Low Dimensional Materials and Catalysts

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Structure of composite mesoporous silica particles synthesized by low-toxic route

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Mesoporous silica is known for its wide range of potential applications. Submicrometer spherical particles can be used as a building material for photonic crystals or, at the same time, as biological markers or carriers for drug-delivery. Large surface area and chemical stability of the material open way for a large set of functionalizations for various purposes.

Here we present a TEM study of highly monodispersed spherical mesoporous silica particles obtained by a novel low-toxic synthesis route [1]. Mesoporous structure of the particles is inherited from porous building blocks – micelles – formed at first steps of the synthesis process. Synthesis conditions were tuned so that the micelles are not likely to exceed 10 nm in size, which provides homogeneity in size distribution of the submicrometer spherical particles, which are further formed by micelles aggregation. The micelle is a hexagonal stack of hollow rods (ca. 2 nm in diameter) with silica walls as was proved by TEM investigation of the material at early growth stages (Figure 1.).

Thus, the spherical particle is built of many of these blocks – micelles – randomly twisted against each other. However, it does not hamper penetrability of the material and it can be soaked by various species, e.g. fluorescent compounds [2]. The particles can easily loss the compound, by which they are soaked, if they are immersed back to the medium dissolving it that can be used for prolonged drug action. Desoaking time depends on the particles size and synthesis conditions and can be tuned from 6h to 400h.

At the same time, a protective shell can be grown around the particle in order to prevent desoaking. The shell is grown by another chemical route which does not lead to formation of mesoporous structure, so that the shell is impermeable for liquids. We performed a combined HAADF-STEM and EDX study of Gd-enriched composite particles, which are supposed to be used for radiotherapy, and found highly uniform distribution of Gd in a particle interior and Gd-free shell protecting from undesirable losses of acting specie (Figure 2).

Thus, the structure of mesoporous silica obtained by a novel synthesis route has been studied by TEM. The material is built of tiny blocks – micelles – which are hexagonal stacks of hollow rods. Random arrangement of micelles does not hamper penetrability of the particles by liquids. Moreover, it also causes appearance of large pores, which increases load capacity of the particle, that, in turn, is important for applications. Composite particles with nonporous protective silica shell can be obtained in order to prevent loss of acting compound.

1. E.Yu. Trofimova, D.A. Kurdyukov et al., Nanotechnology 24 (2013), 155601.
2. E.Yu. Trofimova, S.A. Grudinkin et al., Physics of the Solid State 54 (2012), p. 1298.

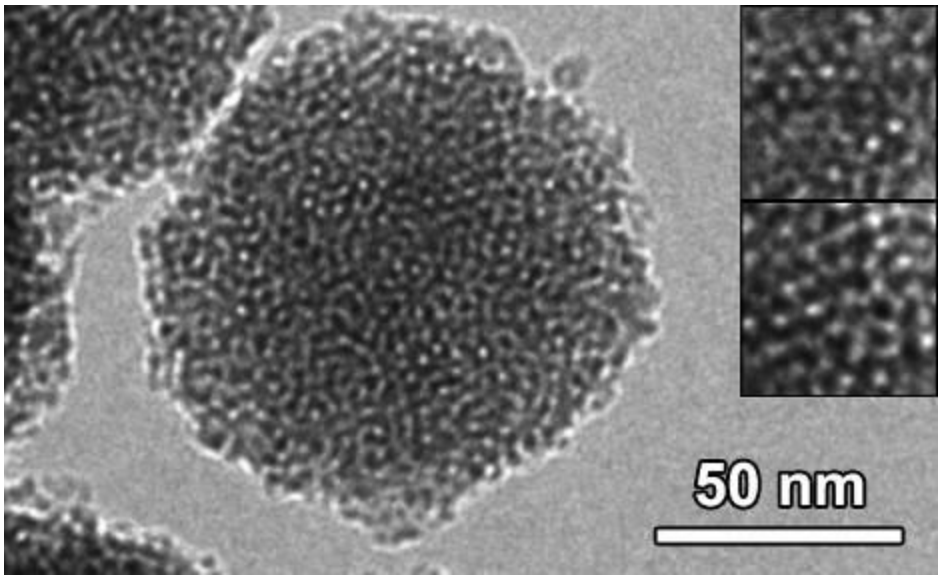

Figure 1. A mesoporous silica particle at an early stage of the synthesis showing its partially arranged structure.

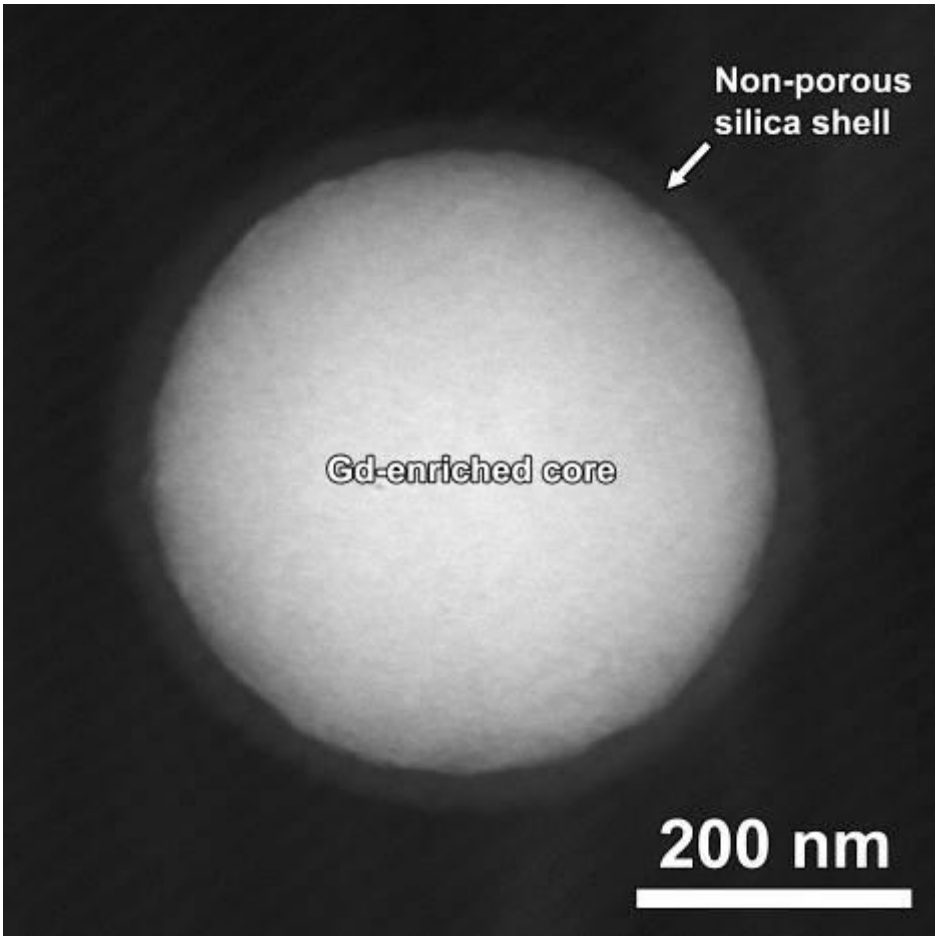

Figure 2. A mesoporous silica particle filled with Gd and covered by protective impermeable shell.