

## Colloidal 2D PbSe Nanoplatelets with Efficient Emission Reaching the Telecom O-, E- and S-band

Lars F. Klepzig<sup>1,2</sup>, Leon Biesterfeld<sup>1,2,4</sup>, Michel Romain<sup>1</sup>, André Niebur<sup>1,2</sup>, Anja Schlosser<sup>1,\*</sup>, Jens Hübner<sup>3,\*</sup>, Jannika Lauth<sup>1,2,4,\*</sup>

<sup>1</sup> Institute of Physical Chemistry and Electrochemistry, Leibniz Universität Hannover, Callinstr.3A, 30167 Hannover, Germany

<sup>2</sup> Cluster of Excellence PhoenixD (Photonics, Optics, and Engineering – Innovation across disciplines, 30167 Hannover, Germany)

<sup>3</sup> Institute of Solid State Physics, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

<sup>4</sup> Institute of Physical and Theoretical Chemistry, Universität Tübingen, Auf der Morgenstelle 18, 72076 Tübingen, Germany

\* Laboratory of Nano and Quantum Engineering, Schneiderberg 39, 30167 Hannover, Germany

**Summary.** Colloidal two dimensional (2D) lead chalcogenide nanoplatelets (NPLs) represent highly interesting materials for near- and short wave-infrared applications including innovative glass fiber optics exhibiting negligible attenuation. However, the direct synthetic access of these optoelectronic materials is still scarce. In this work, we demonstrate a colloidal synthesis route for 2D PbSe NPLs with cubic rock salt structure at low reaction temperatures of 0 °C and room temperature. A lateral size tuning of the PbSe NPLs leads to excitonic absorption features in the range of 1.55 – 1.24 eV (800 – 1000 nm) and narrow photoluminescence (PL) reaching the telecom O-, E- and S-band (1.38 – 0.86 eV, 900 – 1450 nm). The PL quantum yield of the as-synthesized PbSe NPLs is doubled by a postsynthetic treatment with CdCl<sub>2</sub> (e.g. from 14.7 % to 37.4 % for NPLs emitting at 980 nm with a FWHM of 214 meV). Our results open up new pathways for a direct synthesis and straightforward incorporation of colloidal PbSe NPLs as efficient infrared emitters at technologically relevant telecom wavelengths.

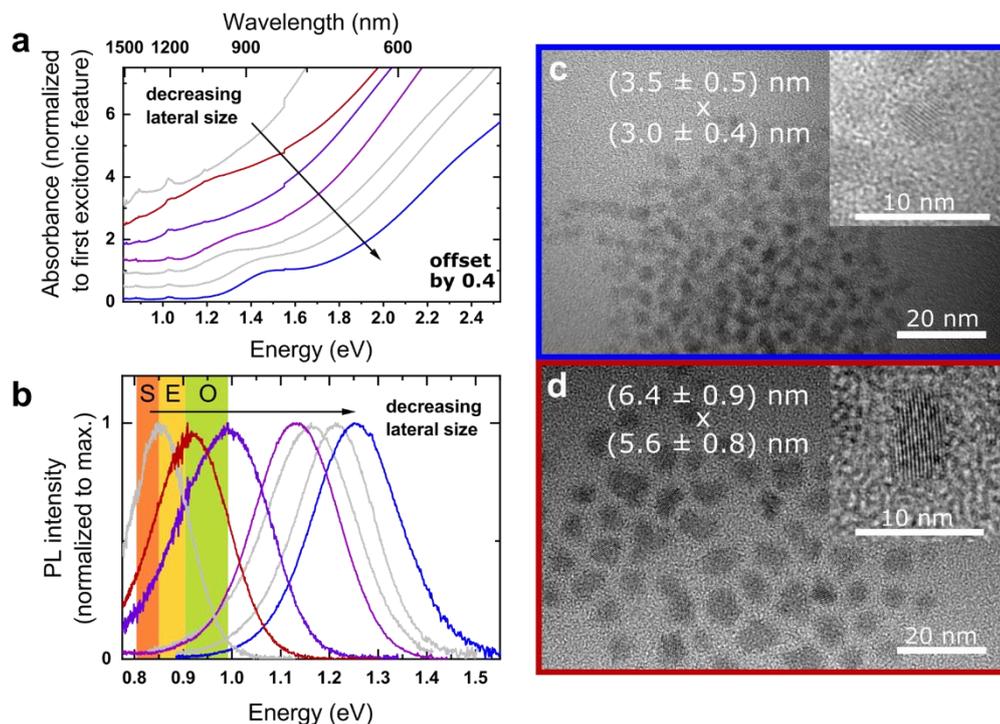


Figure 1: Characterisation of PbSe NPLs by optical spectroscopy and transition electron microscopy (TEM). a) Absorbance (plotted with an offset of 0.4) and b) photoluminescence of exemplary PbSe nanoplatelets. A shift towards lower energies is observable as the NPLs grow in lateral size. c) and d) TEM images of small and large PbSe NPLs, with the color of the frame matching the colors of the graphs in a) and b).

Atomically thin quasi-two dimensional (2D) IV-VI semiconductors, especially lead chalcogenide nanosheets (NSs) and nanoplatelets (NPLs), have attracted significant interest due to their promising optoelectronic properties covering the near-infrared (NIR) and short-wave-infrared (SWIR) wavelength range of the electromagnetic spectrum. However, synthetic access especially to NPLs exhibiting seamlessly tunable and efficient NIR to SWIR Photoluminescence (PL) is scarce. Here, we report the first direct synthesis of 2D PbSe NPLs with efficient broadband tunable infrared emission by using lead oleate and selenourea as precursors in a

mixture of octylamine and oleic acid. PbSe NPLs are synthesized at room temperature or below and exhibit distinct excitonic absorption features between 800–1000 nm (1.55–1.24 eV, Fig. 1a), while narrow PL is obtained at technologically relevant telecommunication wavelengths between 900–1450 nm (1.38–0.86 eV, Fig. 1b), reaching the O-, E- and S-band (0.98–0.91, 0.91–0.85 and 0.85–0.81 eV, resp.). Due to the large exciton Bohr radius in bulk PbSe (46 nm) the optical properties of the NPLs are tuned by controlling their lateral size rather than their thickness. While a low reaction temperature (0 °C) and a low amount of OcAm present during reaction is favorable for the formation of smaller PbSe NPLs, an increase of the temperature (to room temperature) and/or of the amount of OcAm leads to larger lateral NPL sizes and a tunable red shift of their absorption and PL features (Fig. 1c and d).

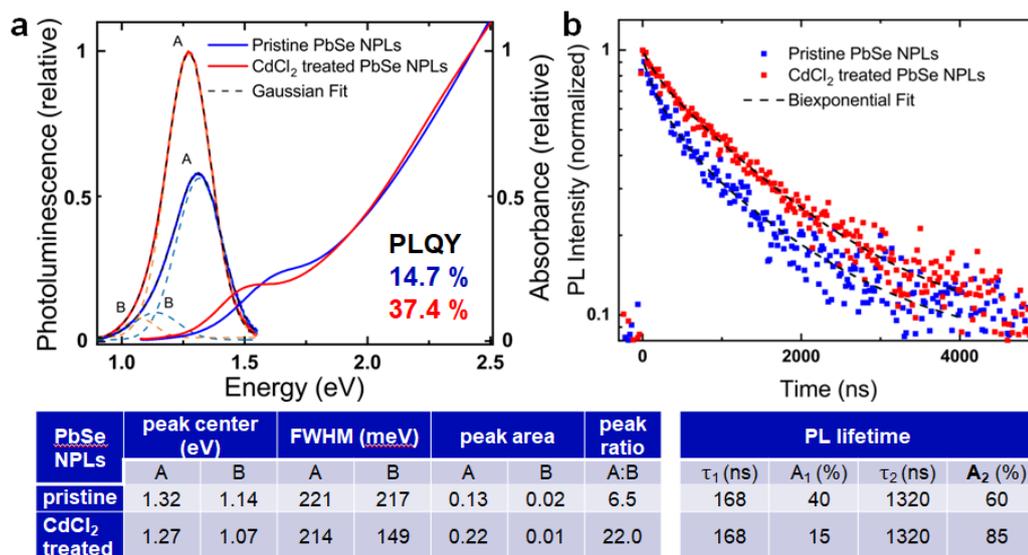


Figure 2: Comparison of a) the photoluminescence and absorption and b) the PL lifetime before and after the CdCl<sub>2</sub> treatment. The parameters for the fit of the PL with two Gaussians as well as for the biexponential fit of the PL lifetime are summarized in the table underneath.

In a subsequent step, a postsynthetic surface treatment of the PbSe NPLs with CdCl<sub>2</sub> leads to an increase of the PLQY of PbSe NPLs (e.g., from 14.7% to 37.4% for NPLs emitting at 980 nm). We fit the PL spectra with the sum of two Gaussians and the Gaussian centered at higher energy (labeled A) is ascribed to the PbSe band gap associated PL, while the lower energy PL (labeled B) is related to surface traps (Fig. 2a). A decreased contribution of the trap state is apparent after the CdCl<sub>2</sub> treatment. A characterization of the photophysics and charge carrier dynamics of pristine and CdCl<sub>2</sub> treated PbSe NPLs by transient absorption spectroscopy and multi-channel scaling PL lifetime analysis underpins this. While multiple relaxation pathways are present in pristine PbSe NPLs, CdCl<sub>2</sub> treated PbSe NPLs show less complex relaxation behaviour. The PL lifetime is fitted biexponentially, and we find the contribution of the faster time constant assigned to the trap states significantly reduced from 40% to 15%, associated with an increase of the slower time constant to 85%. This opens up new insight into further surfactant treatment and renders PbSe NPLs efficient colloidal quantum emitters at telecommunication wavelengths.

For further information, see:

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