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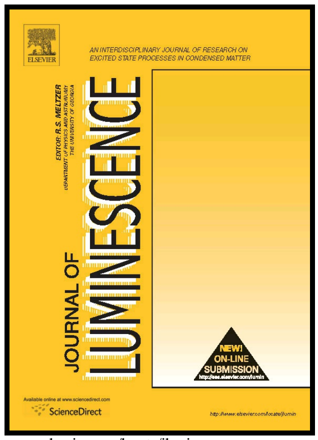

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Energy transfer in poly(vinyl alcohol)-encapsulated Mn-doped ZnS quantum dots

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Abstract

Poly(vinyl alcohol) (PVA)-encapsulated Mn^{2+}-doped ZnS quantum dots (PVA-ZnS:Mn^{2+} QDs) synthesized at 80 °C in air. The structural property was investigated using X-ray powder diffraction (XRD). The XRD analysis shows that the ZnS:Mn^{2+} QDs possessed a zinc blende structure and the complexes of ZnS:Mn^{2+} QDs with PVA molecules have been formed. The photoexcitation energy transfer is found and investigated between PVA molecules and ZnS:Mn^{2+} QDs using characterization techniques such as Fourier transform infrared spectroscopy (FTIR), UV–vis absorption spectroscopy, photoluminescence excitation (PLE) and photoluminescence (PL) spectroscopy. The studied results show the photoluminescence enhancement of the Mn^{2+} $^4T_1(G)$ – $^6A_1(S)$ emission intensity is due to the efficient energy transfer process from the ZnS host lattice and PVA capping molecules to Mn^{2+} centers. Moreover, Förster resonance energy transfer (FRET) efficiency from PVA molecules to the Mn^{2+} center within PVA-ZnS:Mn^{2+} QDs is about 20.28%.

Keywords: Energy transfer; Mn^{2+}-doped ZnS; Quantum dots; Photoluminescence

1. Introduction

Semiconductor quantum dots (QDs) have attracted great interest in recent years due to their unique optical properties and potential applications. Among II-VI semiconductors, zinc sulfide (ZnS) is relatively a non-toxic material when compared to Cd-based QDs. ZnS has a wide direct bandgap of 3.6 eV, a small exciton Bohr radius of 2.5 nm [1] and particularly suitable as a host material for a large variety of luminescent ions such as Ag^+, Cu^{2+}, Mn^{2+}, Eu^{3+}, Sm^{3+}, Tb^{3+}. Recently, these semiconductor QDs have been systematically investigated, particularly Mn^{2+} doped ZnS quantum dots (ZnS:Mn^{2+} QDs), and have attained many successes although many debates still exist.

Additionally, the ZnS:Mn^{2+} QDs can be applied in a variety of fields such as optoelectronics [2-5], fluorescent ink [6] and fluorescent labeling agents [7,8]. In particular, the hybrid polymer-semiconductor quantum dots are becoming increasingly attractive because of a large number of applications in thin film electroluminescent (EL) devices [3,5]. Recently, the poly(vinyl alcohol) (PVA)-capped ZnS:Mn^{2+} QDs [9-12], poly(vinyl pyrrolidone) (PVP)-capped ZnS and PVP-capped ZnS:Mn^{2+} QDs [13] have attracted great attention. Poly(vinyl alcohol) (PVA) is chosen as a good host material for QDs due to its excellent thermo-stability, transparency over the whole visible spectrum, chemical resistance, high mechanical strength and good adhesion to hydrophilic surfaces. Additionally, hybrid ZnS:Mn^{2+} quantum dot-PVA systems have the inherent characteristics of PVA polymer matrices and unique optical of ZnS:Mn^{2+} QDs [12,14].

However, most of the previous work on PVA-encapsulated Mn^{2+}-doped ZnS QDs is focused on understanding and solving the tasks of optimum Mn^{2+} doping content, PVA concentration and thermal stability of PVA-capped ZnS:Mn^{2+} nanoparticles [9-12]. Viswanath and co-workers [9] reported that the PL color from the polyvinyl alcohol (PVA) capped Mn^{2+} doped ZnS nanocrystals can be tuned from UV to near infrared (IR) region. Very recently, Thai et al. [12] studied the effect of PVA on the photoluminescence enhancement of Mn^{2+} ions in ZnS:Mn^{2+}/PVA nanoparticles. Besides, Kumar et al. [13] indicated the process of energy transfer from the poly(vinyl pyrrolidone) (PVP) surface adsorbate to the dopant Mn^{2+} ions in ZnS nanocrystals resulting in efficient orange-red emission. Anni and co-worker [15] demonstrated efficient Förster resonant energy transfer from a blue-emitting conjugated polymer to colloidal CdSe/ZnS core/shell quantum dots in hybrid films.