NIR-excitable Upconversion Nanoprobes: Challenges for Bioanalytical Applications

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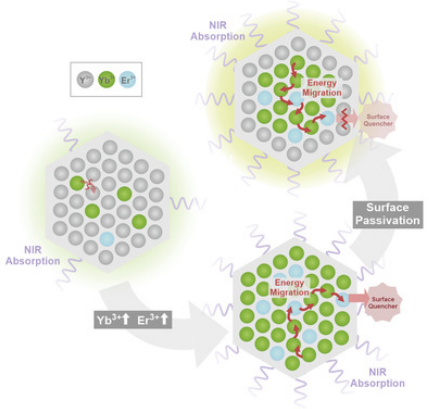
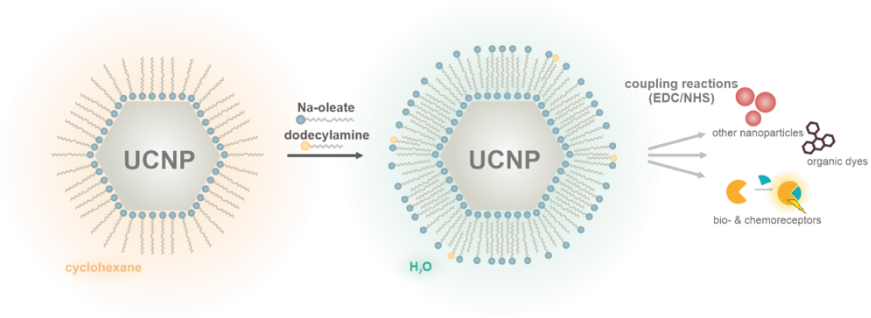
Upconversion nanoparticles (UCNPs) from the type of $NaYF_4$(Yb,Er) are known to spectrally shift NIR excitation to visual emissions. This principle is attractive in biology to overcome limitations caused by autofluorescence. Furthermore, advantages like low scattering and therefore deep tissue penetration of the excitation light, outstanding photostability, and sharp emission bands are offered. In contradiction to this, the low efficiency of the upconversion process limits the application.

To overcome this challenge, the particle architecture was revisited. So far, most UCNPs consist of a large fraction of up to 80% optically inert host lattice doped with low concentrations of optically active lanthanide ions, as higher doping of active ions is known to cause concentration quenching and thus reduced luminescence intensities. An enhancement strategy based on an increased absorption-rate of NIR light provided by an increase of the sensitizer content, together with the simultaneous blocking of the energy migration pathways to the particle surface is presented [1]. The prevailing theory of concentration quenching was challenged and defeated by construction of a core-shell architecture. It was possible to synthesize small particles with improved luminescence properties.



To use UCNPs for bioanalytical applications a second challenge needs to be overcome: The surface of these nanoprobes needs to be modified and functionalized to provide colloidal stability in biological media and to introduce receptors or reporter molecules. To overcome this challenge a novel bilayer strategy resulting in colloidal and chemically stable particles in biological media was developed. Due to efficient shielding from the aqueous environment, water-quenching effects on the upconversion luminescence are also reduced. The simple strategy is completely versatile and can be used to fabricate C-reactive or N-reactive UCNPs. Those bright bilayer-modified particles have been functionalized with organic dyes, without losing colloidal stability, suitable for FRET applications intended for singlet oxygen detection and for sensing of reactive oxygen species.



By the combination of high lanthanide doping with bilayer modification we can design small but stable NIR excitable probes for biosensing and bioimaging.

Reference:

[1] Schroter A, Märkl S, Weitzel N, Hirsch T. Upconversion Nanocrystals with High Lanthanide Content: Luminescence Loss by Energy Migration versus Luminescence Enhancement by Increased NIR Absorption. *Adv. Funct. Mater* **2022**, 2113065. Doi:10.1002/adfm.202113065.