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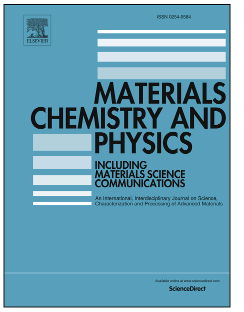

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Hybrid Structures of Fe_3O_4 and Ag Nanoparticles on Si Nanopillar Arrays Substrate for SERS Applications

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Abstract: Surface-enhanced Raman scattering (SERS)-based sensing is the most promising approach to detect trace amounts of chemical and biological molecules. Three-dimensional (3D) nanostructures have been considered as one of the most promising SERS substrates due to ordered arrangement of high-density hot spots and large surface area for adsorbing analyte. This paper designed a hybrid SERS substrate containing structures of Fe_3O_4 and Ag nanoparticles on Si nanopillar arrays, which combines the advantages of highly ordered periodic 3D Si nanopillar arrays and Ag coated Fe_3O_4 core-satellite microspheres, leading to intense light metal and light molecule interactions. The detection limit of the substrate for malachite green (MG) is as low as 10^{-8} M, meeting the requirements for trace detection of analytes. This work provides a new insight for fabricating SERS substrates with high sensitivity.

Keywords: Surface-enhanced Raman Scattering (SERS); Three-dimensional (3D) nanostructure; Si nanopillar arrays; core-satellite; Fe_3O_4.

1. Introduction

Raman spectroscopy provides the fingerprint signatures of each specific compound and contains information about composition and structure of molecules in chemical and biological systems [1,2]. Due to the localized surface plasmon resonance (LSPR) in nanostructured metal (typically gold, silver and copper) surfaces, Surface-enhanced Raman Scattering (SERS) can provide structural information even to single-molecule level [3,4]. Therefore, SERS has become a most powerful analytical tool with advantages of non-destructive, ultra-fast and sensitive detection in many areas of science and technology, including physics, chemistry, biology, and environment [4-7]. The LSPR of metal nanoparticles depends on their sizes, shapes, interparticle distances, and dielectric properties of the surrounding medium. Therefore, architecture and morphology of the substrates influence the intensity and distribution of the SERS signals, as well as molecular adsorption. Fabricating high performance SERS substrates are among the most key factors that influence the practice applications of SERS technology [8]. An ideal SERS substrate should have high enhancement factor, uniform nanoparticle distribution, also should be reproducible and reusable [9,10]. Extensive studies have been focused on optimizing the nanostructures of SERS substrates [11-15]. Typical nanostructures include zero-dimensional tip-like clusters [16], one-dimensional rod-like building blocks [17,18], two-dimensional planar nanostructures [19,20] and tree-dimensional (3D) frameworks [21-24]. Recently, 3D nanostructures with well controlled hierarchical morphologies have attracted considerable attentions, because it offers larger surface areas for adsorbing more analytes, generates high density SERS hot spots and has excellent repeatability [10,21-23]. Among the 3D nanostructures, Si nanopillars decorated with metal nanoparticles as SERS substrates have advantages of large surface to volume ratio, unique light trapping properties and high compatibility with the existing silicon technology [10,23].