Low-phonon nanocrystals doped with lanthanide ions – new materials for efficient up-conversion and photon avalanche

Nanoparticles doped with lanthanide ions are optically active materials that can transform photons into lower energy light (Stokes emission) or higher energy light (anti-Stokes emission). Such nanoparticles can be used for many applications such as luminescence thermometry, bioimaging, photodynamic therapy, super-resolution imaging. The spectroscopic properties of lanthanide ions depend on the matrix in which they are incorporated, in particular on the vibrations of the crystal lattice, the so-called phonons. High energy phonons are able to quench the luminescence from the lanthanide ions by multi-phonon relaxation and probability of emission quenching increases as the available phonon energy increases. For this reason, it is important to study low-phonon matrices in the construction of nanomaterials, which enable the emission from higher energy levels (i.e. at other wavelengths and colors). Among the low-phonon materials, chlorides and bromides are of particular interest. Unfortunately, simple lanthanide chlorides are hygroscopic and decompose when exposed to water or humid environment. Therefore, in the project we focus on more water-resistant type matrices $CsPbX_3$ and KPb_2X_5, where X =Cl, Br.

The aim of the project is to develop synthesis methods of $CsPbX_3$ and KPb_2X_5 materials doped with lanthanide ions in the nanometer scale, as well as to develop the synthesis of core-shell structures. Another goal of the project is to functionalize the surface of the synthesized materials so that they are resistant to water and can be used in the form of aqueous colloidal suspensions. The usefulness of the obtained materials in terms of Stokes and anti-Stokes emission, including photon avalanche emission, as well as the use of these nanocrystals for non-contact luminescent thermometry is also within the scope of the project.

The results obtained in the project will additionally contribute to expanding knowledge about spectroscopic properties of selected low-phonon nanomaterials doped with lanthanide ions, as well as their functionalization and surface engineering, which will allow their use in fields ranging from photonics to biology. Moreover, studying temperature-dependent optical properties of the proposed nanomaterials will expand the library of available materials that can be used as highly sensitive non-contact luminescent thermometers.