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Effect of post deposition annealing on the optical absorption and photoconductivity studies of pure ZnTe and pure MgPc thin films formed by vacuum deposition

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ABSTRACT

Thin films of ZnTe and MgPc were prepared by vacuum deposition technique. The films were deposited at room temperature onto glass substrates with the vacuum pressure at 10^{-5} Torr and with substrate thickness about 200nm to 300 nm. The films were annealed at 50^0C, 100^0C, 150°C and 200^0C. The effect of annealing on the structural, optical, electrical properties and surface morphology were studied. The samples exhibited broad absorption spectra from visible to near infrared region (300nm to 1200nm). The photoconductivity was found to increase with annealing temperature up to 150^0C. The temperature-dependent conductivity of the observed samples was studied and the corresponding activation energies of the samples were determined. The band gaps of the films were found to be 2.23eV for ZnTe and 2.61eV for MgPc.

Key words: Photoconductivity, Thin films, Nano materials, Sensors, Solar energy materials, Physical vapour deposition.

INTRODUCTION

Zinc Telluride (ZnTe) is a II-VI compound semiconductor having a direct band gap of 2.26 eV at room temperature [1, 2]. Specifically, for bright light emitting diodes (LED), ZnTe is a promising candidate since the emission wavelength corresponds to the maximum sensitivity of the human eye [3]. Polycrystalline ZnTe films were also used in tandom solar cell structures [4]. Applications to photovoltaics proved that ZnTe is useful for the production of high efficiency solar cells [5, 6].

Magnesium Phthalocyanine (MgPc) is a P-type semiconductor with a band gap of 2.6 eV [7]. It exhibits high chemical and thermal stability. Metal Phthalocyanines are used in many fields of industry as semiconducting devices, solar cells, liquid crystals, photovoltaic cell, gas sensors and optical data storage [8].

Most phthalocyanine compounds are insoluble in common organic solvents and so it is difficult to prepare them by solution casting techniques. Hence, very often, thin films of phthalocyanines (MgPc) are prepared by vacuum sublimation technique. This method has the advantage of producing high purity films [9]. In the present work, a photoconductor has been attempted using ZnTe and MgPc. In this paper, optical absorption,

photoconductivity, thermal activation energy, optical band gap and their dependence on annealing for pure ZnTe and MgPc thin films have been investigated.

MATERIALS AND METHODS

ZnTe and MgPc (Aldrich) were separately sublimed one after another in vacuum (Hind Hivac 12 A4-D) at a pressure of 10^{-5} Torr. Glass substrates used were first cleaned thoroughly with liquid detergent; then washed with distilled water; and agitated ultrasonically in acetone. Finally the substrates were dried in hot air. The coated films of thickness 200nm were air annealed at 150°C to attain crystallinity. Thickness measurements were recorded using Surface Profilometer (Dektak 6M, M/S. Veeco (USA)). UV-VIS absorption spectra of the films were recorded using UV-VIS spectrophotometer (Schimuzu UV-2450). Photoconductivity and temperature dependent conductivity were measured using Kiethley picoammeter (model 6485).

RESULTS AND DISCUSSION

For ZnTe and MgPc thin films deposited onto glass substrates, it could be experimentally established that the samples obtained were thermally and chemically stable and they exhibited reproducible optical and photoconductive properties, provided they were subjected to post deposition annealing. These heat treatments consisted of several successive heating-cooling cycles within a temperature range of 300-500 K [10].

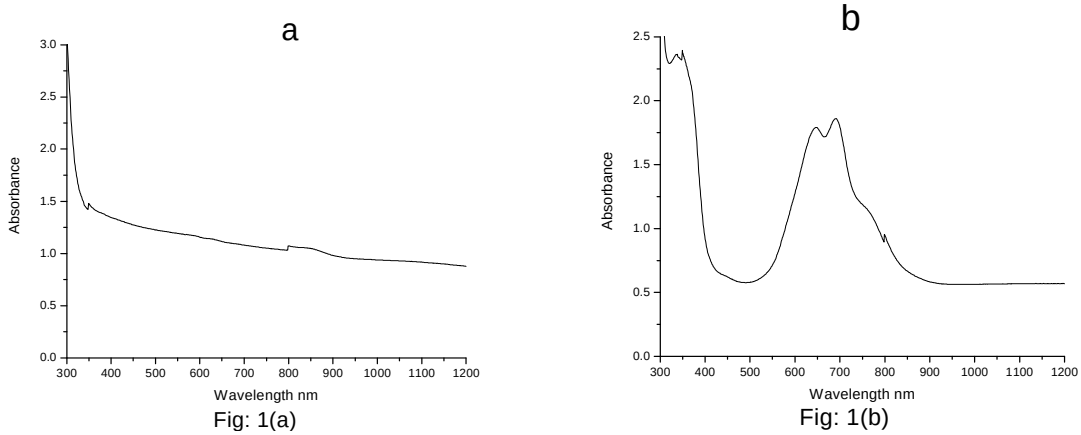

Fig: 1(a) Fig: 1(b)

Fig:1(a) and 1(b) Absorption spectra of pure ZnTe and pure MgPc air annealed at 150°C for 1 hr.

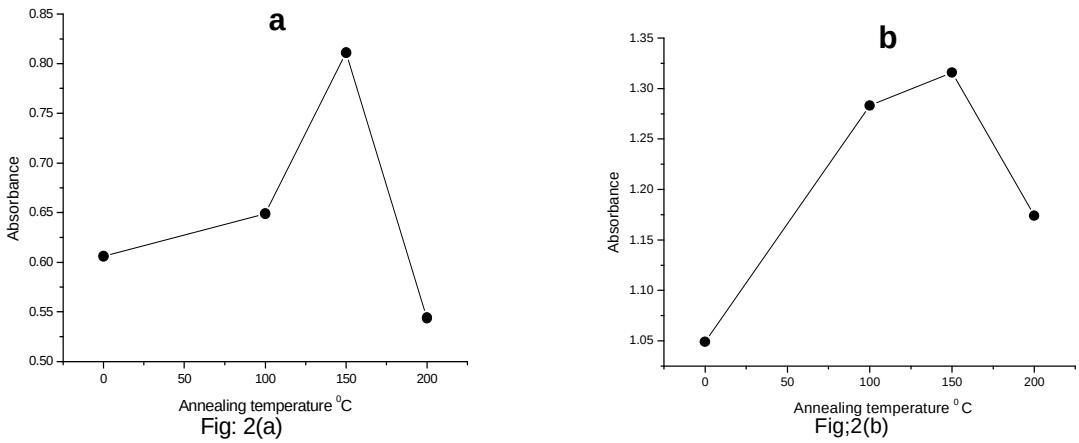

Fig: 2(a) Fig;2(b)

Fig:2(a) and 2(b) Annealing Temperature vs Absorbance for MgPc and ZnTe Thin Films.

Fig:1 shows the absorption spectra of pure ZnTe and pure MgPc thin films air annealed at 150°C. It is observed that both the thin films have a very wide absorption range over the whole visible region with significant peaks at 650 nm and 700 nm for MgPc. The air annealed samples have better absorption when compared with as deposited thin films.

It is observed that for both the films, absorption increases with increase in annealing temperature up to 150^0C. The film loses its crystallinity above 150^0C. Decomposition of the film takes place on further increase in temperature.

Fig.3 (a) and Fig.3 (b) show the field dependent dark and photocurrent plots for pure ZnTe and pure MgPc thin films. Linear increase of dark and photocurrent was observed for the samples.

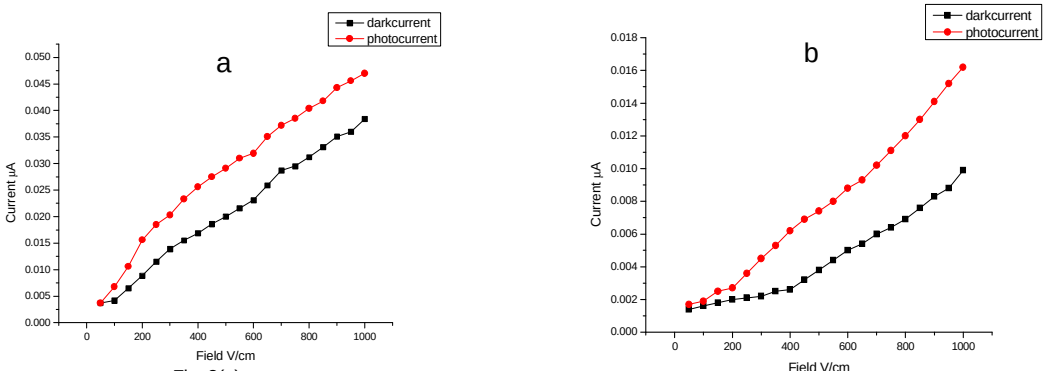

Fig: 3(a) Fig:3(b)

Fig: 3(a) and 3(b). Field dependent Dark and photoconductivity of ZnTe and MgPc film.

There was a significant rise in photocurrent over dark current, when the sample was illuminated with visible light (100 watts halogen lamp). It is observed that the photoconductivity increases with increase in annealing temperature up to 150 ^{0}C for 1 hour. The enhancement of photocurrent in the films is due to its capability to absorb over all regions of visible light. The variation of dark current with temperature for the pure samples was studied. The temperature was varied in the range 30°C-150°C for constant applied field of 500V/cm. The plots indicate the exponential increase of temperature dependent current confirming the semiconducting nature of the samples. From the lnI versus 1/KT plot, the activation energies of ZnTe and MgPc films were calculated (2.71eV and 2.3eV).

The XRD pattern showed that MgPc crystallizes in monoclinic system with cell parameters 14.368 Å, 4.898Å, $\beta = 119.86^0$ with unit cell volume of 1153Å ^{3}. The average volume occupied by a molecule is 288Å^3 , while ZnTe thin films showed polycrystalline cubic structure with a preferential (111) orientation. The lattice constant calculated was found to be 6.089 to 6.112 Å .

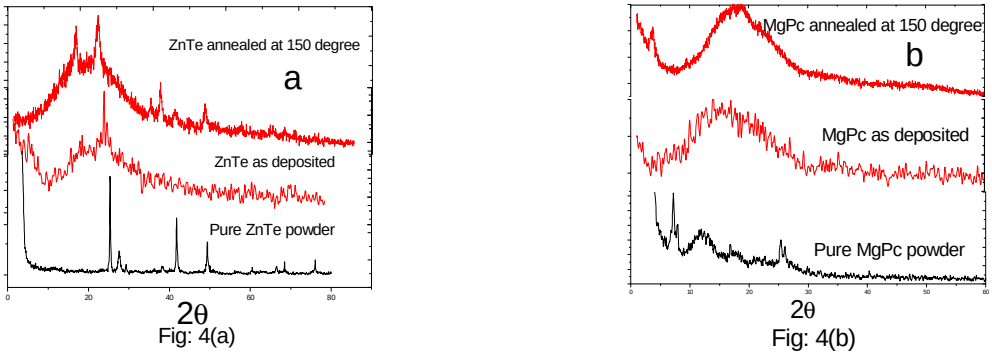

Fig: 4(a) Fig: 4(b)

Fig:4 (a) and 4(b) Powder XRD, as deposited and annealed ZnTe and MgPc Thin film.

The intensity of the peak for as deposited films was weak which reveals amorphous nature. The intensity of the peak found to increase with increasing annealing temperature up to 150^0C. Fig: 5(a) and 5(b) show the band gap of ZnTe and MgPc thin films. From the absorption spectra, the band gaps of the films were found to be 2.23eV and 2.61eV.

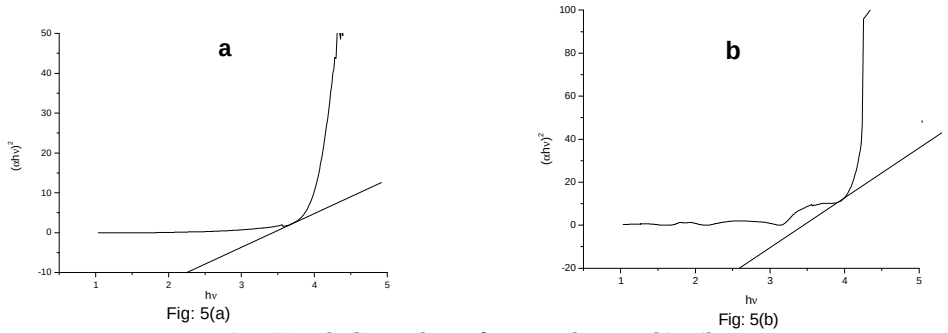

Fig: 5(a) Fig: 5(b)

Fig: 5(a) and 5(b) Band gap of ZnTe and MgPc Thin Films.

Fig: 6(a) and 6(b) and show the surface morphology of the samples. By analyzing the pictures, the film is uniformly distributed for both Pure ZnTe and MgPc thin films. Surface of the films are very smooth and there is no pinhole observed. The grain boundaries are also not observed, which suggest that the films would act as a good photoconductor.

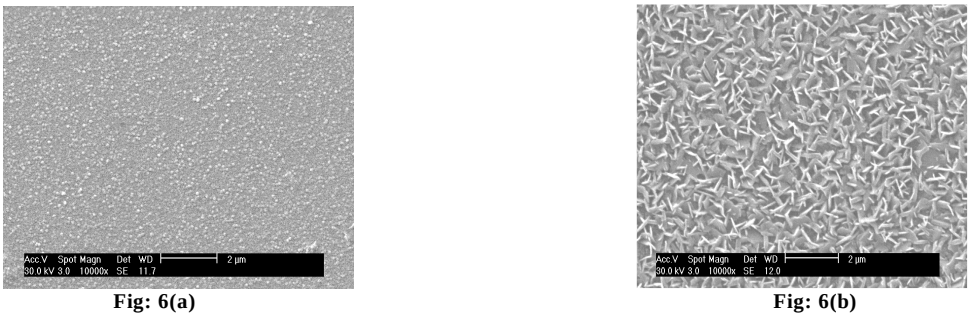

Fig: 6(a) **Fig: 6(b)**

Fig: 6(a) and 6(b) shows SEM Micrograph of ZnTe and MgPc Thin Films.

Table:1 Annealing Temperature Vs Activation Energy for ZnTe and MgPc Thin Films

Annealing Temperature	Activation Energy ZnTe	Activation Energy MgPc
50	2.64eV	2.51eV
100	2.37eV	2.18eV
150	1.92eV	1.86eV
200	2.21eV	2.11eV

Table 1 shows the annealing temperature Vs activation energy for ZnTe and MgPc thin films.It is found that as the annealing temperature increases, activation energy decreases up to 150^0C. The activation energy is found to increase in further increase in temperature.

CONCLUSION

Pure ZnTe and MgPc thin films were coated by physical vapour deposition method. The thin films absorbed almost the entire range of visible light and its absorption and photoconductivity increased with the increasing annealing temperature up to 150^0C. The XRD pattern confirms the crystalline phase of the films with annealing temperature. The temperature dependent conductivity of the thin films indicated exponential behavior of temperature dependent current, confirming the semi-conducting nature of the samples. From the graph of lnI vs 1/KT plots, the activation energy was found out and it is found to decrease with increasing annealing temperature. The thickness of the films

was found to be 200nm. Annealing to optimum temperature results in smooth surface of the films devoid of pin holes and grain boundaries. The band gaps of the films was 2.23eV for ZnTe and 2.61eV for MgPc.

Due to the smoothness of the films, increase in photoconductivity with increase in annealing temperature as well as decrease in activation energy and finally as close proximity of band gaps, both the materials could be combined to evolve an effective solar-cell.

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