STUDYING THE EFFECT OF PbS FILM THICKNESS ON MORPHOLOGY AND OPTICAL PROPERTIES

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Introduction

Lead Sulphide (PbS) is an important binary semiconductor from IV–VI group with a narrow band gap of 0.41 eV. It has a large exciton Bohr radius of 18nm which results in strong quantum confinement for electrons and holes even for large particles. PbS nanoparticles are promising in optical and photonic device applications such as solar cells, gas sensors and other optoelectronic devices and also IR detectors . When the size and shape of PbS are transferred from bulk material to nanoparticles, the optical band gap shifts from 0.41 eV to the values up to 5.2 eV which is suitable to build optical sensors with adjustable properties.

Methodology

Lead sulphide thin films have been synthesized by using chemical bath deposition method (CBD) on glass substrates. An aqueous chemical bath containing $Pb(No_3)_2$ (0.1M). NH_2CSNH_2(1M). NaOH (0.57M) at room temperature. 250ml distilled water was added to the solution to achieve a total volume of 350ml. cleaned glass substrate was put in the solution and taken out of the chemical bath after 30min.

The equations are as follows

$Pb(NO3)_2 + 2NaOH \rightarrow Pb(OH)_2 + 2NaNO_3$ (1)

$Pb(OH)_2 + 4NaOH \rightarrow Na_4Pb(OH)_6$ (2)

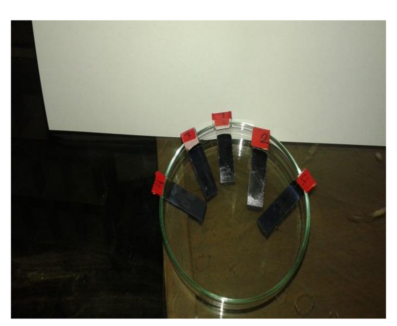
$Na_4Pb(OH)_6 \rightarrow 4Na+ + HPbO_2^- + 3OH^- + H_2O$ (3)

$HPbO_2^- + SH^- SC(NH2)_2 + OH^- \rightarrow CH_2N_2$ (4)

$HPbO_2^- + SH^- \rightarrow$ **PbS** $+2OH$ (5)

1- The beginning of the reaction

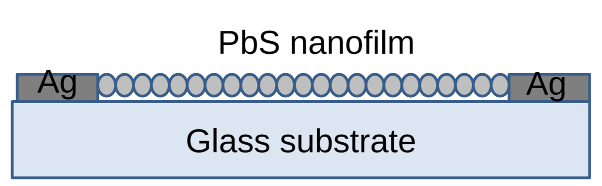
2- After 30 min



3-The prepared samples

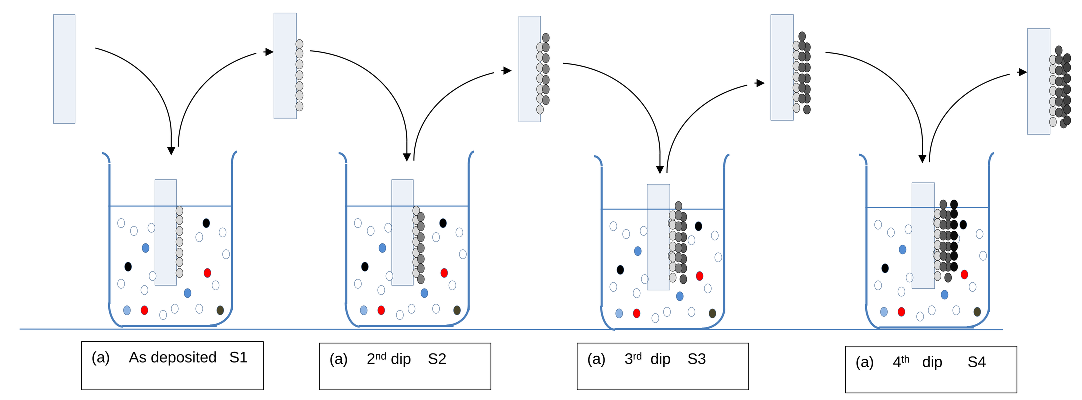
The resulting film was homogenous with dark surface like mirror, The coated substrate was taken out the solution and rinsed with distilled water, dried with N_2 gas and stored in a desiccator the reaction Process for forming PbS thin films using lead nitrate as a lead source.

In order to measure the electrical properties, silver paste is used to make the two electrodes on the surface of the film with spacing of 4mm.



Samples under investigation

The thickness of the thin film semiconductor is very important parameter and all the film characteristics depends on its thickness. In this work the PbS films with different thicknesses were prepared by several insertion of the sample in a fresh reactions solution.

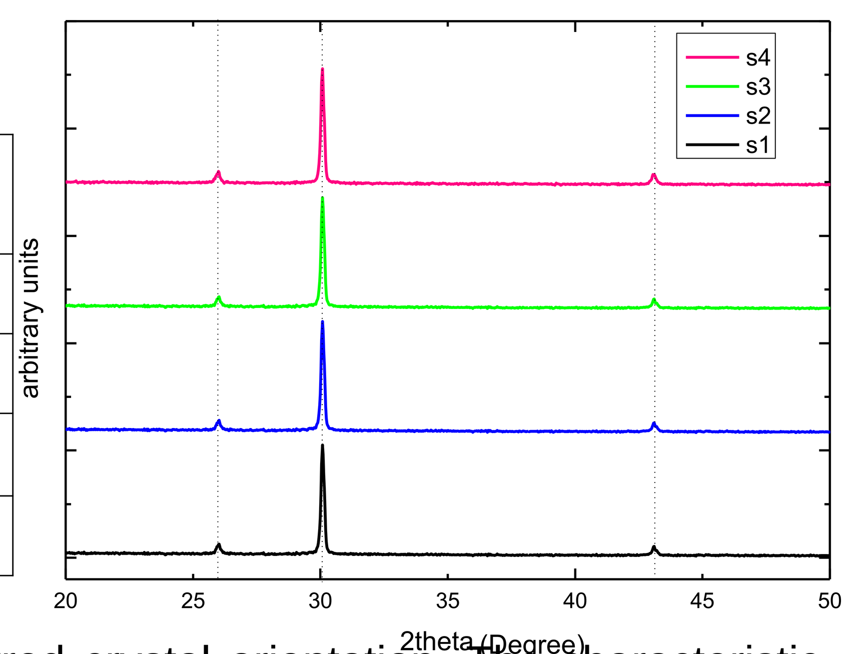


The studied films have thicknesses 300, 600,900 and 1200 nm for S1, S2, S3 and S4 respectively . Measured by Dektak 150 stylus, profilometer

Experimental Results

XRD Analysis

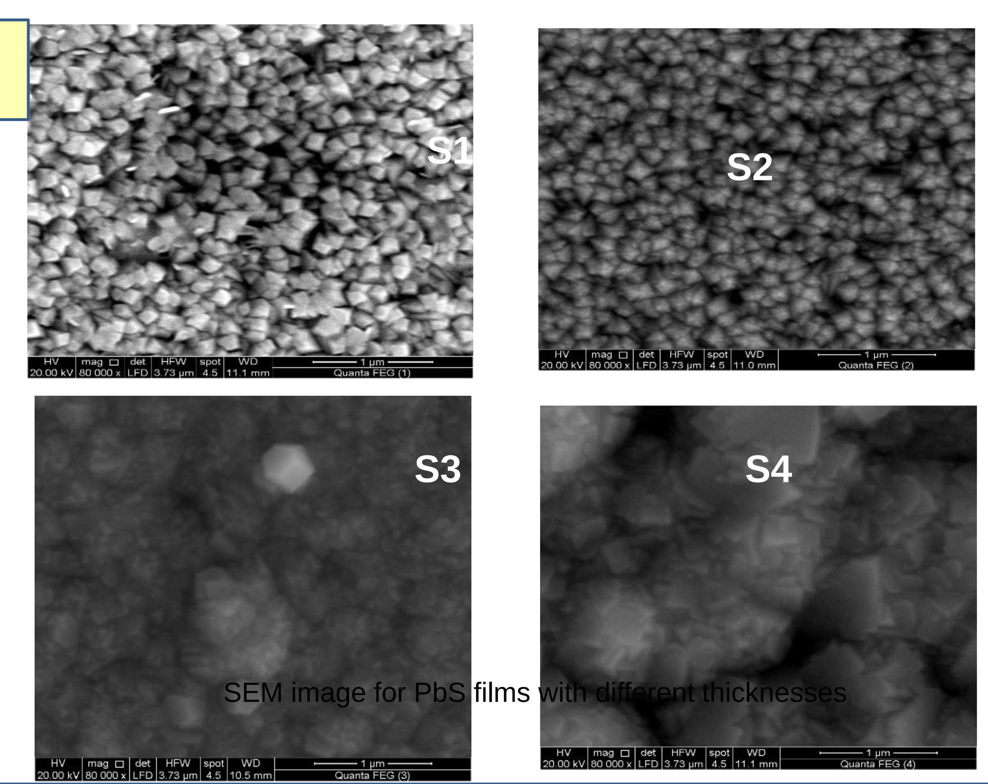
Sample	FWHM (degree) β	Crystallite size D (nm)	Dislocation density x10^{-18} lines/cm^2	Strain x10^{-4}
As prepared(S1)	0.16	50.8	3.87	6.82
Double dip (S2)	0.153	54.2	3.40	6.52
Triple dip (S3)	0.127	67.74	2.17	5.41
Fourth dip (S4)	0.10	81.2	1.51	4.26



All films are polycrystalline with (200) preferred crystal orientation. The characteristic reflection peaks were observed at 25.998^0, 30.0819^0 ,43.1140^0, 51.0107^0, 62.2616^0 which corresponding to diffraction peaks (111), (200),(220),(311) and (222). With increasing the film thickness the peak intensity increases.

Surface morphology

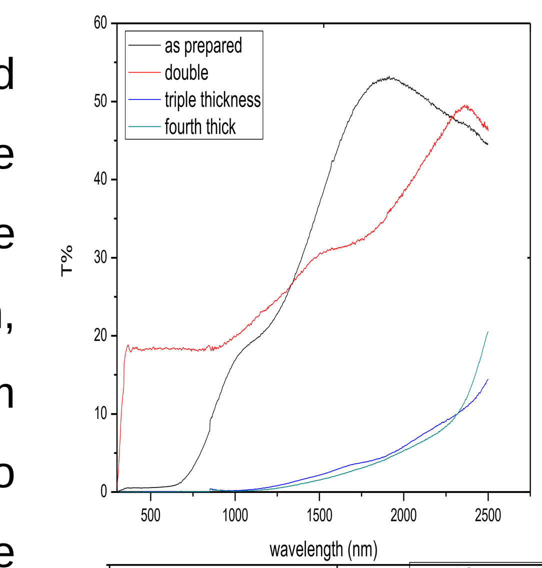
Higher magnification of the SEM images has been used to estimate the grain size present on film surface. we found that with increasing film thickness the grain size increases from 100-200nm.

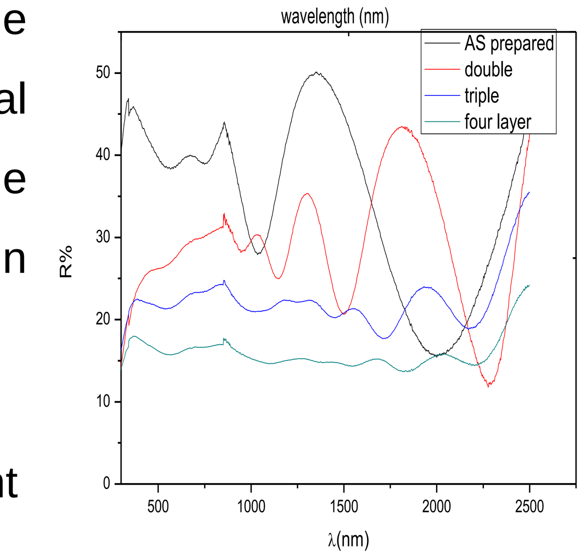


SEM image for PbS films with different thicknesses

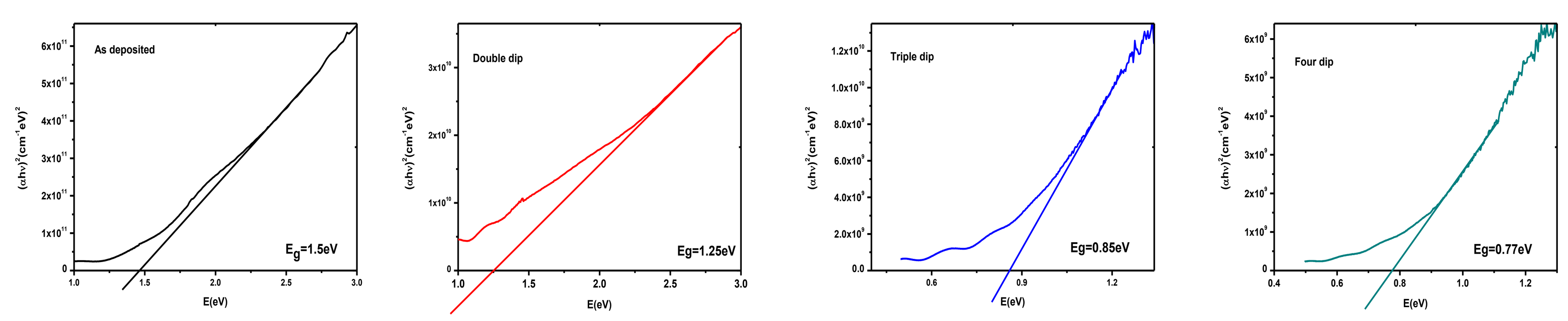
Optical properties

Increasing the film thickness the transmission edge is shifted toward longer wavelength. The band edge shift is related to the decrease in the direct band gap energy. The drop in the reflectance around the band edge is related to the increase in transmission, and the observed interference behavior is related to the film thickness and surface morphology. The reflectance observed to decrease with increasing the film thickness in the spectra range from 400 to 2500 nm which can be attributed to the morphological feature.as the film thickness increases, the grain size and the surface roughness increase also, leading to decrease in reflectance.

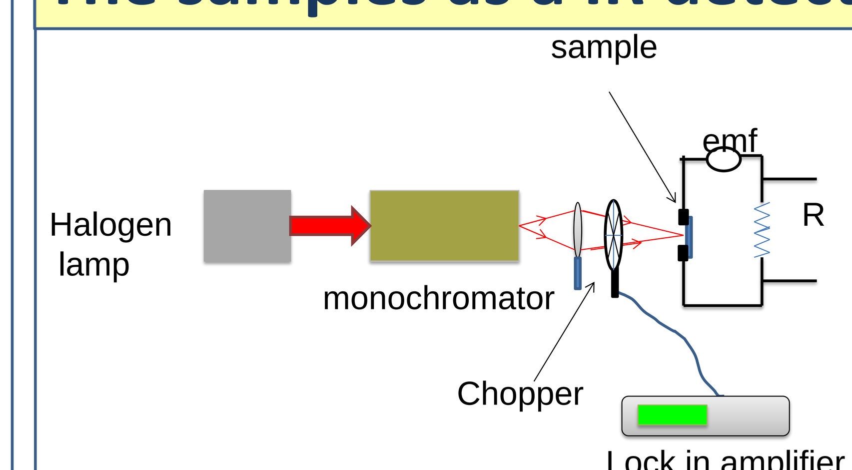


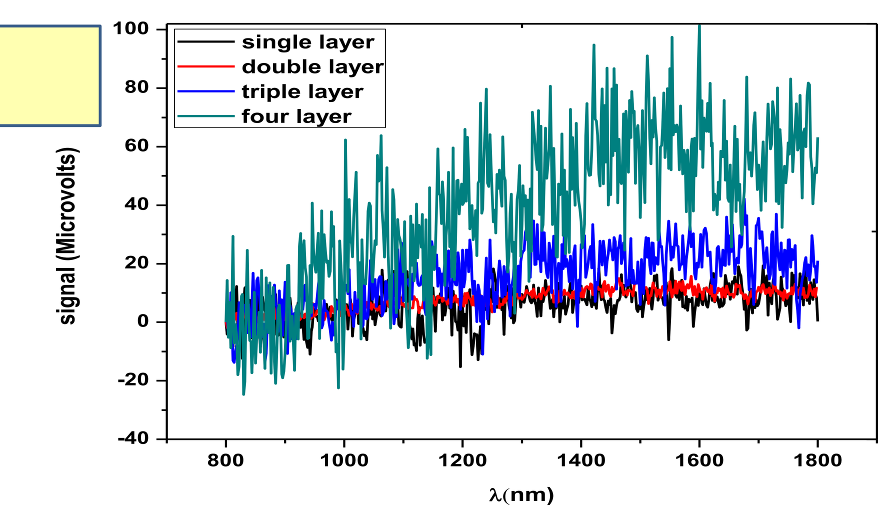


To determine the value of band gap for PbS thin films with different thicknesses we use **Tauc relation** $\alpha h\nu = A(h\nu - Eg)^2$



The samples as a IR detector





The effect of varying the film thickness on the structural, surface morphology and optical properties was investigated. Thicker films exhibit larger crystalline and higher signal as a detector