



SYNTHESIS AND LUMINESCENT PROPERTIES OF Fe³⁺ DOPED CdTe NANOPARTICLES

**K. KOTESWARA RAO^a, K. DURGA VENKATA PRASAD^b,
D. SRIDHAR KUMAR^b, K. RAVINDRANADH^b and M. C. RAO^{c*}**

^aKrishna University, Department of Physics, Andhra Loyola College,
VIJAYAWADA – 520 008 (A.P.) INDIA

^bPhysics Division, Department of Basic Sciences & Humanities, Chirala Engineering College,
CHIRALA – 523157 (A.P.) INDIA

^cDepartment of Physics, Andhra Loyola College, VIJAYAWADA – 520 008 (A.P.) INDIA

ABSTRACT

Semiconductor nanoparticles are currently being extensively studied due to their unique size dependent properties. It has been demonstrated by several groups that nanocrystalline II-VI semiconductors show enhanced luminescence, increased oscillator strength and shorter response time. Polymers are able to achieve surface passivation, prevent particles from agglomeration, which are in favour of controlling the particles size and size distribution effectively. CdTe is an important II-VI semiconductor material, which is very useful for a variety of electro-optical devices and solar energy conversion. Fe³⁺ doped PVA capped CdTe nanoparticles were prepared by co-precipitation method and characterized by luminescent techniques. PL studies of Fe³⁺ doped PVA capped CdTe nanoparticles exhibit blue emission band. CIE chromaticity coordinates were also calculated from emission spectrum of Fe³⁺ doped PVA capped CdTe nanoparticles.

Key words: CdTe, Semiconductors, Iron ions, Co-precipitation, Luminescent properties.

INTRODUCTION

Semiconducting nanomaterials are of great interest for their unique size dependent optical and electrical properties. As size of the particle reduces to nano it gets high surface to volume ratio and increased surface states, which influence the chemical reactions by altering transitions of electrons and holes. Metal oxides and telluride's play a very important role in many areas of chemistry, physics and materials science. These can adopt a vast number of structural geometries with an electronic structure that can exhibit metallic, semiconductor or insulator character. In technological applications, these are used in the fabrication of

* Author for correspondence; E-mail: 1412.ravi@gmail.com

microelectronic circuits, sensors, piezoelectric devices¹. In recent years, nanomaterials have shown keen interest because of their unusual chemical and physical properties, which are significantly different from the bulk materials. Semiconductor nanomaterials have been attracted extensive attention due to their size dependent properties and important potential applications in photovoltaic solar cells; light emitting devices, chemical/biological sensors and photocatalysis². In recent years, there has been growing interest in the synthesis of nanometer-sized II-VI binary semiconductor materials.

CdTe is an important II-VI semiconductor material, which is very useful for a variety of electro-optical devices and solar energy conversion³. 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. Doping is a widely used method to improve electrical, optical and luminescent properties of semiconductor compounds, facilitating the construction of many electronic and optoelectronic devices. In 3d transition metal ions, ferric ions (d^5 configuration) can show an efficient luminescence and its luminescence property involves the intra-configurational $d-d$ transitions, which are both spin and parity forbidden⁴.

Many fabrication techniques have been attempted for depositing CdTe nanoparticles. Some are controlled atmosphere based techniques like sputtering, thermal evaporation, e-beam evaporation, Molecular Beam Epitaxy (MBE), Co-precipitation, Metal-organic Chemical Vapour Deposition (MOCVD)⁵. All these techniques are extremely expensive and require specialized equipment. Among these, co-precipitation is the most convenient method because of its simplicity, low cost, easy to add doping materials and the possibility of varying the film properties by changing composition of starting solution. Rao et al.⁶⁻¹¹ have published their results on different oxide materials, luminescent materials, polymers, glasses and on different drugs in their earlier studies. In the present work, Fe^{3+} 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

Analytical reagent (AR) grade of cadmium chloride ($CdCl_2$), sodium hydrogen telluride ($NaHTe$), polyvinyl alcohol (PVA), iron oxide (Fe_2O_3) 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 hrs at room temperature to swell. After that the solution was warmed up to 80°C and stirred for 6 hrs 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 % iron 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 iron doped PVA capped CdTe nanoparticles was obtained. The excess of insoluble 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

Fe³⁺ 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

PL spectroscopy is an important tool to characterize the optical properties of a semiconductor. PL intensity may be directly correlated with the defect density in a nanomaterial. The luminescent properties of the nanopowders are strongly dependent on the crystal structure of host materials. In general, PL spectrum of CdTe nanoparticles exhibit emission peak at 518 nm, which corresponds to green region. The room temperature photoluminescence spectrum of Fe³⁺ doped PVA capped CdTe nanoparticles was excited at 300 nm is shown in Fig. 1. The spectrum exhibits two emission bands: a strong UV emission band at 365 nm and a weak blue emission band at 443 nm. The emission bands of PVA capped CdTe nanoparticles 365 and 443 nm are assigned to the transition $^4T_{2g}(D) \rightarrow ^6A_{1g}(S)$ and $^4A_{1g}(G) \rightarrow ^6A_{1g}(S)$. The emission spectrum of Fe³⁺ doped PVA capped CdTe nanoparticles exhibit near band edge (NBE) emission in UV region and the deep level emission in visible regions. In this study, a sharp and dominated UV emission at 365 nm and a suppressed blue emission at 443 nm in Fe³⁺ doped PVA capped CdTe nanoparticles indicate that the prepared samples have better crystal quality and good optical properties with less defect states. These characteristic features may represent the possible applications in the fields of UV back lights, UV LEDs and display devices.

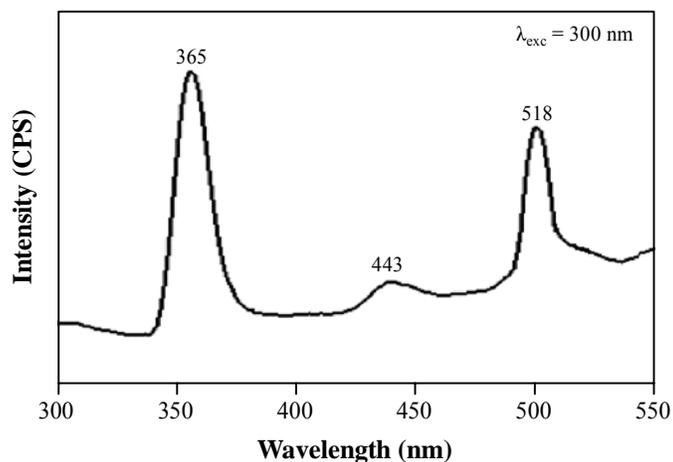


Fig. 1: PL spectrum of Fe³⁺ doped PVA capped CdTe nanoparticles

Chromaticity studies

Most lighting specifications refer to colour in terms of the Commission Internationale de l'Éclairage (CIE) 1931 chromatic colour coordinates, which recognize that the human visual system uses three primary colours: red, green and blue. In general, the colour of any light source can be represented on the (x, y) coordinate in colour space. Colourpurity was compared to the 1931 CIE Standard Source C (illuminant Cs). The chromatic coordinates (x, y) was calculated using the CIE coordinate calculator.

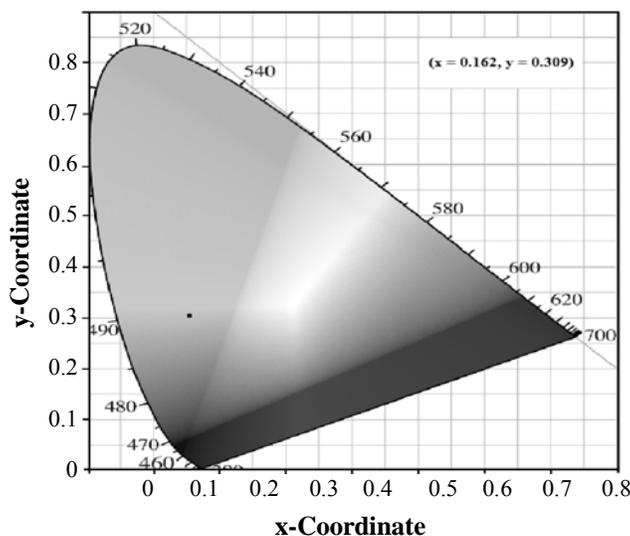


Fig. 2: CIE diagram of Fe³⁺ doped PVA capped CdTe nanoparticles

The CIE chromaticity coordinates of Fe³⁺ doped PVA capped CdTe nanoparticle was calculated from the emission spectrum. The location of the colour coordinates for Fe³⁺ doped PVA capped CdTe nanoparticles in the CIE chromaticity diagram is shown in Fig. 2 by a solid circle sign (•). From this figure, one can see that the colour of Fe³⁺ doped PVA capped CdTe nanoparticles located in the blue green region and the CIE coordinates are (x = 0.162, y = 0.309). These materials may be useful for LEDs, electroluminescence panels and plasma display panels.

CONCLUSION

Fe³⁺ doped PVA capped CdTe nanoparticles were prepared successfully by co-precipitation method. PL spectrum of Fe³⁺ doped PVA capped CdTe nanoparticles shows blue and green emission peaks. From CIE diagram, Fe³⁺ doped PVA capped CdTe nanoparticle emits blue green emission and the corresponding coordinates (x = 0.162, y = 0.309). These materials may be useful for display and LED devices.

REFERENCES

1. M. C. Rao and K. Ramachandra Rao, Int. J. Chem. Tech. Res., **6(7)**, 3931 (2014).
2. Sk. Muntaz Begum, M. C. Rao and R. V. S. S. N. Ravikumar, J. Mol. Struct., **1006(1)**, 344 (2011).
3. Sk. Muntaz Begum, M. C. Rao and R. V. S. S. N. Ravikumar, Spectrochim. Acta Part A: Mol. & Biomol. Spec., **98**, 100 (2012).
4. K. Ravindranadh, B. Babu, Ch. Venkata Reddy, Jaesool Shim, M. C. Rao and R. V. S. S. N. Ravikumar, Appl. Mag. Res., **46**, 1 (2015).
5. M. C. Nuss, D. W. Kisker, P. R. Smith and T. E. Harvey, Appl. Phys. Lett., **54**, 57 (1989).
6. Sk. Muntaz Begum, M. C. Rao and R. V. S. S. N. Ravikumar, J. Inorg. Organomet. Poly. Mater., **23(2)**, 350 (2013).
7. M. C. Rao, J. Crys. Growth, **312(19)**, 2799 (2010).
8. M. C. Rao, Optoelect. Adv. Mater., (Rapid Commu.), **5**, 85 (2011).
9. M. C. Rao, Optoelect. Adv. Mater., (Rapid Commu.), **5(5-6)**, 651 (2011).

10. M. C. Rao, *J. Optoelect. Adv. Mater.*, **13**, 428 (2011).
11. M. C. Rao and O. M. Hussain, *Optoelect. Adv. Mater.*, **13(2-4)**, 1109 (2011).

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