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Study the optical and chemical properties of $Cd_xPb_{1-x}S$/porous silicon nanocomposites

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ABSTRACT: This paper exhibits the optical and chemical properties of combination $Cd_xPb_{1-x}S$ nanostructure on porous silicon substrates at concentrations (x=0,0.25,0.5,0.75,1) using spray chemical method . The physical properties of all samples like Raman scattering, UV visible and FTIR were observed. The results indicates that the Raman scattering intensity of lead and cadmium sulphide on porous silicon increased compared with fresh porous silicon. In detail, the porous silicon substrate remains the crystalline structure of the prepared samples. Besides,the optical energy gap increases with increasing doping cadmium ions Cd^{+2} and its values 2.21, 2.59, 2.61, 2.63, 2.69 eV at composites x=0,0.25,0.5,0.75,1 respectively. Furthermore, The peaks of 599.53cm^{-1} corresponded to Cd-S stretching vibration . Apart of this, we noted the appearance of the weak peaks at 773.69cm^{-1} ,these peaks refer to Pb-S stretching modes.PbS and CdS thin films have been successful, and optical properties on the porous silicon surface have enhanced using the chemical spray method.

KEYWORDS: CdS, PbS , Porous silicon, UV, Raman Scattering.

I. INTRODUCTION

Cadmium sulfide compound(CdS) is regarded one of the interesting industrial and application studies due to its vast numerous important in many applications especially electronic devices as transistor and light emitting diode[1,2,3].CdS compound belongs to II-VI group of the period table ,where the two elements union from the second column was formed .Cadmium sulfide has direct energy gap (2.42eV) and high absorption coefficient[4]. Broadening energy gap of CdS made it into numerous application as optical filters in solar cells as well as gas sensor instead of crystalline silicon because of its low cost and easy preparation as good thin films[5,6,7] . CdS has either cubic (fcc)or hexagonal crystal structure as sodium chloride and diamond respectively. lead sulfide compound belongs to (IV-VI) group of the period table and has cubic crystal structure [8,9,10] . Where the PbS uses in many applications as IR radiation photodetectors , solar cells , optical devices and as well as optical key for CD [11,12]. lead sulfide compound is dark graycolor to black and has narrow energy gap (0.42eV) at room temperature also the PbS composites have solubility in acids and do not soluble in alcohol or potassium hydroxide[13]. Various methods of the thin films deposition were carried out as physical vapor deposition (PVD), spray chemical method , chemical vapor deposition (CVD) and (sol-gel) [14]. Spray chemical method is one of the simple techniques for the unique thin film homogenous and low cost . In the recent years , porous silicon has a numerous important from many researchers due to unique properties which is many applications especially optoelectronic devices as photodetectors and solar cells[15] . The aim of this work is to study the Raman scattering , optical and chemical properties of $Cd_xPb_{1-x}S$/ porous silicon hetrostructure devices .

II. EXPERIMENTATION

2.1 Preparation of cadmium sulfide (CdS) and lead sulfide(PbS) nanostructures

The lead and cadmium sulfides were prepared at concentration 0.1M . The lead chloride($PbCl_2$) and the cadmium chloride ($CdCl_2$) powders were Sigma Aldrich company, 98% purity. The Cd^{+2} cation, Pb^{+2} cation and anion S^{-2} can be obtained from reaction the lead chloride ($PbCl_2$),the cadmium chloride ($CdCl_2$) and Sodium sulfide (Na_2S) respectively . The reaction was noted by the following [16]:

$$Na_2S(aq)+CdCl_2(aq) \rightarrow CdS(s) + 2NaCl\ (aq)$$
$$Na_2S(aq)+PbCl_2(aq) \rightarrow PbS(s) + 2NaCl\ (aq)$$

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The cadmium and lead sulfide solutionswere heated at 70°C using magnetic stirring for 1hr. In the first time ,the color of cadmium sulfidesolution was yellow to orange color at 30 min. After that, the solution color change to darker and turn to dark orange within 1hr. In the same way , the solutioncolor in the baker of the lead sulfidewas gray at 35min . Then, the solution colorgradually becomes darker and turn to dark black within 1hr. The weight concentrations of leadsulfide and cadmium solutions were formed at (x=0,0.25,0.5,0.75 and 1) . Besides, The combination between PbS and CdSsolutions can be obtained at x= 0.25 as $Cd_{0.25}Pb_{0.75}$ S . The color of solution was light orange at 20 min and changed to dark black at 30min. Furthermore, the solution $Cd_{0.5}Pb_{0.5}S$ can be formed at x= 0.5 .The solution color of was light also yellow at 21min and change to dark gray at 27min .Similarity, the solution of $Cd_{0.75}Pb_{0.25}$ S at x=0.75 was light greencolor at 14min and change to dark green at 25min. All solutions were heated separately at 85^o. The final solution of $Pb_{1-x}Cd_xS$ were deposited on glass substrates by the chemical spray method at 250°C and an atmospheric pressure of 7.5 bar as the Figure1(a,b,c).

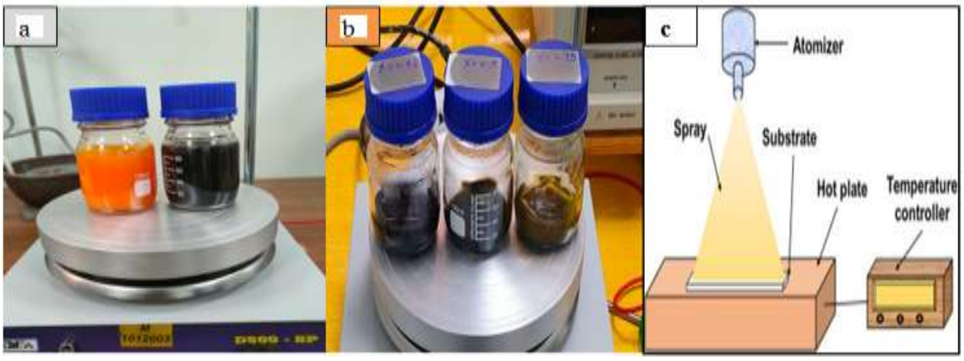

Figure 1. (a) Solution of cadmium sulfide (CdS) and lead sulfide (PbS) , (b) Solution of composites CdxPb1–xS at x=0.25,0.5,0.75 (c) chemical spray method

2.2 Fabrication of porous silicon sample

The porous silicon samples were fabricated by the photo-electrochemical etching method . We used crystalline Si wafers of p-type (111) in Germany company with resistivity of (10 ohm. cm) with Thickness of 500µm. The first time , the circle silicon wafer was cut off as small samples (1.5×1.5 cm) and cleaned with propanol and alcohol solution by an ultrasonic bath for 15 min and then rinsed with deionized water. Firstly , the work cell can be formed from the cylinder plastic Teflon in order to prepare porous silicon sample. Anodization cell consist ofpower supply , Ammeter and voltmeter , The cathode electrode refers to gold mash and anode electrode refers to circle steel as Figure2(a,b) . The crystalline silicon samples immersed into mixturehydrofluoric acid (18%HF) and ethanol (99%) solutions. The current density (10mA/cm^2) and the etching time (5,10,15min) were used.

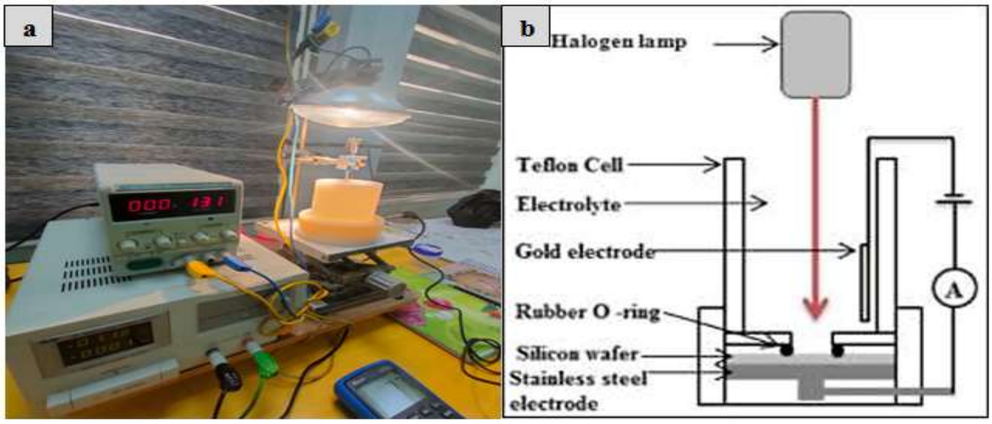

Figure 2. (a) Image of the Photo electrochemical method , (b) diagram of Photo electrochemical method

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2.3 Raman Spectroscopy

Raman Scattering is one of the important tools which can be used to determine the crystal structure of the solid state . The Raman spectra of the fresh porous silicon and the $Cd_xPb_{1-x}S$/PSi thin film samples at x=0.25,0.75 were observed as Figure 3 and summarized in Table 1. It is clear the Raman peak position of the porous silicon can be determine at 484 cm^{-1}. Meanwhile,the peak positions of the composites PbS and CdS formed on porous silicon exhibit the blue shift (higher energies) and can be observed at 513 and 518 cm^{-1}, respectively. The Raman scattering intensity of lead and cadmium sulphide on porous silicon increased compared with fresh porous silicon . Furthermore, FWHM increases at x=0.75 compared with x=0.25 , this refers to decrease the crystallinity size after deposition. The absence of other peak in the Raman scattering confirms that the porous silicon remains the crystalline structure of the prepared samples. The Raman microscope is an inelastic light scattering process where the scattered photon frequency is shifted by interaction with the vibration mode of samples [17,18].

Table 1: Raman spectra result of fresh PSi and $Cd_xPb_{1-x}S$/PSi at x=0.25,0.75.

Sample	Wave number (cm^{-1})	FWHM (deg.)	Intensity (a.u.)
Fresh PSi	541.7	113.14313	1.521
X=0.25	556.9	108.29237	4.417
X=0.75	549.2	109.27125	4.677

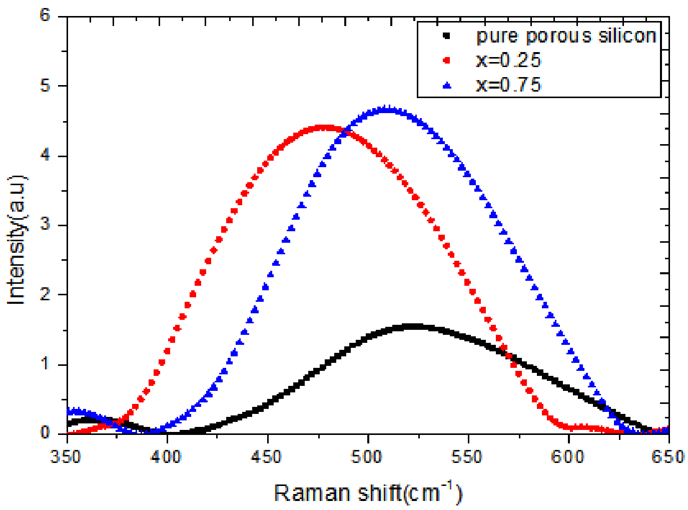

Figure 3 . Raman spectra of the fresh porous silicon and the CdxPb1-xS/PSi thin film samples at x=0.25,0.75

2.4 Optical properties

The optical properties of $Pb_{1-x}Cd_xS$ nanostructures was studied at composites x=0,0.25, 0.5,0.75,1 by (UV-Spectrophotometer). The variation relationship between the absorbance spectra and the wavelength were observed as Figure 4a. It can be seen the curves analysis of the absorbance spectra decrease gradually with increasing doping of Cd^{+2} ions. The absorption edge was observed at wavelength345nm and shifted with shorter wavelength side with increasing concentration. On the other side, the transmittance (T) as a function of wavelength was estimated as Figure 4b. It is clear the transmittance spectra increase with increasing concentration Cd^{+2} due to the change of the electronic excitation in the crystalline phase of molecule .Furthermore, the optical absorption coefficient (α) also decreases with increasing concentration x due to the formation of defects during deposition process as Figure 4c, which could be related to the increase in crystallinity of the deposited films. These defects were an interested component in optoelectronic applications and play an important role in the performance of optical properties[19]. Figure 4dexhibits the relationship between the $(\alpha\ h\nu)^2$ and energy photon (hν) of $Pb_{1-x}Cd_xS$ thin films. We can evaluate the energy gap (Eg) by Tauc formula[20]:

$$\alpha\, h\upsilon = B(h\upsilon - Eg)^{\ r} \qquad (3)$$

Where r refers to 1/2 of the direct transition and 2 of the indirect transition, hυ is symbolize of photon energy, B is constant, and α

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indicates the absorption coefficient. The results show, the optical energy gap increases with increasing doping cadmium ions Cd^{+2} and its values 2.21, 2.59, 2.61, 2.63, 2.69 eV at composites x=0,0.25,0.5,0.75,1 respectively. Increasing of energy gap values leading to the interface band transition at localized states in the energy gap .This is a good agreement with the published works [21,22,23].

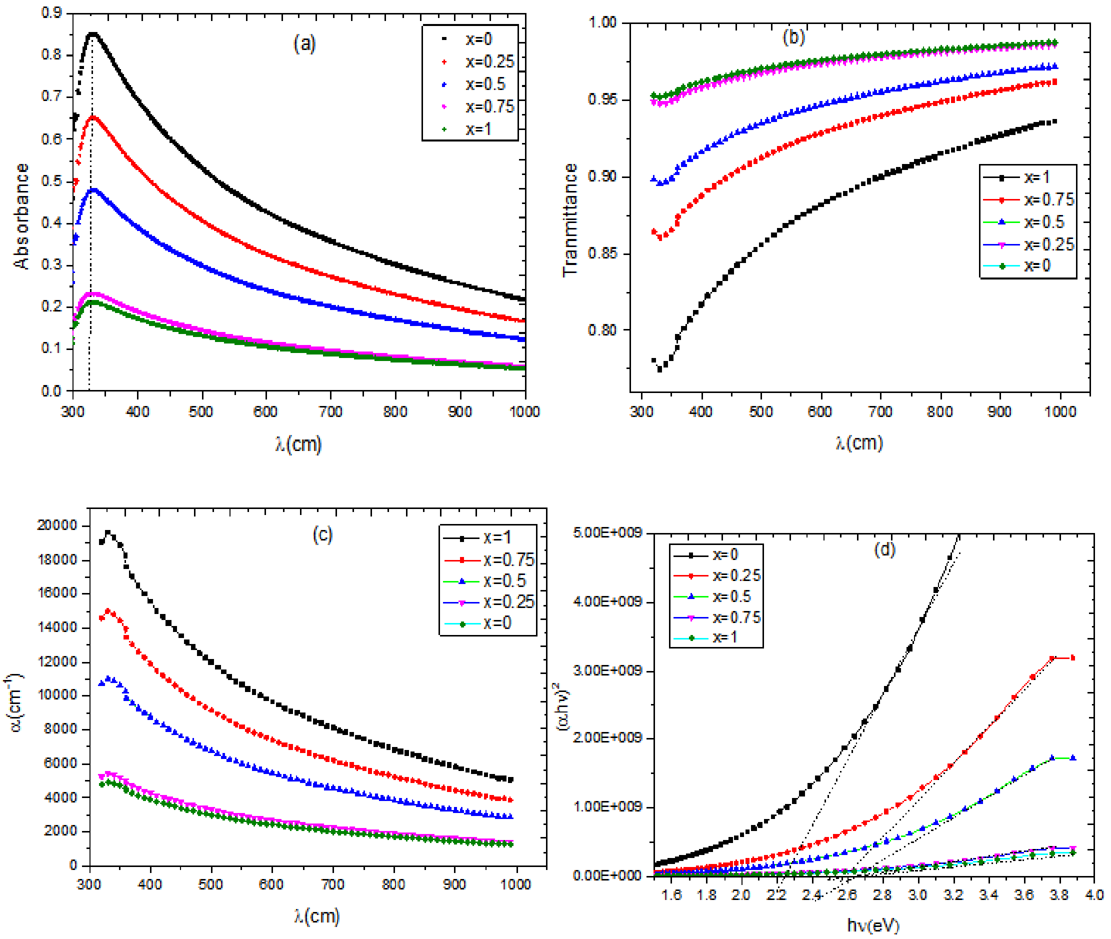

Figure 4.Spectra of UV visible CdxPb1-xS Thin films (a) Transmittance ,(b) Absorbance, (c)Absorption coefficient, (d) Evaluation of energy gap

2.5 Fourier transmission infrared (FTIR)

The FTIR spectra of the $Cd_xPb_{1-x}S$ thin films nanostructure at different composites were observed as Figure 5. The strong peaks were noted at 3437.35cm^{-1} and corresponding to O-H stretching vibration , this bond refers to the molecules of water present by the aqueous solvent used to prepare substrates .The peaks at 2853.11cm^{-1} and 2921.99cm^{-1} were noted and corresponding to Cd-O stretching vibration . Additionally, the peaks at 1630.05cm^{-1} refer to H-O-H bending . The peaks of 1103.2cm^{-1} correspond to C-O stretching vibration. On the other side, The peaks of 599.53cm^{-1} correspond to Cd-S stretching vibration . Furthermore, we noted the appearance of the weak peaks at 773.69cm^{-1} ,these peaks refer to Pb-S stretching modes. This result exhibits suitable agreement with previous papers [24,25].

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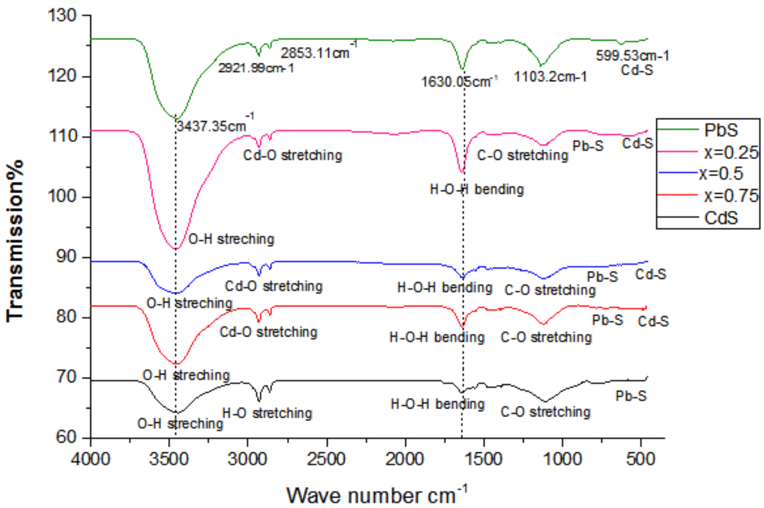

Figure 5..FTIR of composite CdxPb1-xS Thin films at different concentration

CONCLUSION

The performanceof lead and cadmium sulphides nanocomposites on porous silicon multi-junction can be confirmed successfully using spray chemical method.The Raman scattering indicates that the intensity of CdS and PbS nanocomposites on porous silicon increased compared with pure porous silicon substrate. Additionally, the optical energy gap of mixture $Cd_xPb_{1-x}S$ thin films increases with increasing doping cadmium ions Cd^{+2} and its values 2.21, 2.59, 2.61, 2.63, 2.69 eV at composites x=0,0.25,0.5,0.75,1 respectively. Furthermore,The peaks of 599.53cm^{-1} correspond to Cd-S stretching vibration . Besides , the appearance of the weak peaks at 773.69cm^{-1} ,these peaks symbolize to Pb-S stretching modes.Thus, the experimental conditions can be enhanced the configuration as the size and shape of the ultimate structures.

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