Semiconductor Nanocrystals: from discovery to modern development

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The Nobel Prize in Chemistry 2023 was awarded to Moungi G. Bawendi, Louis E. Brus and Aleksey I Ekimov "for the discovery and synthesis of quantum dots”. Nanocrystals (NCs) quantum dots are the most heavily studied of the nanoscale semiconductors. The size dependence of NC optical properties was discovered independently more than 30 years ago in two different materials: in semiconductor-doped glasses by Ekimov et al (1981), and in aqueous solutions by Brus et al (1983). Theoretical description of these optical properties was reported by Efros et al.(1982). I will briefly discuss the history of this discovery, the main obstacles in the development of this field, and the critical breakthroughs along the way [1].

Today, semiconductor NCs have become much more than objects of scientific curiosity. The demonstration of tunable, room-temperature lasing using NC quantum dot solids, the development of NC-based light-emitting diodes and photovoltaic cells, quantum dots TV produced by Samsung, and the first commercial products in the area of NC bio-labeling are just a few illustrations of the broad technological potential of these materials.

Nonradiative Auger recombination is the central non-radiative relaxation process, which negatively affects the performance of all these devices. I will discuss why nonradiative Auger recombination is enhanced in NCs, and how we can suppress it [2].

Finally, I am going to discuss the unusual optical properties of the recently discovered CPbX3 (X=Cl, Br. I) NCs, which are connected with a ground bright exciton state [3]. We calculate the lowest quantum confined levels of electrons and holes and the spectra of the allowed optical transitions. The calculations consider the cubic shape of the perovskite NCs, which results in an inhomogeneous electric field of emitted and absorbed photons. The symmetry of the ground exciton state has been analyzed, and the radiative decay time has been calculated. The results of our theoretical calculations have explained the 200 ps radiative decay time and polarization properties measured in experiments on single CsPb(BrCl2) quantum dots.

References

[1] Al. L. Efros and L. E. Brus, Nanocrystal quantum dots: from discovery to modern development. ACS Nano 15, 6192–6210 (2021).
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[3] M. A. Becker, et al., Bright triplet excitons in cesium lead halide perovskites. Nature, 553, 189 (2018).