# Chemosynthesis of $MoBi_2S_5$ Nanocrystalline Thin Film by Simple Colloidal Route

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**Abstract:** Thin layers of molybdenum bismuth sulphide ($MoBi_2S_5$) have been prepared for the first time by Arrested Precipitation Technique (APT) on glass substrates from aqueous alkaline bath using ammonium molybdate, bismuth nitrate & thioacetamide as a precursor and triethanolamine (TEA) as a complexing agent. The preparative parameters were optimized initially to get good quality $MoBi_2S_5$ thin films. The $MoBi_2S_5$ thin films have been characterized using X-Ray Diffraction (XRD), Energy Dispersive X-ray Spectroscopy (EDS), Scanning Electron Microscopy (SEM) techniques to investigate structural, compositional and morphological properties of $MoBi_2S_5$ thin films prepared at low temperature shows nanocrystalline nature, good agreement in theoretical stoichiometry and experimentally observed one. The micrograph shows that compact with large number of grains. The films exhibited band gap energy 1.20 eV & electrical transport study of the films suggests its n-type semiconductor nature, which makes these films favorable for solar cell devices.
**Keywords:** APT, Thin films, XRD, EDAX, SEM.

## INTRODUCTION

Semiconducting thin film materials, which are based on sulfides, selenides and tellurides, have attracted much attention because of their potential application in solid state devices. Among these, metal-metal sulfides have been extensively studied due to their various applications such as solar cells, rechargeable batteries, optoelectronic device, thermoelectronic devices [1-3]. These applications arise from the optical and electrical properties of that material. The properties of binary and ternary thin films prepared by using various techniques but Arrested Precipitation Technique (APT) has many advantages such as, simplicity, cost effective, minimum material wastage economical way of large area deposition with these advantages in mind, an attempt has been made to deposit $MoBi_2S_5$ thin films with complexing agent Triethanolamine (TEA) at low temperature. The complexing agent is most important component for the slowly release of metallic ions on dissociation and avoid spontaneous precipitation.

In the present investigation, we describe the synthesis of nanostructured $MoBi_2S_5$ thin films and the study of its structural, optical and electrical properties.

## EXPERIMENTAL

### 1.1 Materials and Preparation of $MoBi_2S_5$ Thin Film

$MoBi_2S_5$ thin films were prepared by simple APT method. The deposition bath was prepared by addition of 0.05M Bi-TEA and Mo-TEA complex solution. pH of the bath controlled by 20% ammonium acetate. Following this, 0.1M thioacetamide was added to the above solution. The temperature of the bath was maintained at 321K. After the deposition period of two hr, substrates were removed from the bath and washed with distilled water and dried at room temperature.

### 1.2 Characterizations

XRD analysis was carried out using Brucker AXS Model (D8 Advance) X-ray diffractometer in $10^0$ to $80^0$ range with CuK$\alpha$ ($\lambda$=1.54 $A^0$). The surface morphology was investigated with the help of JEOL-6360 scanning electron microscopy with energy dispersive x-ray analyzer facility. UV-vis spectrophotometer (Shimadzu UV-1800 model) was used to determine band gap energy of $MoBi_2S_5$ thin films in the wavelength range 400-1100 nm.

## RESULTS AND DISCUSSION

XRD pattern of $MoBi_2S_5$ thin film onto glass substrate is shown in fig.1. The diffractogram of thin films seems to exhibit nanocrystalline or amorphous nature because of well defined peaks are absent. Therefore, no definite conclusion about the crystalline structure of the films could be drawn from XRD studies. s

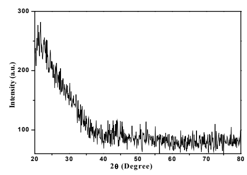


FIGURE 1. XRD pattern of of the $MoBi_2S_5$ thin film.

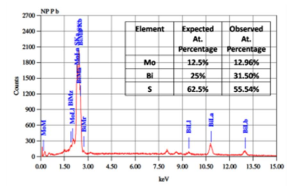


FIGURE 2. EDAX spectrum of $MoBi_2S_5$ thin film.

Fig. 2 shows, the elemental composition of films are nearer to stiochiometric in nature. Inset table of fig. 1 indicate that sulphur percentage is slightly less as compared to stoichiometry of $MoBi_2S_5$ because antisite defect of bismuth [4]. Fig. 3 shows SEM image of $MoBi_2S_5$ thin film at 10,000 clearly demonstrate that the film appear to be made spherical grains having 200 nm grain size.

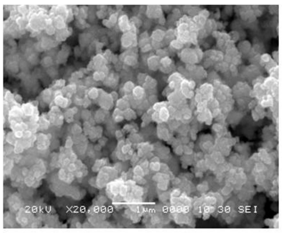

FIGURE 3. SEM image of $MoBi_2S_5$ thin film

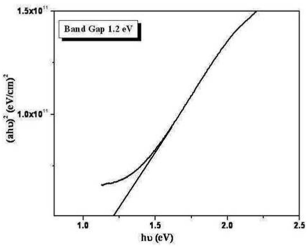


FIGURE 4. Optical band gap energy for $MoBi_2S_5$ thin film

Analysis of optical absorption spectra of thin films provides essential information about type of transition was determined using the relation between absorption coefficient α and the energy hν of the incident photon is given by-

$$\alpha = \frac{A\,(h\nu - Eg)^{1/2}}{h\nu} \qquad \text{----------- (1)}$$

where, hν is the photon energy and A, n are constants. The exponent 'n' depends upon the type of transition and has values of ½ and 2 for direct and indirect transitions, respectively. The variation of $(\alpha h\nu)^2$ with photon energy hν for $MoBi_2S_5$ films as shown in fig.4. The value of the energy band gap (Eg) is calculated by taking the intercept on x-axis. The absorption coefficient of the film is the order of $10^4$ $cm^{-1}$ indicating the direct band gap nature of the semiconductor [5]. The band gap value found to be 1.20 eV for $MoBi_2S_5$ thin film. These band gap value lie in the optimum range for solar energy absorption and point to possible photoconductivity response with visible light irradiation.

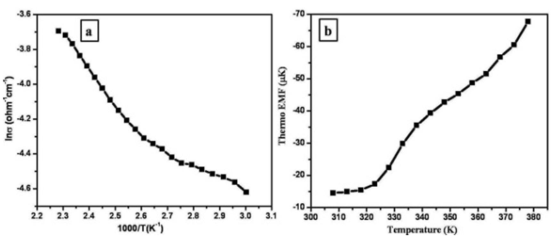


FIGURE 5. Temperature dependence a) Electrical and b) TEP properties of $MoBi_2S_5$ thin film

The dc conductivity measurement gives valuable information about the conduction mechanism of semiconductors fig. 5 (a) shows electrical conductivity of $MoBi_2S_5$ thin films varies in the temperature range 333-443 K. The conductivity increases with increase in temperature, indicating that semiconducting nature of $MoBi_2S_5$ thin films. Activation energy was calculated from slope of the graphs of ln σ versus 1/T. Charge carriers require lower energy of activation in case of materials having higher conductivity. Activation energy of $MoBi_2S_5$ thin film is 0.015 eV.

The type of conduction was determined using the hot-probe method. Fig. 5 shows the variation of the thermoelectric power with temperature in the range 300-400K. Thermoelectric power is negative throughout the temperature range, suggesting that the samples are n-type.

**Conclusions**

$MoBi_2S_5$ thin films were deposited successfully by arrested precipitation technique. The XRD analysis confirms the formation of nanocrystalline nature of $MoBi_2S_5$ thin film. The SEM image clearly show $MoBi_2S_5$ thin film composed of spherical grains and the substrate surface was covered completely at this experimental condition. These films exhibited n-type semiconducting behavior with band gap energy which was 1.20 eV.

## ACKNOWLEDGEMENTS

The author (NBP) is indebted to University Grants Commission, New Delhi for financial support.

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