HgTe a unique platform for the development of infrared optoelectronic devices. The interested reader will refer to a recent review by the INSP group on this subject [1]. However, the polycrystalline nature of the material induces transport by hopping, thus reducing the mobility of carriers relative to the solid material.

Recently the groups of Talapin and Guyot-Sionnest suggested that the transport is partially delocalized between strongly coupled nanocrystals islands and that the diffusion would occur only between these islets [2]. From this hypothesis arises our idea of probing the photoconduction at the scale of a single island of strongly coupled nanocrystals [3]. In collaboration with the group of J.F. Dayen (IPCMS) we use a simple technique to design nanotranches: two electrodes separated by only a few tens of nm, and this only using optical lithography.

We have shown that the photoconduction properties are enhanced when the size of the device is of the order of the diffusion length ≈20 nm. This results in the best infrared detectors made from nanocrystals. In particular, the geometry of the device generates a considerable electronic gain with nearly 105 electrons generated per photon (against less than 1 in a micrometric structure). In addition, the operating mechanism of this device has been studied in detail thanks to our collaborators from IEMN (C. Delerue) and Onera (G. Vincent) who model the electronic structure and the electromagnetic field, respectively.

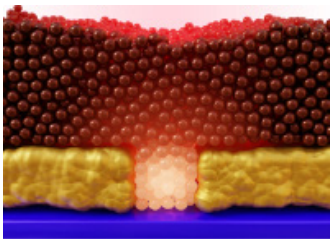

Figure
Scheme of the nanocrystals embeded in nanotrench.
(Each bead is about 10 nm).

There are now two challenges for this device. On the one hand, we target to couple it to optical resonators in order to enhance their absorption, which is currently low due to the small device size. In addition, we aim to integrate it into matrix of pixel to design a focal plane array.

References

[1] Mercury Chalcogenide Quantum Dots: Material Perspective for Device Integration, C. Gréboval et al., Chemical Reviews 121, 3627 (2021)
[2] Quantum dot solids showing state-resolved band-like transport, X. Lan et al., Nat. Mater. 19, 323 (2020).
[3] Infrared photoconduction at the diffusion length limit in HgTe nanocrystal arrays, A Chu et al., Nature Communications 12, 1794 (2021)
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