Article : Preparation and properties of chemically deposited PbS films from acidic and alkaline medium

Author : S. S. Karande , Sangameshwar College, Solapur

Abstract:

The polycrystalline PbS thin films are prepared by chemical bath deposition technique in acidic and alkaline medium. Phase formation is investigated using X-ray diffraction technique. The electrical resistivity is calculated in the order of 10^2 ohm-cm in acidic medium and in alkaline medium is of the order of 10^1 ohm-cm. The activation energy in acidic medium is 0.422 eV and in alkaline medium is 0.258 eV. Photoconductivity, thermoelectric power, optical properties, IR spectra in acidic as well as in alkaline medium are studied.

Keywords: Polycrystalline films, chemical bath deposition technique, resistivity, photoconductivity, thermoelectric power.

Introduction:

M. J. Chochlingam et al [1], deposited a layer of lead sulphide chemically on a ground glass substrate by Kicinsk's [2] method and then heat treated it around 550^{o}c.The layer obtained was P type. Over this layer was deposited n type silver sulphide chemically by a similar method [3] to a thickness of 1.5 μm, dried and given gold contacts with an inter electrode spacing of 4 mm and negative photoconductivity was observed. M. R. Rajebhosale et al [4] have fabricated the heterojunction between CdS and PbS films by chemical bath deposition technique. Heterojunctions involving PbS are highly interesting for their use as near and medium IR detectors. The fabrication of one such combination of CdS- PbS ,in which PbS films were grown epitaxically on CdS single crystal, has been reported by Watanabe and Mita [5-6]. The result of photovoltaic effect has been reported O. A. Gudaev et al [7] shows charge transfer in polycrystalline Pbs films.The peculiarities [8-9] of charge transfer mechanism in polycrystalline Pbs films has showed. It was realized by the help of the holes on the percolation level situated in the region of tail of the density of states. B. H. Bhuse and T.S. Moss [10-11] used PbS with its direct band gap of 0.4eV and absorption coefficient continuously increasing from infrared (150 cm^{-1} at 3μm) through the visible region in infrared detectors since the mid of 1940's. O. Hauser et al [12] , this application of PbS films was known since 1910. R.H.Bhuse et al [10,13] involved the typical process of immersion of glass substrate in alkaline lead- thiouria solution which yielded PbS films of 3 to 5 μm thickness in about 24 hr.B.K.Gupta [14] and O.P.Agnihotri et al [15] have investigated photothermal conversion applications, either independently on metallic substrates or in multilayer stacks of PbS-CdS-PbS[16]. The polycrystalline PbS thin films are prepared by chemical bath deposition in acidic and alkaline medium.

EXPERIMENTAL:

The chemical bath deposition method involves a slow film deposition from a solution which contains lead in a complex form and an organic sulphide containing reducing agent which reacts to give lead sulphide in the thin film form. This method can be formed in acidic medium in which lead acetate and sodium thisulphate are used. The (0.05M) solution of lead acetate [Pb(CH_3 $COO)_2$] (AR grade) and (0.1M) solution of sodium thiosulphate [$Na_2S_2O_3$ $5H_2O$] (AR grade, BDH) are prepared in acidic medium. For each deposition, 40 c. c. of 0.05 M solution of lead acetate and 40 c. c. of 0.1 M solution of sodium thiosulphate are added in the 100 c.c. glass beaker and then the substrates are introduced in the beaker and reaction vessel was heated to 80^{o}c for 1 hr. The PH of the bath is 5-6; films formed were washed several times with distilled water, dried and preserved in the dark dessicator.

In alkaline medium (0.05M) solution of lead acetate [Pb(CH_3 $COO)_2$] (AR grade); (0.05M) solution of thiourea and (0.1M) solution of sodium hydroxide (NaOH) are prepared. For each deposition, 40 c. c. of 0.05 M solution of lead acetate and 15 c. c. of 0.1 M solution of sodium hydroxide are added in the 100 c.c. glass beaker to form a complex compound. In this solution 40 c.c. of (0.05M) solution of thiourea was added and reaction is done at roon temperature for 10 hr. The PH of the bath is greater than seven. Films formed were washed several times with distilled water, dried and preserved in the dark dessicator.

RESULTS AND DISCUSSION:

The thickness of film is measured by weight difference method which is 0.13µm in acidic medium and in alkaline medium is 0.23µm. The x-ray diffraction pattern of the PbS thin film in acidic medium and in alkaline medium shown in Fig. 1. The well-defined (200) peak is observed in XRD pattern. The film are polycrystalline.

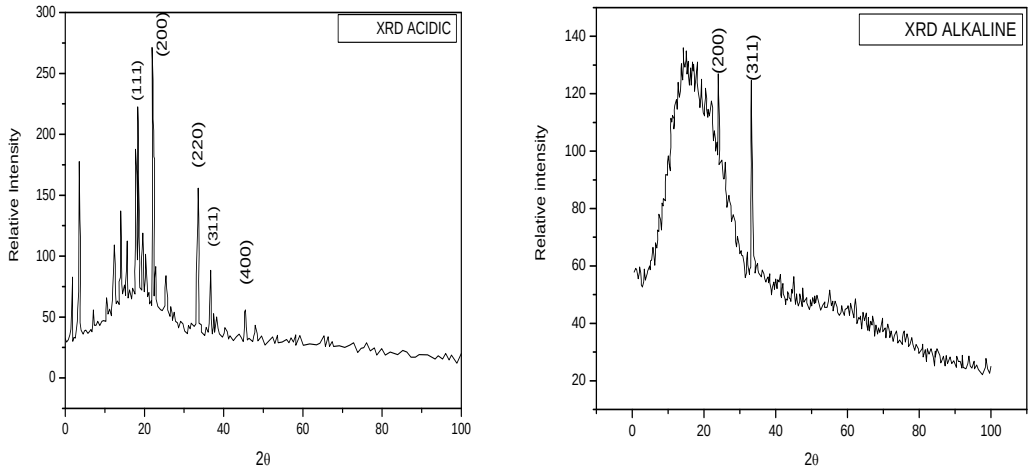

Fig1. XRD pattern of PbS thin film in acidic and in alkaline medium

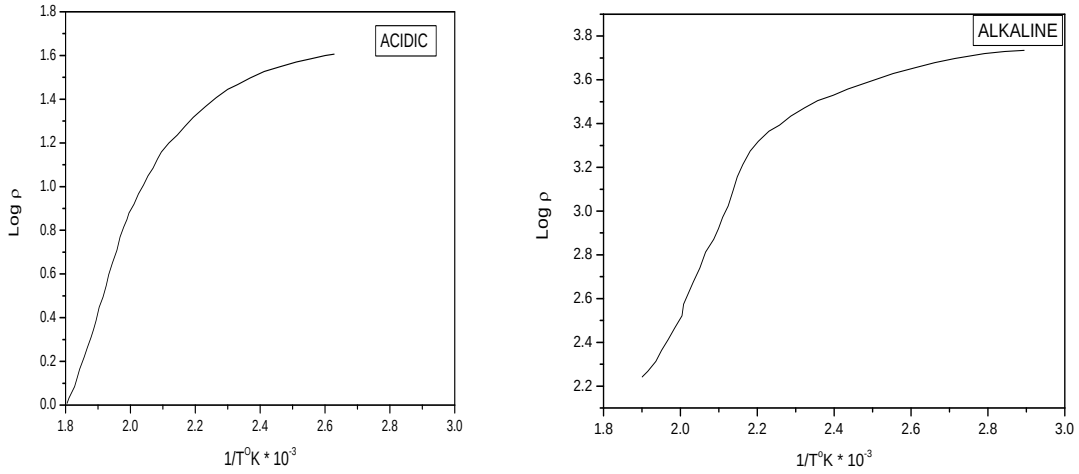

Fig.2. Electrical resistivity of PbS thin film in acidic and alkaline medium

The variation of electrical resistivity (ρ) with temperature is obtained by plotting a graph of Log ρ Vs 1/T * 10^{-3} in acidic and in alkaline medium shown in Fig.2. The nature of plots indicates semiconducting behaviour of the film and in acidic medium, for 80oc bath temperature resistivity of the film is of the order of 10^2 ohm-cm and in alkaline medium, for room temperature resistivity of the film is of the order of 10^1 ohm-cm. The activation energy of this film is 0.422 eV in in acidic medium and in alkaline medium is 0.258 eV.

The PbS samples are photoconductive. The photocurrents of the samples are at an intensity of 200 watt from a tungsten lamp. The plot of photocurrent in acidic and alkaline medium is shown in Fig.3

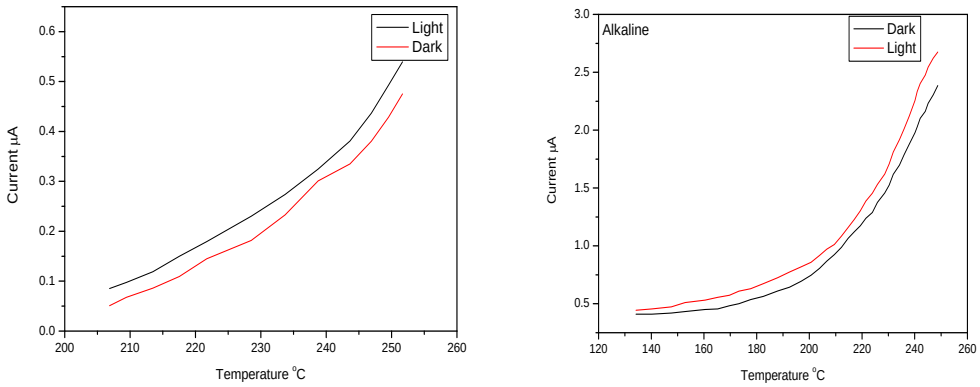

Fig.3 Photoconductivity of PbS film in light and dark from acidic and alkaline medium

From thermoelectric power the lead sulphide material is found to be n type. The plot of thermoemf voltage Vs temperature (^{o}c) in acidic and alkaline medium is shown in Fig.4.

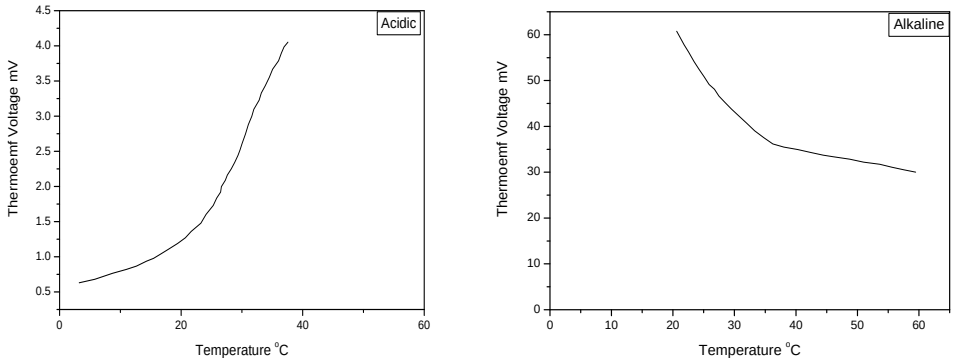

Fig. 4 Thrmoemf voltage Vs temperature of PbS thin film in acidic and alkaline medium

From the TEP graph we have calculated carrier concentration by using the formula,

Log n = 3/2 log T – 0.005 TEP + 15.719

The carrier concentration is the function of substrate temperature is plotted I Fig.5. The carrier concentration decreases with increase in substrate temperature in acidic medium.

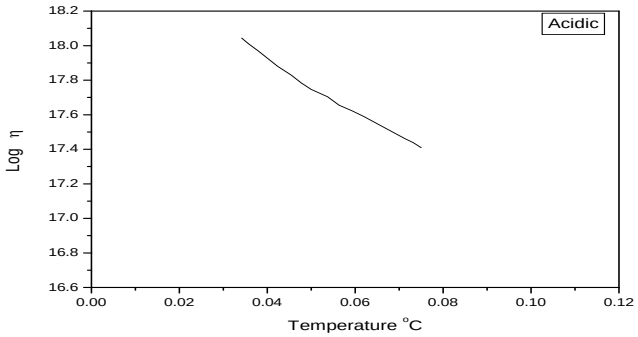

Fig.5. Carrier concentration of PbS thin films in acidic medium

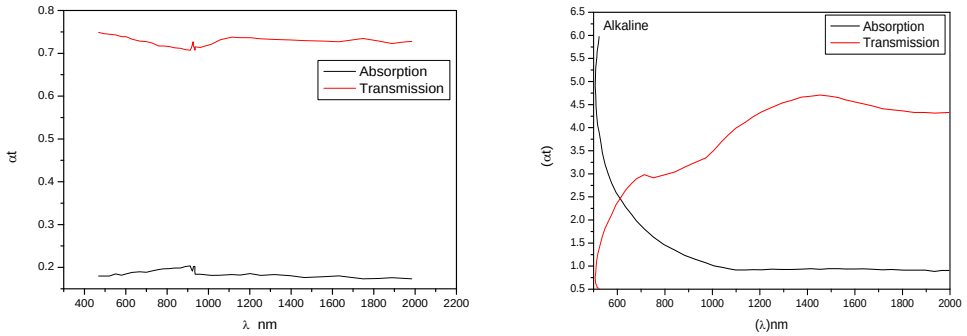

Fig.6 optical absorption and transmission of the PbS film in acidic and alkaline medium

Fog.6. shows the optical absorption and transmission of the PbS film studied in the wavelength range 400-2000nm in acidic and alkaline medium. Nearly 100% transmittance is

observed in the studied wavelength range in acidic medium. In alkaline medium the absorption coefficient is $10^{-4}cm^{-1}$. The plot of $(\alpha hv)^2$ Vs hv shown in Fig.7. On extrapolating the linear portion to hv axis, a band gap of 1.88 eV is obtained.

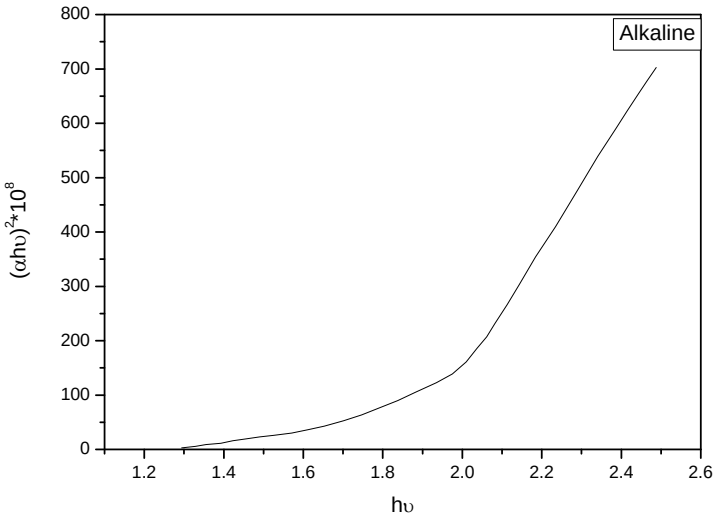

Fig.7 $(\alpha h\nu)^2$ Vs $h\nu$ of PbS thin film in alkaline medium

The IR spectra of PbS power collected from the acidic and alkaline bath which is acid free, studied in the 200-4000 cm^{-1} shown in fig. 8

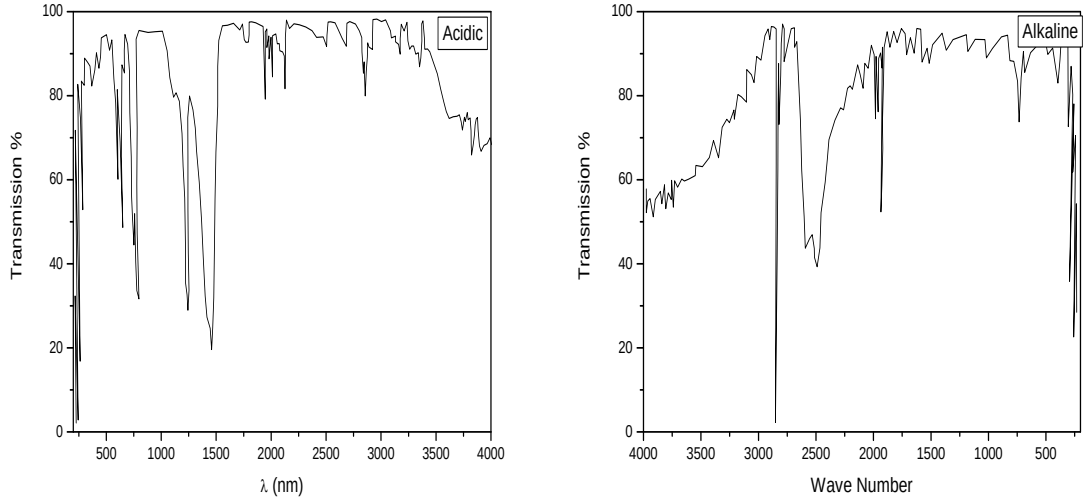

Fig .8. IR spectra in acidic and in alkaline medium

CONCLUSION:

From the x-ray diffraction pattern the PbS films from acidic and alkaline medium are polycrystalline. The electrical resistivity of PbS film in acidic medium is in the order of 10^2 ohm-cm, in alkaline medium in the order of 10^1 ohm-cm and of the semiconducting behaviour. The thermoelectric power in acidic and alkaline medium shows lead sulphide is n type. The PbS films also shows the photo conducting property which is more photoconductive in alkaline medium than acidic medium. In alkaline medium, band gap of 1.88 eV is obtained. Comparison with standard IR spectrum confirms formation of PbS. The films from alkaline medium are superior to acidic medium.

REFERENCES:

[1]. M.J. Chocklimgam, K.N. Rao, N. Rangrajan, C. V. Suryanarayan, Phys. Stat. Sol.,(a)2 (1970)K17
[2]. F.Kicinski, Chem. And ind., (1948) 54
[3]. M.J. Chocklimgam, K.N. Rao, N. Rangrajan, C. V. Suryanarayan, Indian J, Pure and applied physics,
[4]. M.R. Rajebhosale and S.H. Pawar, Journal shivaji University (Science); 18(1978)45
[5]. Watambe S. and Mita Y.; J. Electrochemical soc., 116(1969)989
[6]. Watambe S. and Mita Y.; Solid state electronics , 15(1972) 5
[7]. O.A. Gudaev, V. K. Molinovsky and E.E.Paul , Thin solid films; 198(1991)35
[8]. O.A. Gudaev, V. K. Molinovsky, E.E.Paul and V.A. Treshikhin; Solid state Comun., 72(8) (1989)791
[9]. O.A. Gudaev, V. K. Molinovsky, E.E.Paul and V.A. Treshikhin; Solid state Comun., 74(10)(1990)1169
[10]. R.H.Bube, Photoconductivity of solids, Wiley New York, (1960) 234
[11]. T. S. Moss, Proc. IRE, 43(1955)1869
[12]. O. Hauser, E. Biesalski, R. A. Zingaro and D. O. Skolvin, Journal of Electrochem. Soc., 111(1964)42
[13]. L.Genzel and H. Muser, Z. Phys., 134(1953)419
[14]. B.K. Gupta, R. Thangaraj and O. P. Agnihotri, Solar energy Matter, 1(1979) 417
[15]. O. P. Agnihotri and B.K. Gupta, Solar Selective Surfaces, Wiley, New York(1981) P. 130.
[16]. G. B. Reddy, V. Dutta, D. K. Pandya and K. L. Chopra, Solar energy Matter, 5(1981)187