Physics of colloidal quantum dots superlattices

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Colloidal quantum dot superlattices (CQDS) are emerging as a new type of solids allowing easy fabrication of optoelectronic devices such as solar cells. Moreover, this new class of thin films displays peculiar physical properties, which make the investigation of their transport properties extremely interesting. These peculiar properties are due to strong size-dependent quantum confinement of the individual quantum dots (QDs), responsible for the variations of their electronic bandgap and optical absorption. The quasi 0D nature of the QDs leads to the formation energy sub-bands.

To utilize these CQDS as component of complex heterostructures, as the one necessary to build efficient solar cells, it is necessary to be aware of their energy levels configuration but also to understand the transport mechanism occurring in these superlattices.

I will discuss a powerful method to determine the electronic energy levels of CQDS from their intrinsic charge carrier transport characteristics. The method utilizes ambipolar field-effect transistors (FET) – fabricated with the CQDS – which are gated with highly capacitive ionic-liquid-based ion gel (sheet carrier density ~ $10^{14}/cm^2$). In this kind of FET, the Fermi energy can be deeply tuned accessing energy levels beyond the HOMO and LUMO of the QDs. The PbS CQDS with different QD diameters are used as model system and this experimental method is combined with advanced ab-initio theory using both self-energy approach and total energy calculations, considering electron addition/removal and the spin-orbit coupling. The values experimentally obtained with this new method correlate very well with the calculated values, giving confirmation of the reliability of the method. Importantly, from the transfer characteristics of the supperlattice we also obtain experimental evidence of the formation of mini-bands in quantum dots arrays.

At the end I will discuss the role of the quantum dots quality in the transport mechanism and efficiency of CQDs solar cells.

References

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