Novel multifunctional nanocomposites for theranostics

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Hybrid nanoparticles consisting of a gold-silver nanocage core and a mesoporous silica shell doped with a photodynamic sensitizer have been fabricated, characterized, and tested in vitro and ex vivo.

Multifunctional nanoparticles that combine therapeutic and diagnostic modalities are a new trend in nanobiotechnology. One attractive option for theranostic applications are systems that combine the unique optical properties of plasmonic nanoparticles\(^1\) and the advantages of mesoporous silica functionalized with an appropriate photosensitizer. However, there is limited data available on such materials.

Recently, we suggested nanoparticles consisting of a gold-silver (Au-Ag) nanocage core and a mesoporous silica (SiO\(_2\)) shell that is doped with the photodynamic sensitizer ytterbium-hematoporphyrin (Yb-HP).\(^2\) The synthesis of such composites includes four basic steps (see Figure 1). First, silver nanocubes are prepared by the sulfide-mediated polyol method.\(^3\) Then, these cubes serve as templates to create partly hollow Au-Ag alloyed structures called nanocages, whose formation is accompanied by controllable red shift of the plasmon resonance from 435nm to 650–900nm. Finally, the third and fourth steps involve fabricating a mesoporous silica shell (20–120nm) doped with Yb-HP molecules.

Figure 2 shows images of cuvettes with silver nanocubes, Au-Ag nanocages, and silica-coated nanocages. Straightforward evidence for the successful functionalization of the composite particles with Yb-HP is provided by the photo on the right, bottom, which shows cuvettes containing the nanocomposites with and without attached Yb-HP, and with free Yb-HP molecules. Under white light illumination, cuvettes 1 and 2 show a blue-green color while 3 looks faint pink because of selective absorption near 400nm. When irradiated with a UV lamp, cuvettes 1 and 3 exhibit intense pink fluorescent emission whereas 2 remains blue. Additional evidence for the successful functionalization of the particles was obtained from measurements of singlet oxygen (\(^{1}O_2\)) generation.

We used IR luminescence for the ex vivo detection of Au-Ag/SiO\(_2\)/Yb–HP nanoparticles in different organs taken from tumor-bearing mice: see Figure 3(a). To assess the potential

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The hybrid nanoparticles combine several promising theranostic modalities: an easily tunable plasmon resonance across the 650–950nm spectral band with possible use in photothermolysis; a mesoporous silica shell that preserves the plasmon resonance from an aggregation shift and provides a convenient possibility of surface or volume functionalization with various molecular probes; and a combination of singlet oxygen generation with IR-luminescence band of Yb-HP, which can be used for optically controlled photodynamic therapy.

We are now attempting to fabricate silica-coated Au-Ag nanocages and Au nanorods functionalized with hematoporphyrin, which we plan to characterize using transmission electron microscopy, absorption and fluorescent spectroscopy, and other methods. These nanocomposites will be tested as potential antimicrobial agents against several pathogenic bacteria.

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