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The Effect of Dopant Metal on the Crystallite Size and Photovoltaic Efficiency of PbS

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To examine how the Mn-doped metal affects the crystallite size and photovoltaic efficiency of PbS, Mn-doped PbS thin films were synthesized by a cost-effective chemical bath deposition technique. In order to calculate the crystallite sizes of the synthesized thin films and to examine the photovoltaic efficiency, X-ray diffraction (XRD) and incident photon-to-electron conversion efficiency (IPCE) were performed, respectively.

1. Introduction

With a significant Bohr radius of 18 nm and a narrow band gap of 0.41 eV at 300 K, PbS is one of the most significant IV-VI semiconductors. Thus, by manipulating the crystallite size, it provides strong quantum and electron confinement that controls the band gap value [1,2]. PbS has also been proposed as a sustainable material for cost-effective photovoltaics. This material is very important for infrared detector applications. In addition, PbS thin films are also used as an absorber for solar cells. Changing the energy band gap via doping is one technique that can be used to improve PbS's performance in application areas. Sharp atomic energy levels are created in the PbS lattice when different metals are doped into nanocrystalline PbS thin films [3-5].

Earlier studies have underlined that depending on the type and concentration of dopant utilized, the characteristics and performance of the PbS thin film based device are greatly improved. According to a study on the optical properties of Ni doped PbS thin films, Ni doping increased the optical energy band gap of thin films. [6] Another study found that, when compared to pure PbS, the energy band gap of doped PbS thin films rose from 1.7 to 2.37 eV. It was also mentioned that the electrical resistivity and energy band gap values of thin films rose. [7] The dopant considerably enhances the optical characteristics of pure PbS thin films, according to the early tests stated above.

Different production techniques are utilized to synthesize thin films in thin film technology. Chemical bath deposition is one of these methods. Previous research has claimed that this method can be used to create thin films that are both affordable and of a good caliber. When compared to other thin film deposition techniques that simply need aqueous solution at (relatively) low temperatures and minimum infrastructure, chemical bath deposition is advantageous for industrial applications since it is incredibly affordable, straightforward, and reliable. [8] Chemical bath deposition is easily scalable to continuous deposition or batch processing over a broad area.

This study used a practical chemical bath deposition method to create Mn-doped PbS thin films. The major goal of the study is to examine how Mn doping metal affects the performance of PbS-based solar cells. X-ray diffraction (XRD) was also used to examine the structural characteristics of generated Mn-doped PbS thin films. Chemical bath deposition is easily scalable to continuous deposition or batch processing over a broad area.

2. Results and Discussion

Structural characteristics and crystal sizes of pure PbS and Mn-doped PbS thin films were studied using XRD measurements. Figure 1a and 1b show the diffraction patterns for each sample. It was discovered that diffraction patterns of both thin films were identical and that the structures of the samples were cubic. The absence of any unfavorable diffraction patterns can be shown in Figure 1b, which shows that Mn-doped PbS may be experimentally produced at ambient temperature. The crystallite sizes of the thin films synthesized

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were calculated using the Debye-Scherrer formula. The diameters of the crystallites in the pure PbS and Mn-doped PbS thin films were predicted to be 25.97 nm and 24.12 nm, respectively, based on the XRD peaks representing the (111), (200), and (220) planes depicted in Figures 1(a-b). It was determined that Mn-doped PbS had smaller crystallites than pure PbS. Because of this, Mn-doped PbS has a smaller size than PbS even if its structural makeup remains the same.

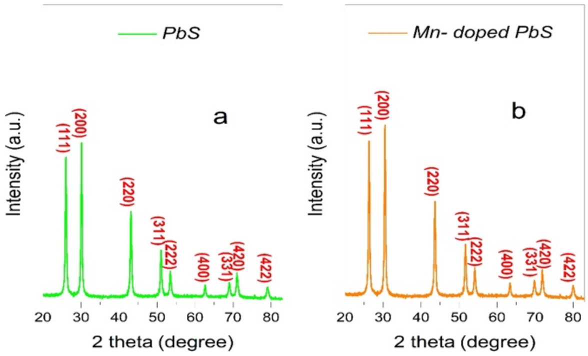

Figure 1. X-ray diffraction patterns for two samples.

Figure 2 displays the spectra of pure PbS and Mn-doped PbS thin films for incident photon to electric current conversion efficiency (IPCE). Two interesting findings from the data should be mentioned: (1) Mn-doped PbS has a higher IPCE (%) value than pure PbS. In other words, Mn-doped metal improves photovoltaic capabilities of PbS. (2) Mn doping causes the spectrum response of Mn-doped PbS to be wider than that of PbS.

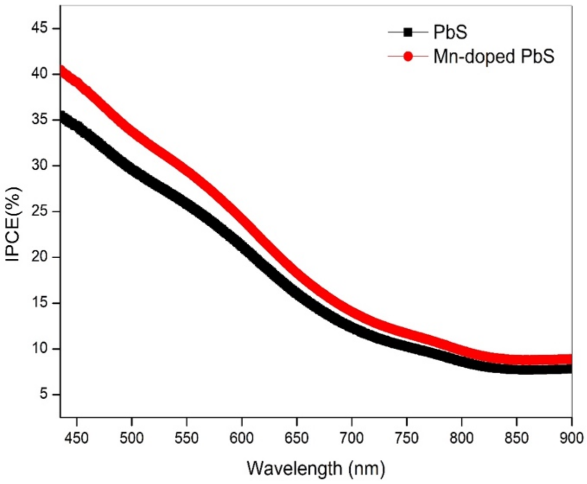

Figure 2. IPCE spectra for two samples.

3. Conclusion

This study used a practical chemical bath deposition method to create Mn-doped PbS thin films. Both thin films were found to have cubic structures when the structural characteristics of thin films were determined. The crystallite sizes of pure PbS and Mn-doped PbS thin films were determined to be 25.97 nm and 24.12 nm, respectively, based on XRD observations. How the IPCE value of the Mn-doped PbS thin film will vary in the presence of Mn dopant metal is another crucial stage in the current work. The IPCE (%) value of Mn doped PbS was discovered to be higher than that of PbS as a consequence of the IPCE spectra that were obtained. Thus, it is evident that Mn doping metal has an impact on specific PbS parameter.

Method

The pH of 0.2 M lead acetate solution was changed to 11 by adding NH3 solution dropwise in a beaker in order to manufacture undoped PbS thin film. This solution was combined thoroughly with an equal-molar thio-urea solution using a magnetic stirrer. The solution was applied vertically to the cleaned glass surfaces, and they were heated at 313 K for one hour. The solution was left at room temperature over the course of the night to allow the nanocrystalline PbS thin film to completely deposit. The PbS-coated glass substrates were taken out of the bath after deposition, frequently rinsed with deionized water, and allowed to air dry at room temperature.

The aforementioned procedures were repeated while 2 wt% manganese acetate was added to a 0.2 M lead acetate solution to create Mn-doped PbS thin films.

Authors' contributions

S.H.: Conceptualization, investigation, experiments, writing- original draft, reviewing and editing.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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