Stimuli-responsive polymersomes encrusted with biocompatible surfactants for rapid luminescence lifetime imaging through encapsulation of UCNPs

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The design of stimuli-responsive delivery systems, particularly those tailored to the acidic tumour microenvironment, has attracted considerable scientific interest. [1] Among different colloidal vehicles, polymer-based nanocarriers with modern supramolecular architectures – polymersomes (PS), stand out. These are vesicular structures composed of amphiphilic copolymers that offer several advantages, including improved colloidal stability, enhanced loading capacity, biodegradability, ease of modification, and high versatility in surface functionalization. [2,3] For instance, PS can be used to encapsulate lanthanide-doped up-converting nanoparticles (UCNPs), which, with appropriately selected doping, will exhibit luminescent properties in the short-wave IR spectral region. This enables the development of desired NIR-emissive nanoplatforms with potential applications in biosensing and bioimaging. Furthermore, the application of appropriate surface-active agents, PS application features like long-term stability and the way they respond to stimulus can be regulated and improved.
In the presented contribution, biocompatible copolymers of poly (ethylene glycol)-block-poly(L-lactide-co-glycolide) (PEG-PLGA) were applied for the self-assembly of PS, which were carefully optimized and co-stabilized with coco-betaine, a mild amphoteric surfactant, along with non-ionic polymeric amphiphilic agent from the Pluronic group (F-127). After that, polymersomes were loaded with core@shell UCNPs – $NaErF_4$@CaF_2, which enabled the creation of luminescent stimuli-responsive nanoplatforms with pH-sensitivity owing to the PLGA building blocks, and the use of high dopant of Er^{3+} ions with recently reported high sensitivity towards water molecules. [4]
Our results show that the presence of the selected surfactants improves the colloidal stability of supramolecular vesicles, while the use of PEG-PLGA enables the pH-responsiveness of designed nanoplatforms. Moreover, we conclude that the surfactant choice remains a key factor in designing such nanosystems, as we observed different trends in the UCNPs NIR-lifetime kinetics within the pH-induced degradation of UCNPs-polymersome structure for amphoteric and non-ionic surfactants. Presented intense emission and long luminescence lifetimes within the NIR region after excitation with the 980 nm laser show great potential of the proposed colloidal nanoplatforms in sensing and detection of the local microenvironment changes within biological tissues with decreased scattering and lack of autofluorescence.

Keywords:
polymersomes, lanthanide-doped UCNPs, long luminescence lifetime, stimuli-responsive colloidal biomaterials, NIR-emissive nanoplatforms

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