PbS Quantum Dot Light-Emitting Field-Effect Transistors

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Colloidal semiconducting quantum dots (QDs) are solution-processable, size-tunable and efficient emitters. For optoelectronic applications, such as solar cells, light-emitting diodes (LEDs), and QD lasers it is crucial to understand and control their charge transport, recombination and emission dynamics, which are influenced by trap-states. These trap states can be filled and thus deactivated when operating devices at very high carrier densities. While carrier densities in light-emitting diodes are generally low, very high charge densities (up to 1 charge per QD) can be achieved in light-emitting field-effect transistor (LEFET).
Here, we demonstrate the first quantum dot LEFET. This is accomplished by using electrolyte-gated PbS QD thin films. They exhibit near-infrared electroluminescence from a confined region within the channel with identical size-dependent electroluminescence and photoluminescence spectra (see Figure 1), which proves true ambipolar transport through the S_h and S_e states of the PbS QDs. In contrast to QD LEDs, external quantum efficiencies in LEFETs continuously increase with current density. This effect correlates with the unexpected increase in photoluminescence quantum yield and longer average lifetimes at higher electron and hole concentrations. We attribute the initially low emission efficiencies to non-radiative losses via electron and hole traps. At higher carrier densities trap states are deactivated and emission starts to be dominated by trions with fast radiative decay rates.

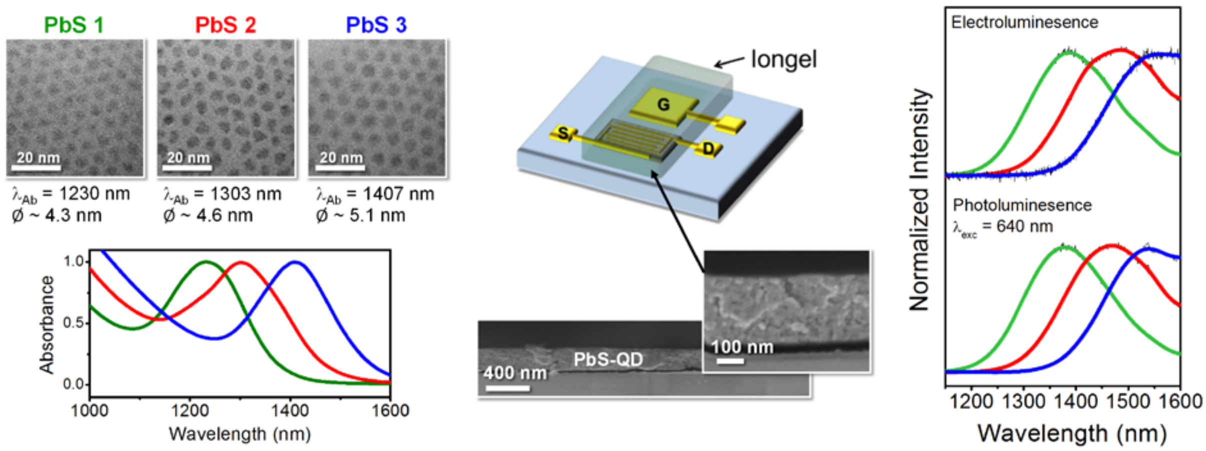

Fig. 1. PbS quantum dots of different sizes used to create thin films and electrolyte-gated light-emitting field-effect transistors that show near-infrared electroluminescence.

References

1. J. Schornbaum et al., *Nano Lett.* (2015), doi: 10.1021/nl504582d.