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Research Article

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Luminescent Studies on Mn^{2+} Doped CdTe Nanoparticles

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ABSTRACT

Nanoparticles based on II-VI and III-V semiconductors have been the most widely studied systems in the recent decades. Among different semiconductor materials, II-VI semiconductor nanoparticles are considered to be an important group with considerable progress in the synthesis and utilization of their unique properties. CdTe is an important II-VI semiconductor material, which is very useful for a variety of electro-optical devices and solar energy conversion. Mn^{2+} *doped PVA capped CdTe nanoparticles were prepared by co-precipitation method and characterized by luminescent techniques. Room temperature PL spectrum of* Mn^{2+} *doped PVA capped CdTe nanoparticles were excited at 425 nm. Emission peak observed at 638 nm is corresponds to the transition* $^4T_1 \rightarrow {}^6A_1$. *PL studies of* Mn^{2+} *doped PVA capped CdTe nanoparticles exhibit orange-red emission band. CIE chromaticity coordinates were also calculated from emission spectrum of* Mn^{2+} *doped PVA capped CdTe nanoparticles.*

Keywords: CdTe, Semiconductors, Manganese ions, Co-precipitation and Luminescent properties.

INTRODUCTION

Significant interest has arisen in the research of nanoparticles during the last decade, in particular for luminescent applications. The integration of nanotechnology into the field of optical devices has opened new possibilities. Working with nanomaterials has allowed a better understanding of emitting properties. In recent years, there has been growing interest in the synthesis of nanometer-sized II-VI binary semiconductor materials. Nanocrystalline semiconductor films are emerging as a new class of future photonic materials due to their unique nonlinear optical effects and quantum confinement [1]. Metal oxides play a very important role in many areas of chemistry, physics and materials science. The metal elements are able to form a large diversity of oxide compounds. These can adopt a vast number of structural geometries with an electronic structure that can exhibit metallic, semiconductor or insulator character [2-10]. Nowadays a great attention is focused on research and development of lighting technology, the global problem of energy saving. Recently, solid-state lighting is used in white light emitting diodes (W-LEDs) have attracted world-wide attention because of their important benefits including energy saving, safety, reliability, maintenance and environment friendly characteristics [11]. Inorganic luminescence materials have drawn great attention, as they are widely applied in light emitting display, optoelectronics and as fluorescent markers in biomedicine. The phosphate based luminescent materials in nano-dimensions are extensively studied owing to their potential applications in solid-state lighting, which could be supplanting the conventional incandescent and fluorescent lamps in future lighting [12, 13].

CdTe is an important II-VI semiconductor material, which is very useful for a variety of electro-optical devices and solar energy conversion [14, 15]. CdTe nanoparticles have been the subject of numerous investigations. Because of high quantum efficiency and multicolour availability, CdTe nanoparticles can find applications in solid-state lighting, displays, optical communications, sensors, as well as in biological imaging and detection [16-37]. Having a large exciton Bohr diameter (15.0 nm) [38], nanoscale CdTe probably possesses some unique physical properties

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with potential applications in optical devices, such as lasers and photodetectors. CdTe has a direct band gap in the range of 1.4 - 1.5 eV at room temperature and its high absorption coefficient (≈105 cm^{-1}) makes it suitable for these purposes [39]. One of the most significant progresses in the area of luminescent properties is the use of transition metal ions as dopant for host lattice. Among these 3d transition metal ions, Mn^{2+} is an efficient activator and it exhibits high luminescence efficiency, flexible emission colors. Several Mn^{2+}doped materials are used widely as fluorescent lamps (FLs), cathode-ray tubes (CRTs) and white LEDs. In the present work, Mn^{2+} doped CdTe nanoparticles were prepared by co-precipitation method. The prepared samples were characterized by photoluminescent and chromaticity studies to collect the information about the luminescent properties of the prepared sample.

EXPERIMENTAL SECTION

Analytical Reagent (AR) grade of cadmium chloride ($CdCl_2$), Sodium hydrogen telluride (NaHTe), polyvinyl alcohol (PVA), Manganese Oxide (MnO) were used as starting materials and used without further purification. Double distilled water was used as a solvent in the experiment. 0.045 g of cadmium chloride was added to 2.3 g PVA and volume of the solution was completed to 50 mL by double distilled water. The complete solution was left for 24 hours at room temperature to swell. After that the solution was warmed up to 80°C and stirred for 6 hours until viscous transparent solution was obtained. One milliliter (mL) of sodium hydrogen telluride (NaHTe) was dropped into the solution with gentle stirring and then 0.01 mol % manganese oxide was added to it to get the transparent solution. The prepared solution was casted on flat glass plate dishes. After the solvent evaporation, a thin film containing manganese doped PVA capped CdTe nanoparticles was obtained. The excess of unsoluble salts were removed from the surface of the films by washing the films using de-ionized water before characterization. Photoluminescence (PL) spectrum is taken at room temperature on Horiba Jobin-Yvon Fluorolog-3 spectrofluorimeter with Xe continuous (450 W) and pulsed (35 W) lamps as excitation sources. Chromaticity spectrum is taken by using MAT lab software.

RESULTS AND DISCUSSION

Mn^{2+} doped (0.01 mol %) PVA capped CdTe nanoparticles was prepared by using by co-precipitation method. The prepared samples were characterized by PL and CIE studies to collect the information about the luminescent properties of the prepared sample. The analysis of X-ray diffraction pattern revealed that the prepared samples are pure crystalline in nature.

Photoluminescence Studies

Surface states are very important for physical properties especially for the optical properties of nanomaterials. Electrons and holes may be excited easily and escape from the ions. Many carriers trapped at the surface states or defect sites may be released by photo excitation. So fluorescence efficiencies of nanomaterials are higher than those of bulk materials. According to reports, the $3d^5$ multiplet energies of Mn^{2+} in crystals depend largely on covalency interactionwith the host crystal, because 3d electrons of transition metal ions are the outermost electrons [23]. Transition metal ions have been widely used in luminescent materials. Room temperature PL spectrum of Mn^{2+} doped PVA capped CdTe nanoparticles were excited at 425 nm is shown in Figure 1.

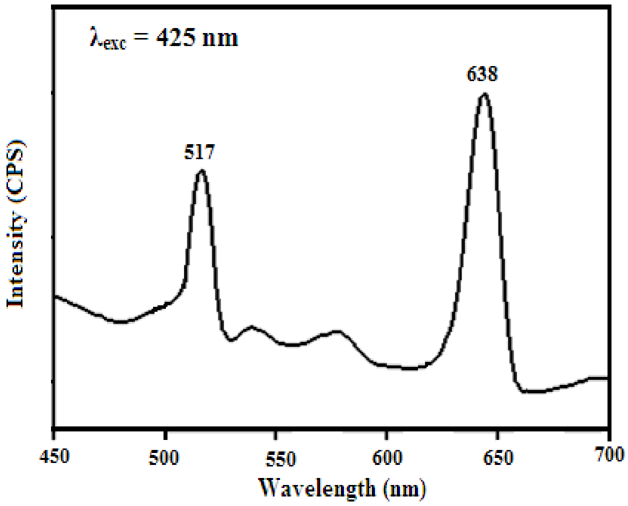

Figure: 1 PL spectrum of Mn^{2+} doped PVA capped CdTe nanoparticles

In undoped PVA capped CdTe nanoparticles, emission peak is observed at 517 nm corresponds to green region and in the case of Mn^{2+} doped PVA capped CdTe nanoparticles emission peak was observed at 638 nm corresponds to re region. Emission peak observed at 638 nm is corresponds to the transition $^4T_1 \rightarrow {}^6A_1$.

Most lighting specifications refer to colour in terms of the 1931 Commission Internationale deI'Eclairage (CIE) chromatic colour coordinates which recognize that the humanvisual system uses three primary colours: red, green and blue. The colour purity of a phosphor depends on spectralenergy distribution of emission. Generally, colour purity can be determined by measuring its (x, y) coordinates on a standard CIE colour chart. The colour gamut of a phosphor is represented as an area in the CIE 1931 chromaticity diagram with curved edge representing monochromatic colours [21]. The Commission Internationale deI'Eclairage (CIE) chromaticity coordinates of Mn^{2+} doped PVA capped CdTe nanoparticles are calculated from emission spectra and is shown in Figure 2.

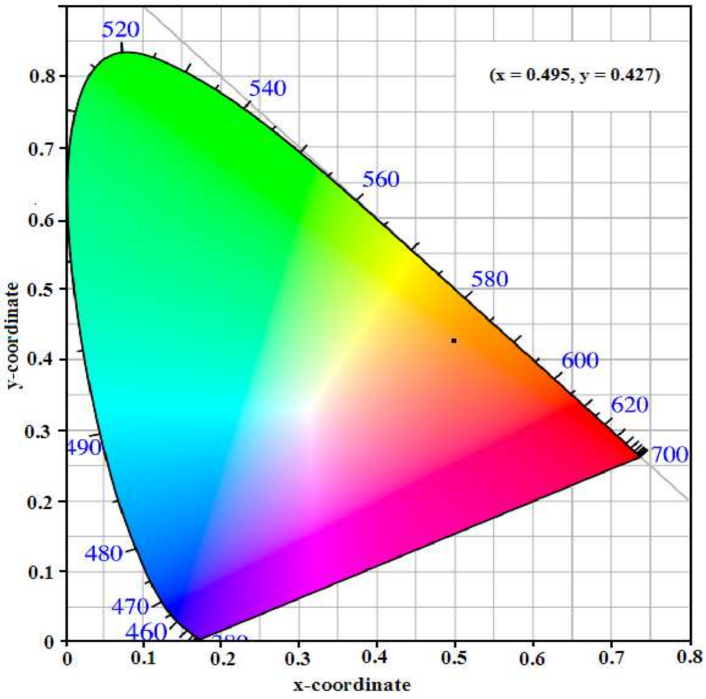

Figure: 2 CIE diagram of Mn^{2+} doped PVA capped CdTe nanoparticles

The location of color coordinates are represented in CIE chromaticity diagram by solid circle (●). From this figure, one can see that the color of undoped and Mn^{2+} doped PVA capped CdTe nanoparticles are located in orange-red region and the corresponding CIE coordinates are denoted as (x = 0.495, y = 0.427). These materials may be useful for LEDs, electroluminescence panels and plasma display panels.

CONCLUSION

CdTe is an important II-VI semiconductor material, which is very useful for a variety of electro-optical devices and solar energy conversion. Mn^{2+} doped PVA capped CdTe nanoparticles were prepared successfully by co-precipitation method. PL spectrum of Mn^{2+} doped PVA capped CdTe nanoparticles shows red emission. From CIE diagram, Mn^{2+} doped PVA capped CdTe nanoparticle emits orange-red emission and the corresponding coordinates are (x = 0.495, y = 0.427). These materials may be useful for display and LED devices.

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