Streszczenie w j. angielskim

This doctoral dissertation is focused on synthesis, physicochemical characterization, and validation of potential application of inorganic phosphors, doped with lanthanide ions, particularly Pr^{3+}, Tm^{3+}, Gd^{3+}, Yb^{3+}, and Nd^{3+} ones. These materials, prepared in the form of colloidal nanoparticles (NPs) or microcrystals (MCs) powders were engineered in a way to emit both ultraviolet (UV) and near-infrared (NIR) radiation. The spectral regions of interest are of great importance for biomedical applications due to their utility in non-invasive high-contrast *in vivo* bioimaging, deep-tissue penetration, light-triggered disinfection, or photodynamic therapy. Within the research, I explored various strategies to enhance the luminescent properties of these materials, all aimed at improving the efficiency and versatility for advanced biomedical applications. The materials were synthesized under controlled conditions using thermal decomposition, hydrothermal, and solid-state synthesis methods, tailored to achieve specific size and structure. The characterizations of structure, morphology, and elemental composition were performed using X-ray diffraction (XRD), scanning and transmission electron microscopy (SEM, TEM), and energy-dispersive X-ray spectroscopy (EDS), respectively. Optical properties were investigated with the means of photoluminescence (PL) spectroscopy, with the main focus on emission intensities in UV and NIR regions of radiation, and luminescence lifetimes (LTs) registration.

In particular, I developed and optimized Pr^{3+},Yb^{3+}-co-doped β-$NaYF_4$ NPs and $LiYF_4$ NPs with bimodal optical properties for biomedical use. Under 447 nm excitation, they exhibited intense Visible(Vis)-to-UV up-conversion (UC) luminescence, the resultant UV-C radiation was sufficiently strong to damage double-stranded DNA (dsDNA). On the other hand, their NIR-to-NIR emission, occurring under 980 nm laser excitation and peaking at ca. 1320 nm, enabled effective imaging in an oral-cavity-mimicking model. To further enhance upconverted UV emission, I employed co-doping with another UV-emitting lanthanide ion, i.e., Gd^{3+}, and synthesized core@shell nanostructures. These modifications improved UV-C emission from Pr^{3+} ions and reduced surface quenching, respectively. Transferred into aqueous phase, the materials in the form of suspensions served as effective UV-emitting disinfectants, capable of inactivating human virus species under Vis irradiation. Furthermore, in order to minimize parasitic energy migration processes occurrence, I designed and synthesized core@multi-shell nanostructures in which optically active ions were spatially separated from each other. This approach enabled the maximization of emission intensity in both the UV and NIR regions, strongly required for theranostic applications. In the next step, I explored Pr^{3+} co-doping

in Tm^{3+}-based β-$NaYF_4$ MCs. By utilization of this lanthanide ions pair, I generated the enhanced both UV-C and NIR emissions, compared to solely Tm^{3+}-doped material, due to efficient energy transfer (ET) between ladder-like energy level structure of lanthanide ions. Lastly, I conducted investigation on Pr^{3+}-doped $Y_2Si_2O_7$ crystalline powders for light-triggered antimicrobial applications. The results showed that tuning the optically-active lanthanide dopants improved the efficiency of the material in inactivating widespread bacteria and fungi, simultaneously presenting a safer alternative to conventional UV-based disinfection methods.

The presented research introduces innovative strategies for enhancing luminescence performance of lanthanide-doped colloidal NPs and MCs powders in both UV and NIR spectral regions. Their successful use in proof-of-concept applications – ranging from NIR-guided *in vivo* bioimaging to visible light-induced inactivation of viruses, bacteria, and fungi based on UV emission generation – demonstrates their strong potential for real-world biomedical use.