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Transmittance and Reflectance properties of Cu-Doped and Undoped Lead Iodide Thin Films Deposited by Vacuum Evaporation Technique

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ABSTRACT

Cu-doped and undoped Lead Iodide crystals have been grown by gel technique. Then, thin films of Cu-doped and udoped Lead Iodide crystals have been deposited, of various thicknesses, successively by thermal evaporation technique. These thin films were characterized by XRD, Transmittance and Reflectance. The lattice parameters of thin films of Cu-doped and undoped, were well matching with the ASTM data for Lead Iodide. The absorption coefficient, band gap energy and dielectric constants were determined at room temperature by normal incidence method. The transmittance measurements enable the evaluation of the value of band gap energy Eg.

Keywords: Gel technique, thin films, XRD, Transmittance and Reflectance.

INTRODUCTION

Due to potential applications in the area of radiation detectors, photo-optical devices and solar cell technology Lead Iodide has attracted the attention of many researchers [1-5]. Large theoretical and experimental investigations have been carried out into its optical, electrical and physical properties [6-9]. Lead Iodide, with a band gap of 2.55 eV, is a technically important class of materials in view of its band to band type of transition and high optical absorbance without any phonon assisted mechanism, which makes it very useful in several electronic and optoelectric device applications [10]. The band gap energy of Lead Iodide has been reported by several authors [11-12].

There are several methods to investigate the band gap of Lead Iodide, such as photoluminescence, electrical conductivity, and optical absorption, among others. Here we have used the optical transmittance method to investigate the band gap of thin films of synthesized Cu-doped and undoped Lead Iodide.

In our previous paper [10] it has been reported that, thin films of gel grown Lead Iodide can successfully synthesized by thermal evaporation method. In the present paper it has been decided to prepare the thin films of synthesized Cu-doped Lead Iodide crystal grown by gel technique. Optical properties have been studied and reported. This is somewhat novel idea to prepare the thin films of gel grown crystals, since such literatures are not available.

MATERIALS AND METHODS

Cu-doped and undoped Lead Iodide crystals were synthesized by gel technique. A.R.grade chemicals used throughout the research work. Acetic acid was taken in a beaker (7ml) them Sodium metasilicate was added slowly drop by drop in the acetic acid with constant stirring till the 4pH obtained. Then, in this mixture, Copper acetate and Lead acetate was added again with the constant stirring by magnetic stirrer. Then this mixture was poured slowly in the test tube of length 15cm and diameter 2.5cm. The mouth of the tube was covered by cotton to avoid from entering the dust in the test tube. After setting the gel, nearly 8 to 10 days are required; Potassium Iodide was added slowly over the set gel. The growth of the crystals can be seen with the naked eye. After completion of growth, these crystals were taken out with high precaution, washed with water and acetone and crushed in small size (150 mesh).

RESULTS AND DISCUSSION

X-ray diffraction (XRD): X-ray diffractometry is useful in analyzing crystal structure, evaluation of‘d’ values, cell parameters, system to which the sample under study belongs, grain size, etc. The x-ray diffractograms were performed by (Rigaku, Minifles Japan) with Cu Kα radiation of wave length 1.5418Å with angle of rotation of 20-90^0 at North Maharashtra University, Jalgaon and University of Pune, Pune. The recorded X-ray diffractogram of Cu-doped and undoped Lead Iodide thin films were already reported [12]. Hence the diffractogramms are not shown in this paper. The‘d’ values were computed from computer programming-computer programme for indexing of powder pattern and refinement of unit cell parameters (not given). ‘d’ values calculated agree well with reported ones [13].

Transmittance and Reflectance: The transmittance and reflectance curves for undoped and Cu-doped Lead Iodide thin films were shown in Fig.1 and Fig.2 respectively.

Film thickness 1000Å (undoped PbI_2): For this sample, transmittance increases from 55% at the wavelength 2500 nm slowly rises to 62% at the wavelength 2000nm, then slowly decreases as wavelength decreases to 7% at 300nm. In this curve there is noise over wavelength range 2050 to 2110nm and 700 to 875nm.

Film thickness 2000Å (undoped PbI_2): For this sample, transmittance from 50% at 2500nm to 56% to at the wavelength 2100nm, then slowly decreases to 3% at 300nm. In this curve there is noise over the wavelength 2050 to 2110nm and 700 to 875nm.

Film thickness 3000Å (undoped PbI_2): For this sample, transmittance increases from 50% at the wavelength 2500nm to 56% 2100nm, then slowly decreases as the wavelength decreases to 3% at the wavelength 300nm. In this curve there is noise over wavelength range 2050 to 2110nm and 700 to 875nm.

Film thickness 4000Å (undoped PbI_2): For this sample, transmittance increases from 62% at the wavelength 2500nm to 63% at 2300nm, then slowly decreases as the wavelength decreases to 1% at the wavelength 300nm. In this curve there is noise over wavelength range 2050 to 2045nm and 690 to 850nm.

Film thickness 2000Å (Cu doped PbI_2): For this sample, transmittance is constant over the wavelength 1900 to 2500nm then slowly increases from 46% at the wavelength 2500nm to 64% 1500nm, then slowly decreases as the wavelength decreases to 1% at the wavelength 300nm. In this curve there is noise over wavelength range 2040 to 2100nm and 670 to 850nm.

Film thickness 4000Å (Cu doped PbI_2): For this sample, transmittance increases from 59% at the wavelength 2500nm to 72% 2100nm, then slowly decreases as the wavelength decreases to 1% at the wavelength 300nm. In this curve there is noise over wavelength range 2105 to 2045nm and 690 to 875nm.

From these observations, it is obvious that the film material is highly absorbing. It is also observed from these curves that transmittance variation is function of thickness of the sample. That is maximum transmittance is for the lower thickness samples. This obviously expected for the absorbing material.

Reflectance Observations

For the sample 1000 Å (undoped PbI_2): For this sample, interestingly the reflectance variation seems to be sinusoidal. The reflectance goes on increasing from 6% at the wavelength 2500nm to 42% at the wavelength 2000nm decreasing to 8% at the wavelength 1400nm again increasing to 47% at 1100nm, then decreases to 18% at 1000nm increasing to 30% at 900nm again decreasing to 14% at 800%. Thereafter it increases to 26% at 700nm decreasing to 18% at 500nm and finally it increases to 35% at the wavelength 200nm. There is noise in the curve between 1600 to 1655nm and 875 to 600nm.

For the sample 2000 Å (undoped PbI_2): For this sample, the reflectance variation seems to be sinusoidal. The reflectance goes on increasing from 6% at the wavelength 2500nm to 40% at the wavelength 2000nm decreasing to 37% at the wavelength 1900nm again increasing to 43% at 1600nm, then decreases to 8% at 700nm and finally increasing to 19% at the wavelength 200nm. There is noise in the curve between 1560 to 1650nm and 875 to 700nm.

For the sample 3000 Å (undoped PbI_2): For this sample, the reflectance variation seems to be sinusoidal. The reflectance goes on increasing from 16% at the wavelength 2500nm to 36% at the wavelength 2100nm decreasing to 8% at the wavelength 1600nm again increasing to 39% at 1300nm, then decreases to 12% at 1100nm increasing to 38% at 900nm again decreasing to 11% at 700% and finally increases to 42% at the wavelength 200nm. There is noise in the curve between 160 to 1650nm and 875 to 650nm.

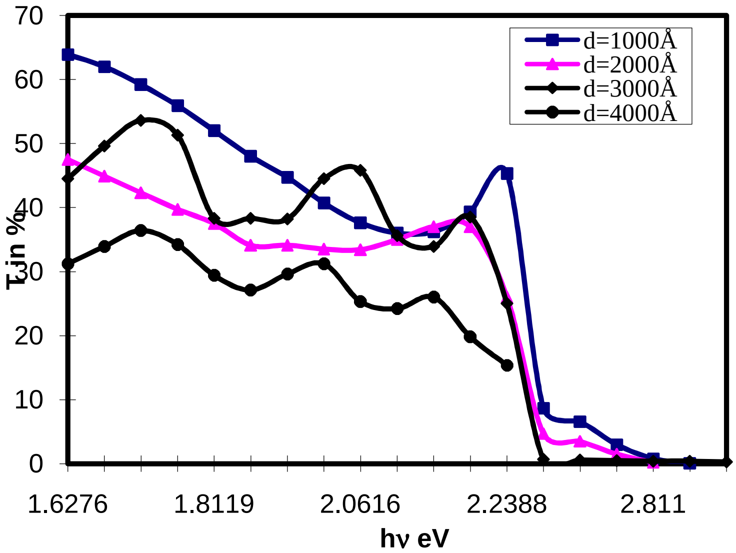

Fig. 1 Plots of T Vs hν (undoped PbI_2)

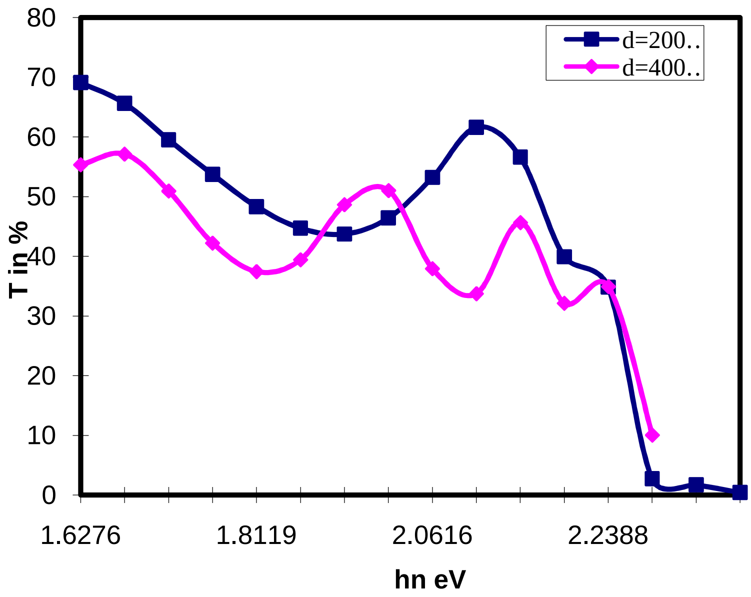

Fig. 2 Plots of T Vs hν (Cu-doped PbI_2)

For the sample 4000 Å (undoped PbI_2): For this sample, interestingly the reflectance variation seems to be sinusoidal. The reflectance goes on increasing from 21% at the wavelength 2500nm to 23% at the wavelength 2300nm decreasing to 11% at 1800nm again increasing to 32% at 1500nm decreasing to 1% at 1200nm then increases to 28% at 1100nm decreasing to 1% at 800nm increasing to 18% at 700nm and finally it increases to 20% at the wavelength 200nm. There is noise in the curve between 1575 to 1675nm and 875 to 700nm.

For the sample 2000 Å (Cu doped PbI_2): For this sample, the reflectance variation seems to be sinusoidal. The reflectance goes on increasing from 14% at the wavelength 2500nm to 37% at the wavelength 2000nm decreasing to 7% at the wavelength 1600nm again increasing to 37% at 1300nm, then decreases to 9% at 1100nm increasing to

34% at the wavelength 900nm then decreases to 8% at 800nm and finally increases to 44% at 200nm. There is noise in the curve between 1600 to 1650nm and 700 and 875nm.

For the sample 4000 Å (Cu doped PbI_2): For this sample, the reflectance variation seems to be sinusoidal. The reflectance remains constants from 4% at 2500nm to 2200nm and goes on increases to 37% at the wavelength 1500nm decreasing to 6% at the wavelength 1200nm increasing to 37% at 1000nm, then decreases to 7% at 800nm increasing to 20% at the wavelength 400nm then decreases to 7% at 300nm and finally increases to 21% at 200nm. There is noise in the curve between 1575 to 1675nm and 700 and 875nm.

CONCLUSION

1. Thin films of gel grown, Cu-doped and undoped Lead Iodide crystals can be well prepared at 80^0C. This is new trend, since such reports are not available in the literature.
2. The thin films all the samples are crystalline in nature having hexagonal structure.
3. The lattice parameters ‘a’ and ‘c’ of thin films of samples are well matched with the reported value and the ASTM data (Card no. 7-235) of Lead Iodide.
4. The unit cell volume of all the samples are sensitively affected by dopant materials.
5. For lower thickness, the thin films are uniform and highly reflecting.
6. The crystallinity of the thin films of all the samples turns to amorphous as the thickness of the samples are increased.
7. Optical studies are reproducible within the ±5% tolerance.

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