

NEXT LITE-SEMINAR

"Nano- and single-crystals of lead halide perovskites: from bright light emission to hard radiation detection"

Maksym V. Kovalenko

ETH Zurich, Department of Chemistry and Applied Biosciences
Empa-Swiss Federal Laboratories for Materials Science and Technology

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Host: Joachim Krenn

Abstract

Chemically synthesized inorganic nanocrystals (NCs) are considered to be promising building blocks for a broad spectrum of applications including electronic, thermoelectric, and photovoltaic devices. We have synthesized monodisperse colloidal nanocubes (4-15 nm edge lengths) of fully inorganic cesium lead halide perovskites (CsPbX_3 , X=Cl, Br, and I or mixed halide systems Cl/Br and Br/I) using inexpensive commercial precursors [1]. Their bandgap energies and emission spectra are readily tunable over the entire visible spectral region of 410-700 nm. The photoluminescence of CsPbX_3 NCs is characterized by narrow emission line-widths of 12-42 nm, wide color gamut covering up to 140% of the NTSC color standard, high quantum yields of up to 90% and radiative lifetimes in the range of 4-29 ns. Identical synthesis methodology is perfectly suited also for hybrid perovskites $\text{CH}_3\text{NH}_3\text{PbX}_3$ [2].

Post-synthetic chemical transformations of colloidal NCs, such as ion-exchange reactions, provide an avenue to compositional fine tuning or to otherwise inaccessible materials and morphologies. While cation-exchange is facile and commonplace, anion-exchange reactions have not received substantial deployment. Here we present fast, low-temperature, deliberately partial or complete anion-exchange in CsPbX_3 NCs [3]. By adjusting the halide ratios in the colloidal NC solution, the bright photoluminescence can be tuned over the entire visible spectral region (410-700 nm). Furthermore, fast inter-NC anion-exchange is demonstrated as well, leading to uniform $\text{CsPb}(\text{Cl}/\text{Br})_3$ or $\text{CsPb}(\text{Br}/\text{I})_3$ compositions simply by mixing CsPbCl_3 , CsPbBr_3 and CsPbI_3 NCs in appropriate ratios.

We also present low-threshold amplified spontaneous emission and lasing from CsPbX_3 NCs [4]. We find that room-temperature optical amplification can be obtained in the entire visible spectral range (440-700 nm) with low pump thresholds down to $5 \pm 1 \mu\text{J cm}^{-2}$ and high values of modal net gain of at least $450 \pm 30 \text{ cm}^{-1}$. Two kinds of lasing modes are successfully realized: whispering gallery mode lasing using silica microspheres as high-finesse resonators, conformally coated with CsPbX_3 NCs, and random lasing in films of CsPbX_3 NCs.

Here we also demonstrate that 0.5-1 centimeter large, solution-grown single crystals of MAPbI_3 can serve as inexpensive, operating at ambient temperatures solid-state gamma detectors (e.g. for direct sensing of photons with energies as high as mega-electron-volts, MeV) [5]. Such possibility arises from extremely high room-temperature mobility(μ)-lifetime(τ) product of $10^{-2} \text{ cm}^2 \text{ V}^{-1}$, low dark carrier density $10^9 - 10^{11} \text{ cm}^{-3}$ and low density of charge traps $3 \times 10^{10} \text{ cm}^{-3}$, and high absorptivity of hard radiation by lead and iodine atoms.

1. L. Protesescu et al. Nano Letters 2015, 15, 3692–3696
2. O. Vybornyi et al. Nanoscale 2016, DOI: 10.1039/C5NR06890H
3. G. Nedelcu et al. Nano Letters 2015, 15, 5635–5640
4. S. Yakunin et al. Nature Communications 2015, 9, 8056.
5. S. Yakunin et al. submitted