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Embedding Ag or Au nanoparticles within the nano-sized wall of $YbPO_4:Er^{3+}$ inverse opals and resulting enhanced upconversion luminescence

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ABSTRACT

Metal nanoparticles preparation in the interior of nanoscale skeleton of inverse opals made up of crystallized matrix is more difficult than the preparation of pure inverse opals. In the present work, the Ag or Au nanoparticles embedded $YbPO_4:Er^{3+}$ inverse opals were prepared by a simple approach, which involved the infiltration of opal template by using the transparent $YbPO_4:Er^{3+}$ sol including silver nitrate or chloroauric acid and the sintering at high temperature. The 20–30 nm Au or 5–10 nm Ag nanoparticles were formed in the interior of nanoscale skeleton in the $YbPO_4:Er^{3+}$ inverse opals, and the Ag or Au nanoparticles embedded $YbPO_4:Er^{3+}$ inverse opals were prepared. The influence of Ag or Au nanoparticles on the upconversion photoluminescence of $YbPO_4:Er^{3+}$ inverse opal was studied, and the upconversion luminescence enhancement induced by the Ag or Au nanoparticles was observed. The mechanisms of upconversion luminescence enhancement of $YbPO_4:Er^{3+}$ inverse opals induced by Ag or Au nanoparticles were discussed. The enhancement of upconversion luminescence induced by Ag nanoparticles was attributed to the enhancement of the excitation field, and the enhancement of upconversion emission induced by Au nanoparticles was related to the increasing of the radiation decay rate of Er^{3+}.

1. Introduction

Over the past few decades, the noble metal nanostructures with localized surface plasmon resonance (LSPR) and the photonic crystals with photonic band gap were extensively investigated in the two separated fields [1,2]. The composites consisted of photonic crystals and noble metal nanoparticles are desirable because the combination of two parts with various properties could extend their potential applications [3]. For example, the incorporation between Au nanoparticles and TiO_2 inverse opals can enhance their photo-catalytic properties [4]. The photoluminescence of upconversion nanoparticles can be improved by the combination of the LSPR of noble metal nanostructures and the photonic band gap of photonic crystals [5]. At present, the various kinds of composites consisted of photonic crystals and metal nanoparticles were prepared such as the Au and Ag nanoparticles infiltrated SiO_2 inverse opals and the Ag nanoparticles coated opals [6–9]. For the composite preparation of Au or Ag nanoparticles/SiO_2 inverse opals, the traditional approach is to infiltrate the Au or Ag nanoparticles into the SiO_2 inverse opals [9]. In such composite, the Au or Ag nanoparticles are located at the surface of nanoscale skeleton of SiO_2 inverse opal, and their stability and distribution uniformity are relatively difficult to control. Additionally, the magnetron sputtering method was used to prepare the metal nanoparticles coated opals, and the metal nanoparticles were located at the surface of opals prepared by the PS or SiO_2 microspheres [10]. Despite the achievements on the preparation of metal nanoparticles/photonic crystals composites, however, the introduction of metal nanoparticles within the nanoscale skeleton of inverse opals is desirable due to their high stability, which is advantage for their practical applications. Very recently, we developed a simple one-step approach to prepare the metal nanoparticles embedded inverse opals [11]. In this approach, the Ag or Au nanoparticles in the interior of nanoscale skeleton of SiO_2 inverse opals were prepared by sintering the opal templates infiltrated with the transparent SiO_2 sol including silver nitrate or chloroauric acid [11,12]. However, the preparation of metal nanoparticles in the interior of nanoscale skeleton of inverse opal photonic crystals made up of crystallized matrix is more difficult than the preparation of metal nanoparticles embedded SiO_2 inverse opals, which is rarely reported.

Rare earth ions doped inverse opals exhibit a lot of novel applications in the many areas such as the low threshold lasers and the high-

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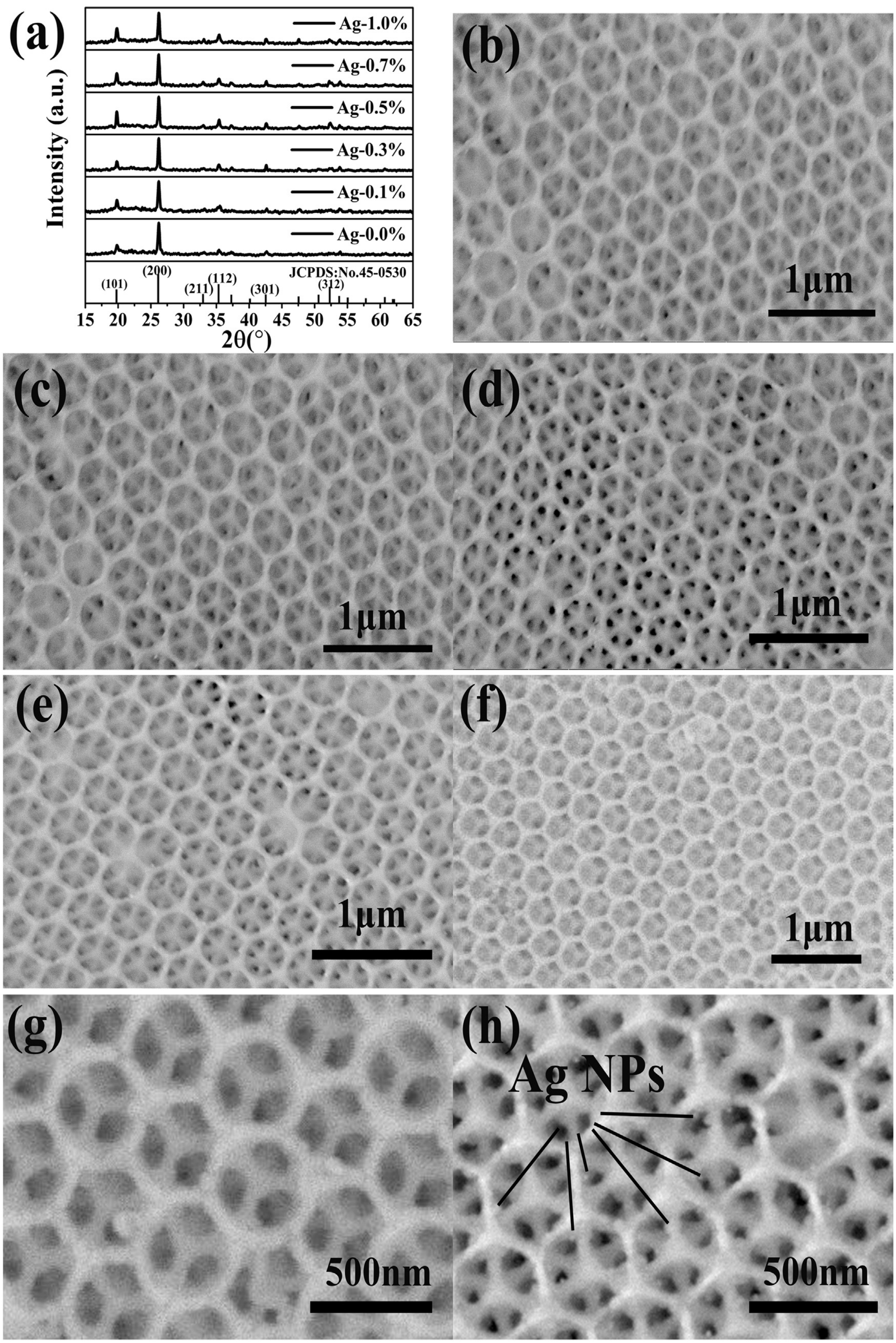

Fig. 1. The XRD patterns of $YbPO_4$: 1 mol% Er^{3+}, x mol%Ag (x = 0.1, 0.3, 0.5, 0.7 and 1.0) inverse opals (a); the SEM images of inverse opals without Ag (b) and with 0.1 (c), 0.3 (d), 0.5 (e), 0.7 (f) and 1.0 mol% (g) Ag; the backscatter SEM image of $YbPO_4$: 1 mol% Er^{3+}, 1 mol%Ag inverse opals (h).

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