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Structural, Morphological & Optical Properties of $(Cd_{0.90}Zn_{0.1})S$: AgPhosphor Synthesized by Conventional Solid-State Reaction Technique

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ABSTRACT

Here, we have discussed thatAg-doped cadmium zinc sulphide phosphor has been synthesized by high-temperature conventional solid-state reaction techniqueunder a nitrogen atmosphere. The influence of Ag (5 mol %)) concentrationon the crystal structure, morphology, and optical properties of $(Cd_{0.90}Zn_{0.1})S$ crystals has been investigated by X-ray diffraction (XRD), Scanning Electron Microscopy (SEM), and photoluminescence (PL) emission spectroscopy. The PXRD pattern have revealed a hexagonal crystalline phase. The morphology images have confirmed the microcrystalline behaviour and better connectivity with grain. The photoluminescence spectra have obtainedby irradiating the samples with 345-nm UV light. The effects of 5 mol % concentration of silver ions on the photoluminescence spectra of thesynthesized phosphor have investigated in detail.

Keywords: **$(Cd_{0.90}Zn_{0.1})$ S: Ag (5 %); Solid-state synthesis; Powder X-ray diffraction (PXRD; Scanning Electron Microscopy (SEM), Photoluminescence (PL).**

INTRODUCTION

Group II–VI materials for semiconductors have served as the forefront of comprehensive research in both theory and experiment for a number of decades. These semiconductor-related substances additionally prove very interesting for development in industries as well as basic research. Group II–VI microcrystalline semiconductor have future research uses as sensors, conductors, diodes, and optical devices owing to their nonlinear optical capabilities, electrical qualities, exceptional luminescent quality, quantum cutting, and other great physical and chemical distinctive characteristics[1, 2]. It is essential that these compounds have optical characteristic tunability, since this might broaden their potential for use [3, 4].An extremely wide band gap material with a noticeable spectrum of applicability in optoelectronics is (CdZn)S. It produces outstanding outcomes for numerous applications owing to its outstanding brightness, tunability, and moderate the conductivity of light, among other morphological characteristics [2, 5, 6].

Conventional solid-state reaction procedure is an efficient way to manufacture Ag-doped (CdZn)S compounds alongside other approaches.Both volumetric and interior homogeneous heating may be achieved using this technique. Furthermore, consistent variation in particle size and excellent purity may be produced with short processing times at an inexpensive price using the solid-state reaction approach. A review of literature indicates that multiple investigators have previously examined various aspects of (CdZn)S.The primary objective of the present research is to investigate how the concentration of silver ions affects the structural (XRD), morphological (SEM) and optical (Photoluminescence) behavior of Ag-doped $(Cd_{0.90}Zn_{0.1})$ S phosphor that have synthesized by solid-state synthesis technique in a N_2 atmosphere.

Experimental Study

Ag-doped $(Cd_{0.90}Zn_{0.1})S$ phosphors have prepared using high temperature conventional solid-state reaction method. Luminescence grade CdS & ZnS (Fluka, Switzerland) and silver nitrate (Ag $(NO_3)_3$; Merck) were acquired, as well as potassium chloride (KCl; Merck) for use as a flux. The fixed CdS & ZnS amounts (0.90% and 0.1%, respectively) were mixed with Ag^+ ion concentration (5 mol%) for preparation of the phosphor. The mixture was placed in an alumina crucible, and then heated in a silica tubular furnace maintained at 900°C for 1 hr under an inert atmosphere of flowing nitrogen gas. The mixture of ingredients was permitted to cool to room temperature in the same furnace once the heating process was finished. The sample was quickly crushed after cooling to produce a finely ground material with consistent crystal size [Fig. 1].

Figure 1. Mechanism of the solid-state synthesis of Ag (5 mol %)-doped ($Cd_{0.90}Zn_{0.1}$) S phosphor.

Characterization Details

To determine the average particle size and the phase of the samples, X-ray powderdiffraction (XRD) pattern was measured by using a D-8 Advance diffractometer with Cu-K_{α}radiation. The morphology of the phosphor was characterized by scanning electronmicroscope (SEM) [Model: JEOL-JSM 5600].Photoluminescence characteristics, including excitation and emission spectra, were analyzed using a Shimadzu RF5301 PC Spectro fluorophotometer.

RESULTS AND DISCUSSION

X-ray diffraction (XRD)

The XRD pattern of Ag(5 mol %)-doped($Cd_{0.90}Zn_{0.1}$)S phosphor sample is shown in Fig. 2. The intense peaks have shown the hexagonal crystal structure. The peak width shows the behaviour of the sample. Thepeak width decreases as the size of the crystal increases; thus, the width increases as crystal size decreases. Thesize of the crystal was calculated using the full widthat half maximum (FWHM) of all peaks obtained by theDebye Scherrer formula and then finding the average ofthese values [7]. The formula used for this calculation was: where Dis crystal size in nm, β is the full width at halfmaximum (FWHM), λ is the wavelength of X-ray source(1.5405 Å), and θ is the angle of diffraction.The average crystal size of the sample has obtained152 nm for 5 mol % of Ag ions.

$$D = \frac{0.9\lambda}{\beta \cos \theta}$$

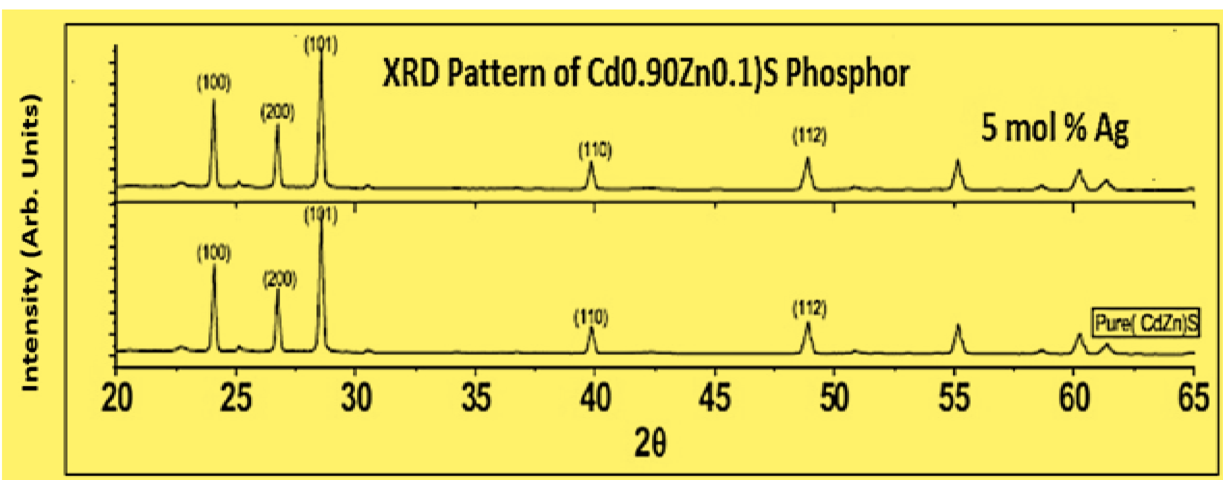

Figure 2. Powder X-ray diffraction pattern of Ag (5%)-doped ($Cd_{0.90}Zn_{0.1}$) S phosphor.

Table 1 Determination of Average Crystallite Size with their Respective Planes

S. No.	Matrix	Phase Structure	Planes	Crystal size in nm	Average Crystallite Size
1.	($Cd_{0.90}Zn_{0.1}$) S: Ag (5 mol %)	Hexagonal	100	142	152 nm
2.	($Cd_{0.90}Zn_{0.1}$) S: Ag (5 mol %)		200	148	
3.	($Cd_{0.90}Zn_{0.1}$) S: Ag (5 mol %)		101	152	
4.	($Cd_{0.90}Zn_{0.1}$) S: Ag (5 mol %)		110	156	
5.	($Cd_{0.90}Zn_{0.1}$) S: Ag (5 mol %)		112	162	

Scanning Electron Microscopy (SEM)

The preparation process and crystal composition have a noticeable impact on the morphologies. SEM was also used to study the crystals' surface shape, which provided images of the surface morphologyof Ag (5%)-doped ($Cd_{0.90}Zn_{0.1}$)S phosphors (Fig. 3). The produced phosphor exhibits microcrystalline behavior and strong connection with grain, as seen by the SEM images, demonstrating that powder size and shape are adequately controlled. No significant difference was observed in the XRD pattern and SEMmicrograph; therefore, all samples are well crystallizedinto hexagonal ($Cd_{0.90}Zn_{0.1}$) S:Ag structure. These indicate that the enhancement in luminescence efficiency isnot caused by grain morphology.

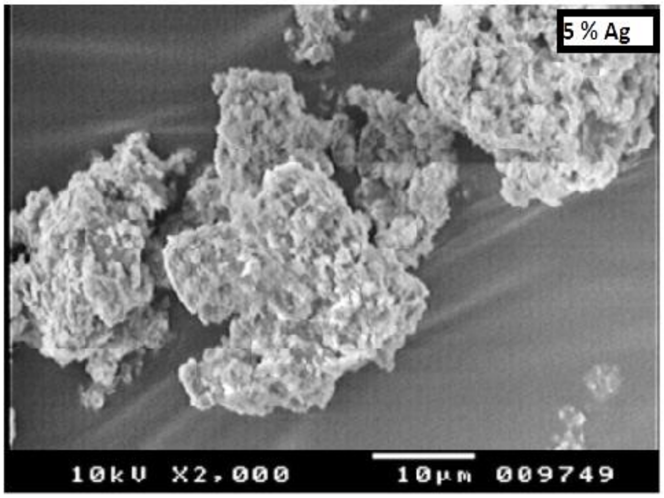

Figure 3. SEM micrograph of Ag (5%)-doped ($Cd_{0.90}Zn_{0.1}$) S phosphor.

Photoluminescence Spectra

Photoluminescence (PL) is a very sensitive technique that investigates defects and impurities. Thus far, numerous PL studies on Ag-doped ($Cd_{0.90}Zn_{0.1}$)S phosphorshave been performed. PL spectra of the ($Cd_{0.90}Zn_{0.1}$) S phosphorswith fixed (5 mol %) concentration of Ag ions at room temperatureare shown in Fig. 4. The measurements were performedat an excitation wavelength of 345 nm. The PL spectra show broad peaks, which imply the superposition ofmultiple emission bands [2]. These transitions belong tothe defects produced by the Ag ions. A small emission peak at 528 nm can be attributed to the transitionfrom the shallow trap level, while the peak at 552 nmcan be assigned to the radiative transition from a deeptrap state due to the vacancy in the synthesized lattice.The peak intensities corresponding to 528 and 552 nm increased withincreasing silver concentration [2, 8] (Fig. 4). Maximum PL intensity have obtained at 5 mol % concentration of Ag ions. Thus,the PL peak suggests that the sulphur vacancies are occupied by the Ag^{+}ion in the lattice host material of the($Cd_{0.90}Zn_{0.1}$)Sphosphors, which reduces the participation of the sulphur content in excitation and chemical reactions [9].

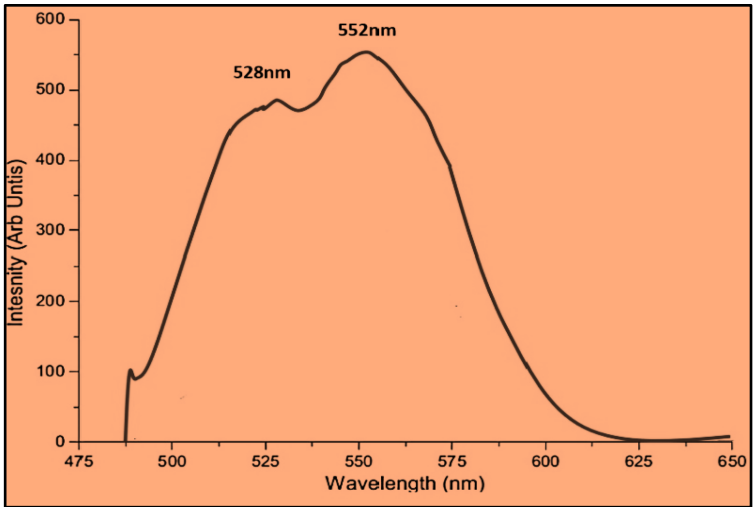

Figure 4 Photoluminescence spectra of Ag (5%)-doped ($Cd_{0.90}Zn_{0.1}$)S phosphor

CONCLUSION

Silver-doped ($Cd_{0.90}Zn_{0.1}$)S phosphor have prepared using high temperature conventional solid-state reaction technique. The structural and, morphological behaviour was defined by XRD and FESEM analysis. The XRD intense peaks have shown the hexagonal crystal structure. The structural and optical properties have investigated as a function of 5 mol % concentration of Ag^+ ions.The average crystal size of the sample has obtained152 nm for 5 mol % of Ag ions. The SEM images have shown in micrometer range. Thus, crystal size increases with increasing Ag^+ ion concentration. In the PL emission spectra, the emission peak has located in the green region at 552 nm. A small emission peak at 528 nm can be attributed to the transition from the shallow trap level, while the peak at 552 nm can be assigned to the radiative transition from a deep trap state due to the vacancy in the synthesized lattice. Maximum PLintensity have obtained at 5 mol % of concentration of Ag ions.

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