RESEARCH ARTICLE

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Obviously Enhanced Fluorescent Signal of Core-Shell Nanostructures through Simultaneous Regulation of Spectral Overlap and Shell Thickness for Imaging and Photothermal Therapy of Ovarian Cancer Cells

Xianyang Li, Jingyuan Huang, Xin Wu, Xianling Piao, Danning Lv, Gude Zhang, Dong June Ahn,* and Chunzhi Cui**

In this research, by simultaneously regulating the two major factors affecting the plasmonic enhanced fluorescence (PEF), spectral overlap and the distance between the fluororophores and the noble metal nanoparticles, a significantly enhanced fluorescent signal is achieved. Core-shell nanostructures composed of aspect ratio (AR) adjustable gold nanorods (GNRs) and various thickness of SiO_2 are prepared and the decorated fluorophores are realized optimized PEF. A typical stimuli-responsive conjugated polymer, polydiacetylene (PDA), and a near-infrared (NIR) dye Cy5.5 are selected as fluorophores and their fluorescent signal are enhanced 7.26 and 4.41 times, respectively. Based on the optimized optical properties, a multifunctional antibody modified Mab-Cy5.5-GNRs@SiO_2 is successfully demonstrated the targeting, imaging, and photothermal therapy (PTT) effects on SKOV-3 ovarian cancer cells.

1. Introduction

Noble metal nanoparticles and nano-rough films possess localized surface plasmon resonances (LSPRs) that imbue these materials with unique optical properties.[1–3] Especially, owing to tunable absorption bands based on their aspect ratios (ARs), excellent photothermal conversion efficiency, biocompatibility and low toxicity, gold nanorods (GNRs) are considered promising photothermal agents in photothermal therapy (PTT).[4–6] Additionally, elongated nanostructures penetrate tumor cells more rapidly due to excellent transmembrane transport and diffusion rates than spherical nanoparticles (NPs).[7–9] Based on these factors, various nanostructures containing GNRs have recently been vigorously developed in biomedicine.[10–14] Precise and effective PTT need to be supplemented by a clear imaging guidance.[15] The GNR itself has imaging capabilities, namely photoacoustic imaging.[16,17] However, due to the principle of imaging, photoacoustic imaging has two main fatal disadvantages. First, the heat energy caused by constant light irradiation can lead to the deformation of GNR and a sharp decrease in the imaging and PTT effects.[18] Second, photoacoustic imaging is only suitable for a dense tissue environment.[19] For the above reasons, the combination of traditional luminescent materials to the protected GNR is still recommended.[12,20,21] In these cases, another effect based on LSPR, plasmon-enhanced fluorescence (PEF) has been extensively studied by scholars. The enhanced fluorescent signal could be contributed to the bio-imaging of the GNR-containing nanostructures by being decorated with various fluorophores or quantum dots.[22–24]

From the perspective of the imaging function, due to PEF could increase the quantum yield and improve the photo-stability of fluorophores, hence it ensures imaging effects in complex biological environments.[25–27] In general, spectral overlap and distance between fluorophores and plasmon resonant novel metal NPs are considered the main factors of the PEF.[28–31] However, until now, few studies have simultaneously regulated both factors and achieved an optimized PEF effect.[32–36]

In this research, we developed GNR-containing nanostructures decorated with fluorophores, a stimuli-responsive polydiacetylene (PDA), and a near-infrared (NIR) Cy5.5 dye, respectively. Optimized fluorescent signals were achieved through simultaneous regulation of spectral overlap and distance between

X. Li, X. Wu, G. Zhang, C. Cui
Department of Chemistry
Yanbian University
Yanji 133002, China
E-mail: cuichunzhi@ybu.edu.cn
J. Huang, D. J. Ahn
Department of Chemical and Biological Engineering
Korea University
Seoul 0 2841, South Korea
E-mail: ahn@korea.ac.kr
X. Piao
Affiliated Hospital of Yanbian University
Yanji 133000, China
E-mail: 9000002394@ybu.edu.cn
D. Lv, C. Cui
Interdisciplinary Program of Biological Functional Molecules
College of Integration Science
Yanbian University
Yanji, Jilin Province 133002, China

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