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Gold@Silver@Gold Core Double-Shell Nanoparticles: Synthesis and Aggregation-Enhanced Two-Photon Photoluminescence Evaluation

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Abstract

A facile, straightforward, and low-cost method is proposed to synthesize gold@silver@gold core double-shell nanoparticles. The technique is a seed-mediated growth protocol that contains four steps of (1) gold seed synthesis, (2) gold seed growth, (3) silver layer coating through silver salt reduction, and (4) gold layer deposition via gold precursor reduction. The prepared nanoparticles had a narrow size distribution and the average particle size of 28 ± 1 nm. Cysteine was introduced to the nanoparticles solution as a coupling agent to assemble nanoparticles. Aggregation-induced two-photon photoluminescence enhancement of three types assembled nanoparticles, i.e., gold@silver@gold, gold@silver, and gold nanoparticles, was studied. It was observed that the assembled core double-shell nanoparticles presented huge enhancement in two-photon photoluminescence signal in comparison with two other nanoparticles. Moreover, the gold@silver@gold nanoparticle is a stable and biocompatible plasmonic nanosystem. This paper provides a novel candidate for two-photon photoluminescence excitation sensing and imaging for biomedical applications.

Keywords Gold@silver@gold · Core double-shell · Localized surface plasmon resonance · Two-photon photoluminescence · Plasmon coupling

Introduction

Plasmonic materials indicate unique optical characteristic known as localized surface plasmon resonance (LSPR) in which resonant oscillation of conduction band electrons on the illuminated nanomaterial surface brings about localized electromagnetic field, strong light scattering, and absorption [1]. When the frequency of irradiated light is the same as free electrons collective oscillation, resonance can be generated [2]. These materials have drawn wide attention due to their novel applications in biology [3], photovoltaic [4], catalysis [5], sensing [6, 7], molecular detection [8], medical diagnostic [9], and surface-enhanced Raman scattering (SERS)-based detection [10]. Noble metal nanoparticles are an essential category of plasmonic materials. Surface plasmon resonance in these nanoparticles depends on the shape, size, composition, and surface characteristic of particles as well as environmental conditions [11–16]. In wet chemical synthesis methods, morphological and compositional parameters can be well controlled via a proper selection of solvent, metal salt, reduction agent, and capping agent in addition to adjusting precursor concentration, medium pH, and process temperature [12]. LSPR band also is affected by plasmon coupling between metal nanoparticles strongly [17]. Plasmon coupling considerably amplifies the local electric field within the gap of coupled particles that leads to optical responses enhancement such as two-photon photoluminescence (TPPL) [18]. Aggregation-enhanced TPPL of metal nanoparticles can be used for the development of two-photon excitation sensing and imaging in biomedical applications, in particular, in vivo examinations [19–21].

Electronic, optical, and catalytic properties of the heteronanosystem are much different and more sensitive in comparison with each component so that a small variation in shape, size, and composition of nanosystem results in an unexpected change in its physicochemical properties [22–25]. Therefore, by integrating two or more noble metals in the shape of a single nanoparticle, their properties can be merged and tuned for specific usages.

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