Transient Charging and Charge Carrier Trapping in Semiconductor Nanocrystals

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ABSTRACT

The size- and composition-dependent tunable bandgap or emission color of cadmium chalcogenide quantum dots and hybrid halide perovskite nanocrystals are fascinating inventions in nanoscience and nanotechnology.[1,2] The tunable optical and electronic properties accompanied these tiny crystals to various disciplines of basic research,[1,3] making them promising for brilliantly luminescent displays, high-efficiency photovoltaics, and sophisticated quantum computers. However, photo-generated carriers in these tiny crystals show stochastically fluctuating carrier/exciton recombination rates, rendering these semiconductors intermittent or blinking light emitters at the single particle levels.[4-9]

Conversely, interparticle states and carrier traps enable delayed emission in closely packed states, extending the photoluminescence lifetime to the microsecond scale. For single quantum dots, the blinking time fluctuates on a wide time scale – from microseconds to minutes, preventing the applications of these nanomaterials to on-demand light sources. The size, ligands, surface morphologies, chemical compositions, the nature and density of defects, the intensity and energy of incident light, and band-edge states affect the exciton, carrier, and intermittency stabilities/durations. Although the relations of blinking to the intensity and energy of incident light and the nature and density of defects are widely appreciated since 1995,[3] the development of non-blinking quantum dots or nanocrystals is challenging even today.

This presentation highlights synthesis, quantum confinement, bandgap engineering, and optical properties of selected semiconductor quantum dots with special references to the origins of long photoluminescence lifetimes,[10-12] and intermittent emission[5-8,13] and suggests methods to cosset the blinking by carrier de-trapping, electron transfer, or defect passivation.

REF.

1. V. Biju, *Chem. Soc. Rev.* 43, 744 (2014).
2. L. Chouhan, V. Biju *et al. Chem. Soc. Rev.* 49, 2869 (2020).
3. V. Biju, *et al. Chem. Soc. Rev.* 39, 3031 (2010).
4. M. Nirmal, B. O. Dabbousi, M. G. Bawendi, *et al. Nature* 383, 802 (1995).
5. L. Chouhan, S. Ghimire, V. Biju, *Angew. Chem. Int. Ed.* 58, 4875 (2019).
6. E. M. Thomas, S. Ghimire, R. Kohara, V. Biju, *et al. ACS Nano* 12, 9060 (2018).
7. M. Hamada, S. Nakanishi, T. Itoh, M. Ishikawa, V. Biju, *ACS Nano* 4, 4445 (2010).
8. L. Chouhan, S. Ito, E. M. Thomas, V. Biju, *et al. ACS Nano* 15, 2831 (2021).
9. S. Yamashita, M. Hamada, V. Biju, *et al. Angew. Chem. Int. Ed.* 54, 3892 (2015).
10. S. Ghimire, V. Biju, *et al. ACS Energy Lett.* 4, 133 (2019).
11. V. C. Nair, C. Muthu A. L. Rogach, V. Biju, *et al. Angew. Chem. Int. Ed.* 56, 1234 (2017).
12. Z. Zhang, V. Biju, *et al. ACS Nano*, 16, doi.org/10.1021/acsnano.1c04944 (2022).
13. A. Dey, J. Ye, A. De, E. Debroye, V. Biju, *et al. ACS Nano*, 15, 10775 (2021).