Smart hybrid silica nanocarriers with finely tuned structure for control release

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Mesoporous silica nanoparticles (MSNs) have been used in theranostic applications as nanocarriers in cutting-edge applications due to their excellent biocompatibility, high surface areas, large pore volumes, high loading capacity, uniform and tunable pore sizes, and versatile surface functionalization [1]. This synthetic versatility allow i) the incorporation of fluorescent dyes into the silica structure yielding hybrid nanomaterials with excellent optical properties for imaging [2]; ii) the modification of the external surface with biomolecules for active targeting [3]; and iii) coating of the external surface with stimuli-responsive polymers for delivery control [4]. One important challenge remaining in their preparation is the ability to tune their diameter in the range of a few tens of nanometers, with narrow size dispersity, preferably using a simple and sustainable process.

In this communication we will start by presenting a fully controllable low-temperature and purely aqueous sol-gel method to prepare MSNs with user-defined diameters from 15 nm to 80 nm and narrow size dispersity [5-6]. The method also allows modification of the pore structure and offers the possibility of incorporating a luminescent species in the silica network for optical traceability. Control was achieved by tuning the colloidal stability of the assembly of cylindrical micelles that template the MSN synthesis. Using CTAB cylindrical micelles as template and NaOH as catalyst, precise diameter control was achieved either by changing the pH (that controls micelle surface charge) or by adding ionic compounds at constant pH (to tune the ionic strength and charge screening). The specific interactions of salts counterions with surfactant head groups affect their self-assembly properties through intra- and intermolecular forces, and we have rationalized these results based on the Hofmeister series.

We will show how MSNs modified at the external surface with a polymer shell featuring conformational changes induced by pH [7-8] or temperature [9], can act as precise gate keepers to control cargo release from the MSNs pore system. The nanoparticles feature either a polymer brush or a gel-like responsive shell, produced by grafting from RAFT polymerization that offers low size dispersity and well-defined end-groups. Additionally, the internal surface was modified to interact preferentially with the cargo to improve decrease leakage in the “off” release state. These new methodologies open a new path for the use of hybrid polymer-shell MSNs in theranostics.

This work was partially supported by FCT-Portugal and COMPETE/FEDER, projects UIDB/00100/2020, UIDP/00100/2020 and PTDC/CTM-CTM/32444/2017.

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