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Highlights:

1. Monodisperse fluorescent spheres of $NaYF_4$@SiO_2 were synthesized successfully.
2. Upconversion efficiency of $NaYF_4$@SiO_2 Photonic crystal films was improved.
3. Energy transfer process of $NaYF_4$@SiO_2 photonic crystal films was discussed.

Abstract

Fluorescent photonic crystal films (PCFs), which consisted of monodisperse $NaYF_4$:10Yb, 0.5Tm@SiO_2 or $NaYF_4$:10Yb, 0.5Er, 0.2Tm@SiO_2 core-shell spheres (10%, 0.5% and 0.2% represent the reactant mole percentage), were successfully fabricated. The morphologies and structures of PCFs were measured, while the fluorescent properties of $NaYF_4$ in PCFs with different photonic band gap (PBG) positions were investigated. Besides, the energy transfer process in thermal coupled energy levels of $NaYF_4$:10Yb, 0.5Tm@SiO_2 under different temperatures was discussed. The results indicated that the short wave emission of $NaYF_4$ can be enhanced by the regulation of photon mode density (PMD) in photonic crystals. Particularly, when the infrared 800 nm emission peak was in the range of PBG position of the PCF sample, the energy transfer process of $^3H_4$-$^3H_6$ was suppressed and the short wave emission was enhanced by 1.64 times. Due to the well thermal radiation ability of silica shell, the thermal coupled energy levels ($^3F_3$ and $^3H_4$) of $NaYF_4$:10Yb, 0.5Tm@SiO_2 core-shell spheres exhibited more stable emission intensities than $NaYF_4$:10Yb, 0.5Tm nanoparticles, when the experimental temperatures varied from 30 to 300 ^oC.

Keywords: monodisperse $NaYF_4$@SiO_2 spheres, fluorescence, photonic crystal, thermal stability

1. Introduction

Upconversion fluorescent materials, which can convert low energy infrared light into high energy short wave light, are promising in the utilization of sunlight and have been applied in sensor [1], bioimaging [2, 3], photocatalysis [4], 3D display [5] and so on [6, 7]. Among them, $NaYF_4$:Ln^{3+} (Ln = Yb, Er, Tm) is one of the most efficient upconversion materials due to its outstanding properties, such as chemical stability, sharp emission peak and low phonon energy [3, 8, 9]. However, the obstacles of low upconversion efficiency and high excitation threshold of $NaYF_4$ in real applications are still difficult to be solved until now.

Many modification methods were adopted to improve upconversion fluorescence efficiency of