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Study the Effect of Substrate on Thermally Evaporated PbS Thin Film

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Abstract

In the present work, PbS thin films have been synthesized by thermal evaporation technique on two different types of substrate a) glass and b) ITO coated glass. PbS thin films were characterized by different characterization technique like X-ray diffraction (XRD), Scanning electron microscopy (SEM), Atomic force microscopy (AFM) and Energy dispersive analysis of X-rays (EDAX analysis). X-ray diffraction spectra of the film reveal higher crystallinity on ITO coated glass substrate in comparison ofthe film grown on a glass substrate. PbS thin films have been grown with good quality and more adhesion on the ITO coated glass as confirmed by scanning electron microscopy. The average roughness of the film is ~ 10 nm for the film on ITO coated substrate and ~ 19 nm for the film on a glass substrate as obtain by atomic force microscopy. The quality of the film is better with ITO coated substrate in comparison of glass substrate confirmed by different characterizations.

Introduction

Nowadays, the thin film science and technology playing a major role in the high-tech industries and different device fabrication area. In the recent years, thin film science has been grown worldwide into major research areas such as optoelectronic, solar cell and infrared detection application [1-3]. The thin film technology has been developed primarily for the need of the integrated circuits for many devices fabrication. Lead Sulphide (PbS) is relevant binary material which belongs to IV–VI semiconductor group material with direct narrow band gap (~ 0.4 eV at room temperature) and relatively large exciton Bohr radius (~ 18 nm)[4]. PbS thin films are advantageous in many fields like temperature sensors, photo resistance and solar absorption and also exhibit the semiconducting properties [5]. Its semiconducting behaviour plays a significant role in the development of detection system in which the infrared detectors were used. PbS thin film prosperous material for the infrared detector devices because it gives very good signal corresponds to incident photons by changing the detector element temperature [6-7], PbS thin films have also been employed for various application such as photo-resistance, diode lasers, temperature sensors, decorative and solar control coatings [8-10]. PbS thin film can be used in short-wavelength infrared application because it is sensitive material for the specific wavelength (1 to 2.5 μm) [11]. The properties of the PbS thin film can be easily controlled with the different film growth technique and different substrates. To tune the properties of the PbS thin film, many researchers have synthesized PbS thin film using various technique like electrodeposition, spray pyrolysis, photo accelerated chemical deposition, solid-vapor deposition, spin coating, microwave heating and thermal evaporation[12-18]. Thermal evaporation is a suitable technique to synthesize the PbS thin film because it gives high quality film with homogeneous surface morphology and large area deposition which is very useful for device fabrication.

In the present paper, PbS thin films were synthesized by thermal evaporation technique at room temperature. The effect of the substrate on the characteristic of the deposited films is studied in present work. From the structural and surface morphology analysis, it is found that the film deposited on the ITO coated glass is of good quality.

Experimental

Thin films of lead sulphide (PbS) have been synthesized by the thermal vacuum deposited technique at room temperature. Lead sulphide powder of AR grade (sigma Aldrich) was used to evaporate in deep-mouthed molybdenum boat. Highly cleaned glass and ITO coated glass substrates were used as substrate for the film deposition. Prior to a deposition, the glass and ITO coated glass substrates were cleaned in aquaregia, acetone, washed in distilled water and isopropyl alcohol (IPA). After loading the substrate into the deposition chamber they were thermally cleaned by keeping them at an elevated temperature 200ºC for few minutes. The deposition is carried out in a vacuum of the order of 10^{-5} torr with constant current for homogeneous film deposition.
PbS thin films have been characterized by different characterization technique such as X-Ray diffraction, Scanning electron microscopy, Atomic force microscopy, EDX analysis. Structural analysis has been estimated by X-ray diffractometer (Bruker D8-Advance model) with 2θ ranging from 10° to 90° with step size 0.02° and step time 0.5 second. Surface morphology of the film has been confirmed by Scanning electron microscope (ZIESS microscope with 5 kV energy) and Atomic force microscope.

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Results and Discussion

X-ray measurements

The XRD pattern of the PbS thin film on different substrate is shown in Figure 1. It shows different diffraction peaks at 2θ values of 26.28°, 30.39°, 43.47° and 51.49° which were assigned to the Monoclinic and cubic phase produced by (111), (200), (220) and (311) reflection planes respectively of PbS thin film. The dominant and sharp peak at 30.39°indicates that PbS nanocrystals are highly polycrystalline in monoclinic phase. The ITO coated glass provides a better crystalline surface for deposition of PbS films then glass, this is reflected and well define and sharp peak in XRD of PbS films deposited on ITO coated glass while the crystallinity of films deposited glass is not so good. The calculation of particle size of PbS thin films has been calculated using Debye-Scherrer formula using (200) plane from the XRD spectra [19].

$$D = \frac{0.9\lambda}{\beta cos\theta} \quad (1)$$

In expression (1), λ, β, and θ are X-ray wavelength (CuK_α= 1.54Å), full width at half maximum (FWHM) and the Bragg diffraction angle respectively. The calculated size is found to be ~ 22 nm for glass and ~ 27 nm for ITO.The higher crystallite size of the film indicates the higher crystallinity of the film.

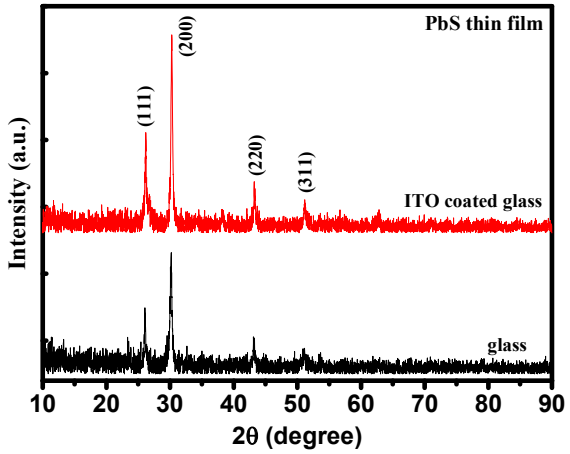
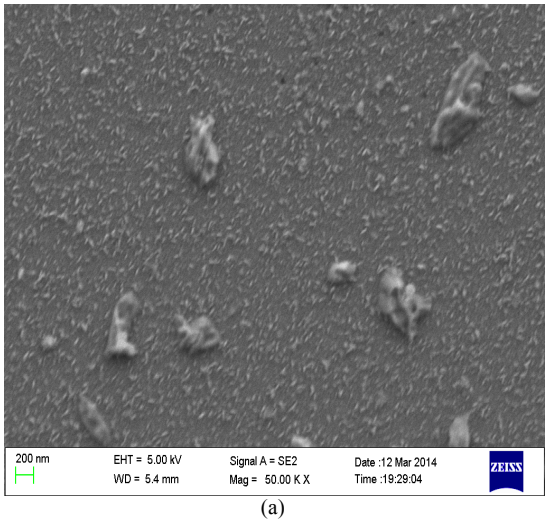


Figure 1: XRD spectra of PbS thin films on glass and ITO coated glass substrate.

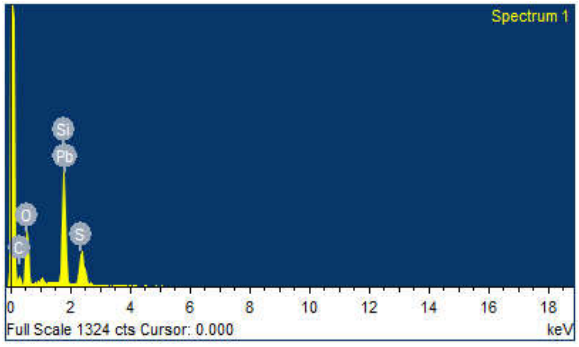
Scanning electron microscopy

The SEM micrograph of polycrystalline PbS thin films at 200nm magnification deposited on both the substrates are shown in Fig. 2(a,b). PbS thin films have a uniform surface morphology with more adhesion over the ITO coated glass substrate rather than the glass substrate. The films deposited on ITO coated glass have fine grains and have good quality in comparison to the glass substrate. The SEM images show that the better surface is achieved on ITO coated glass comparison to the plane glass substrate.

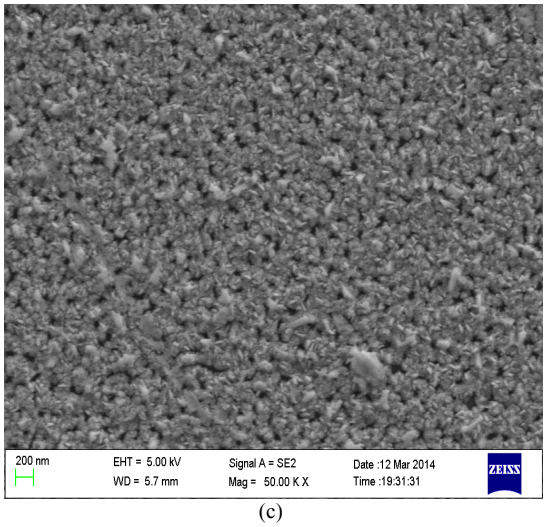
The EDAX Fig. 2(c,d) spectra revealed that the Pb:S ratio varied randomly. This may be due to the surface roughness effect as well as the presence of some intrinsic defects within the films (pores, etc.), which have some effects during the chemical analysis: the incident electron beam interact only with a particular portion of the film (spot analysis), thereby will not give the overall and the average chemical composition of the entire thin film. The EDAX ratio shows that films deposited on ITO glass substrate have good stoichiometry in comparison to the plane glass substrate.



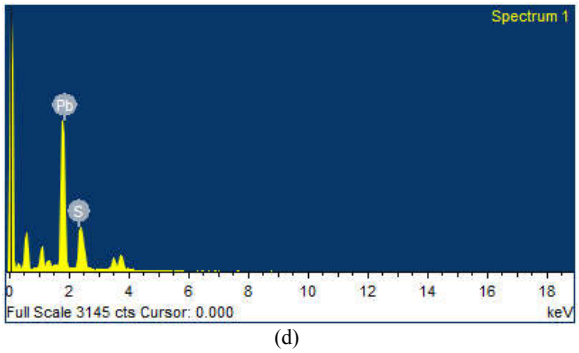
(a)



(b)



(c)

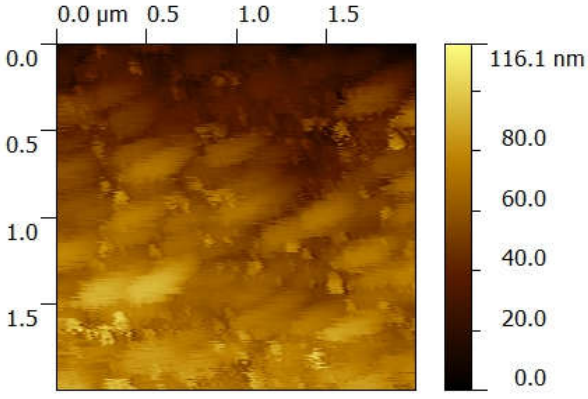


(d)

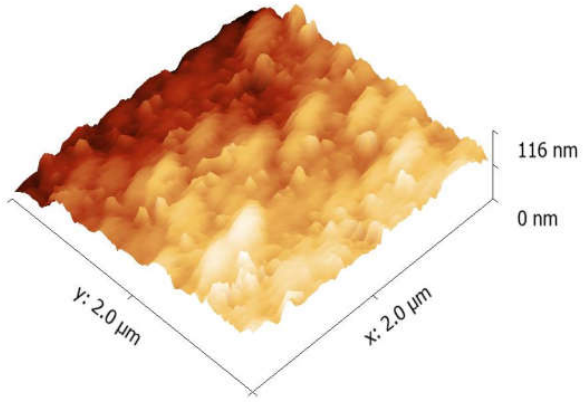
Figure 2: SEM Micrograph with EDX analysis of PbS Thin films Deposited on (a,b) Glass and (c,d) ITO Glass Substrate.

Atomic force microscopy

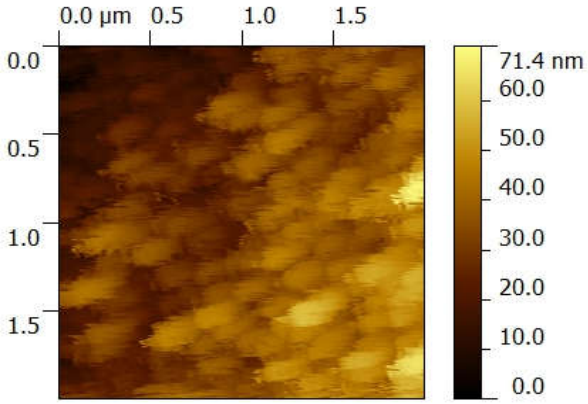
Atomic force microscopy (AFM) micrographs of the vacuum evaporated PbS thin films which were deposited on glass and ITO coated glass substrate are shown in figure 4 (a, b c and d). All the AFM images were taken for an area of 2 x 2 μm orders show that the particles are closely packed. The AFM images of the PbS thin film revealed that the grains are more spherical in shape and are homogeneously distributed over the whole surface in comparison to the PbS film deposited on ITO coated glass substrate. The average roughness of PbS films deposited ITO coated glass and ordinary glass comes out 9.93 nm and 18.5 nm respectively. PbS film on ITO glass show cluster of particles with highly dense structure with high packing density and have advanced surface and typical columnar structure with highly dense grains. These results shows that the better crystalline and surface morphology of PbS thin films is achieved on ITO coated glass substrate which provides the better crystalline surface to deposited crystalline films.



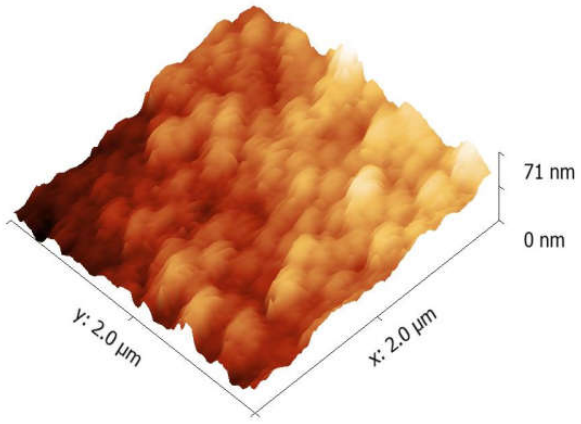
(a)



(b)



(c)



(d)

Figure 3: AFM micrograph of the PbS thin film (a,b) glass substrate; (c,d) ITO coated glass substrate.

Conclusions

PbS thin films have been synthesized by thermal evaporation technique at room temperature. EDX analysis conforms the formation of PbS thin film. The crystallinity of the film is much better on ITO coated glass in comparison of plane glass substrate. Surface morphology of the films has been investigated by scanning electron microscopy and atomic force microscopy. The roughness of the film is lower for the ITO coated glass substrate while in high for plane glass substrate. From the structural analysis, we can conclude that ITO coated glass substrate is better for the film growth because the film has a good crystallinity and more adhesion on the ITO coated glass substrate by thermal evaporation. EDAX measurements of the film confirmed the present stoichiometric compound in the film.

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