14thInternational Symposium on Flexible Organic Electronics (ISFOE21)
5-8 July 2021, Thessaloniki, Greece

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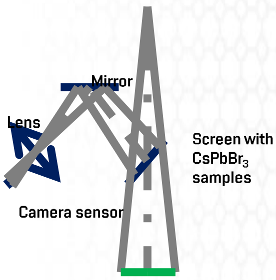
Cesium perovskite as scintillator for high-energy radiation detection

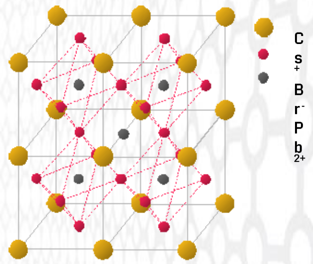
Introduction

The recent extraordinary interest in lead-based perovskites focused on photovoltaic applications helped to uncover their additional properties such as luminescence. Among the most critical limitations of hybrid organic-inorganic perovskites is susceptibility to external influences (moisture, UV radiation) which is usually ascribed to the organic cation in the structure. As a result, an intensive search for candidates to replace the cation with an inorganic one is being conducted. One of the most promising ones is cesium cation Cs+. Cesium lead halide perovskites retain the luminescent properties and are thus interesting as scintillators for radiation detection. Compared to currently commercially used scintillators, perovskites offer lower fabrication cost and further options in layers preparation approach.

Experimental

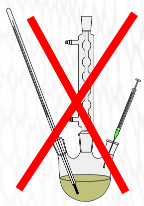


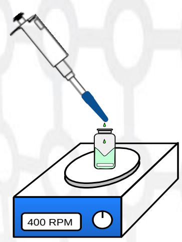
The setup for detection of electron-induced luminescence.



The cesium perovskite (see structure on left) may be utilized either in polycrystalline thin film or in form of (stabilized) nanocrystals (NCs) deposited as a thin film on substrate or as solid-state dispersion of nanocrystals in polymer matrix.

Here we show preparation of oleyl stabilized NCs by re-precipitation method [1, 2] as opposed to hot-injection method [3] much more widely used for all-inorganic perovskites.



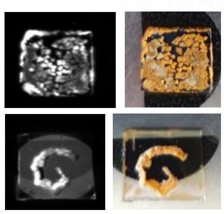


The precursor solution is dripped into vigorously stirred toluene.
The effect of precursor-toluene ratio and the influence of temperature on nanocrystal formation were assessed.

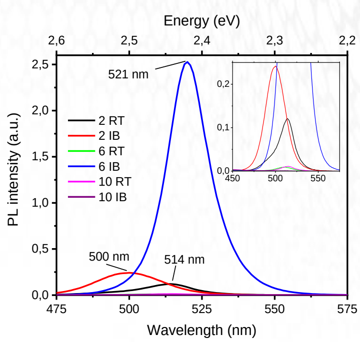
Sample designation:

Precursor/toluene volume ratio	Room temperature (RT)	Ice bath (IB)
$2 \cdot 10^{-3}$	2 RT	2 IB
$6 \cdot 10^{-3}$	6 RT	6 IB
$10 \cdot 10^{-3}$	10 RT	10 IB

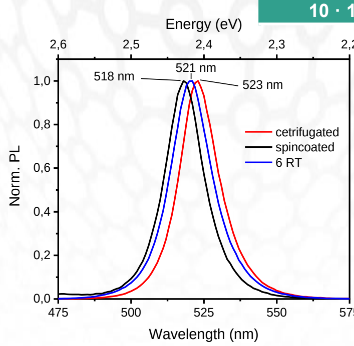
Results

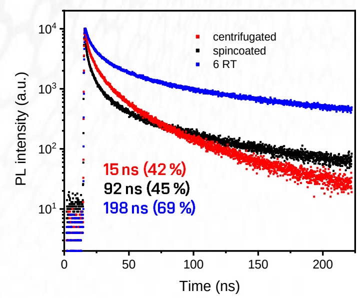


The polycrystalline $CsPbBr_3$ samples show encouraging luminescence upon electron beam excitation (efficiency ~ 0,13 counts/e⁻).

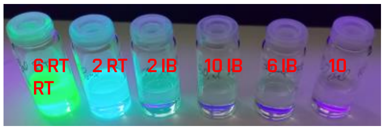


Fluorescence emission spectra of NCs dispersions.



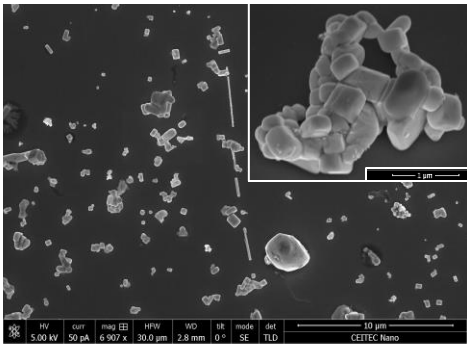


Steady state and time resolved luminescence of thin films deposited from champion dispersion.



PL measurements show moderate shift (20 nm) of PL maxima as a result of altering preparation conditions. Only slight difference can be observed between NCs in dispersion and thin film (with ~5 nm difference between different deposition methods). This may be a result of different size distribution of NCs in samples.
Time resolved fluorescence shows decrease in length of lifetime of prevailing component (out of tetra-exponential fitting). This may indicate some kind of interaction.
The SEM imaging of NCs deposited on Si substrate shows a variety of NC shapes with prevailing cube to cuboid NCs. Based on SEM, the NCs size are in range of few hundreds of nanometers.

SEM image of 6 RT NCs on Si substrate



Conclusions and outlook

- Re-precipitation is suitable for CsPbBr3 NCs preparation.
- Further study is needed to completely understand preparation conditions' effect.
- NCs show bright luminescence both in dispersion and thin film. The lower lifetimes in solid state point toward low afterglow of resulting scintillator.
- In future, electron – luminescence will be studied as well as properties in solid-state dispersions.

Acknowledgement

Authors gratefully acknowledge financial support under BUT projects No. FCH/FSI-J-21-7396 and FCH-S-2...

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