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Comparative studies of band gaps of doped Lead Iodide thin films

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ABSTRACT

The Lead Iodide crystals have been grown by gel technique. Various dopants of different concentrations doped in Lead Iodide crystals. Thin films of various thickness of differenent doped and undoped gel grown Lead Iodide successfully prepared by thermal evaporation technique. Optical properties have been studied by transmittance and reflectance. The band gap of various thin films of different dopants have been calculated, compared and reported. It is found that the band gap varies with the dopant concentrations and thickness of the films.

Keywords: Gel technique, thin films, band gap.

INTRODUCTION

Lead Iodide is a direct semiconductor having hexagonal structure. Interestingly, the band gap of this semiconductor is 2.55 eV, is a technically class of materials in a view of its band to band type transition and high absorbance without any phonon-assisted mechanism, which makes it very useful in several electronic and optoelectronics device applications [1]. Lead Iodide, with a band gap of 2.55 eV, is a technically class of materials in a view of its band to band type transition and high absorbance without any phonon-assisted mechanism, which makes it very useful in several electronic and optoelectronics device applications [1]. Lead Iodide has been studied as a very promising material with large applicability at room temperature nuclear radiation detectors [2-4].

In the present course of investigation, Lead Iodide crystals have been grown by gel technique. Thin films of X-doped Lead Iodide crystals (X=Aluminum, Copper and Zinc) of different concentrations of different thickness have been prepared. On the preliminary basis, effect of doping, particularly, on the band gap of different thickness have been calculated and reported herewith, on the preliminary basis.

MATERIALS AND METHODS

Analar Grade chemicals were used in the present work. The Lead Iodide crystals, doped (Al, Cu and Zn) and undoped, were grown by the gel technique. First, solution of Sodium Silicate (sp.gr.1.04 g cm^{-3}) is mixed with Acetic Acid (1N), Lead Acetate (0.5N) and X-Acetate (X=Al, Cu and Zn), of various concentrations from 0.1 to 0.1 N and allowed to set the gel. Details of the synthesization of Lead Iodide are given elsewhere [5, 6, 7]. The thin films of, pure material of PbI_2, of various thickness and temperatures, have been deposited onto the glass substrates at 30^0C by vacuum thermal evaporation technique which were chemo mechanically and ultrasonically cleaned, by thermal evaporation technique. A.R.grade chemicals have been used for this purpose. The evaporation is carried out in a conventional vacuum coating unit of 1 to 3 x 10^{-5} torr, with constant substrate temperature at 353 K (with different thickness). The thickness was measured by quartz crystal thickness monitor make HindHivac DTM model no. 101. Care is taken to avoid the overheating stock of Lead Iodide during sublimation, otherwise thermal decomposition gives rise to non-stoichiometry in the films, apart from this no special precaution are necessary.

The X-ray diffraction of these thin films, gel grown copper doped and undoped Lead Iodide crystals, has been carried with a 2θ range from 20^o to 90^0 by X-ray diffractometer (Philips PW-1730) using CuKα radiation with Ni filter (1.5418Å). Not reported in this paper. The transmittance and reflectance spectra were recorded for all the films on Hitachi (model 330) spectrophotometer at normal and near normal incidence respectively at Cosist Lab. University of Pune, Pune.

RESULTS AND DISCUSSION

The details of the XRD were already reported [3]. The observations on all various thin films of different thickness were as,

Film thickness 2000Å (Al doped PbI_2)
For this sample, transmittance increases from 58% at the wavelength 2500nm to 73% 2100nm, then slowly decreases as the wavelength decreases to 2% at the wavelength 300nm. In this curve there is noise over wavelength range 2050 to 2110nm and 750 to 950nm.

Film thickness 4000Å (Al doped PbI_2)
For this sample, transmittance increases from 45% at the wavelength 2500nm to 68% 2100nm, then slowly decreases as the wavelength decreases to 3% at the wavelength 300nm. In this curve there is noise over wavelength range 2000 to 2110nm and 700 to 805nm.

Film thickness 2000Å (Zn doped PbI_2)
For this sample, transmittance increases from 46% at the wavelength 2500nm to 65% 1700nm, then slowly decreases as the wavelength decreases to 1% at the wavelength 300nm. In this curve there is noise over wavelength range 2050 to 2110nm and 700 to 950nm.

Film thickness 2000Å (Zn doped PbI_2)
For this sample, transmittance increases from 59% at the wavelength 2500nm to 75% 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 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.

Table 1 shows the comparative chart of band gap.

Table 1: Comparative study of band gap

Compound	Thickness in Å	Band Gap in eV
i) synthesized undoped PbI_2 film	1000	2.623
	2000	2.5802
	3000	2.1636
	4000	2.0262
ii) Al-doped PbI_2 film	2000	2.454
	4000	2.359
iii) Zn-doped PbI_2 film	2000	2.4875
	4000	2.175
iv) Cu-doped PbI_2 film	2000	2.464
	4000	2.295

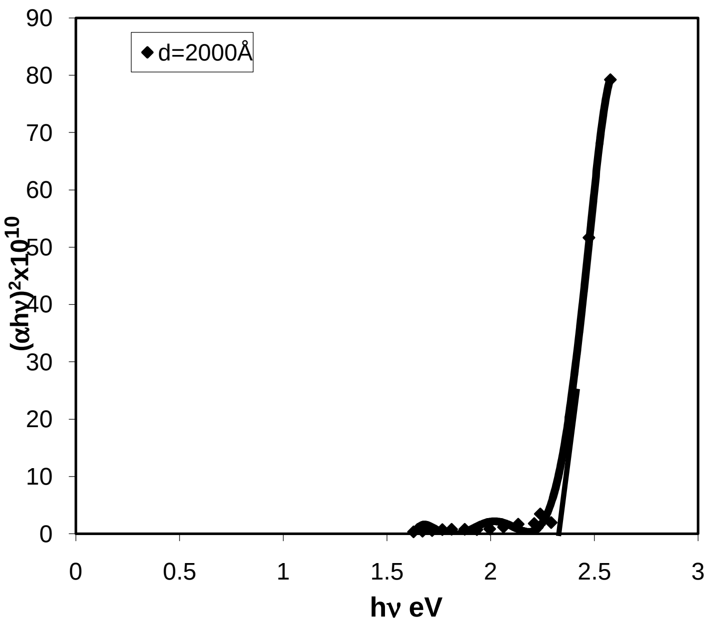

Fig. 1 Plot of $(\alpha h\nu)^2$ versus hν (Al-doped)

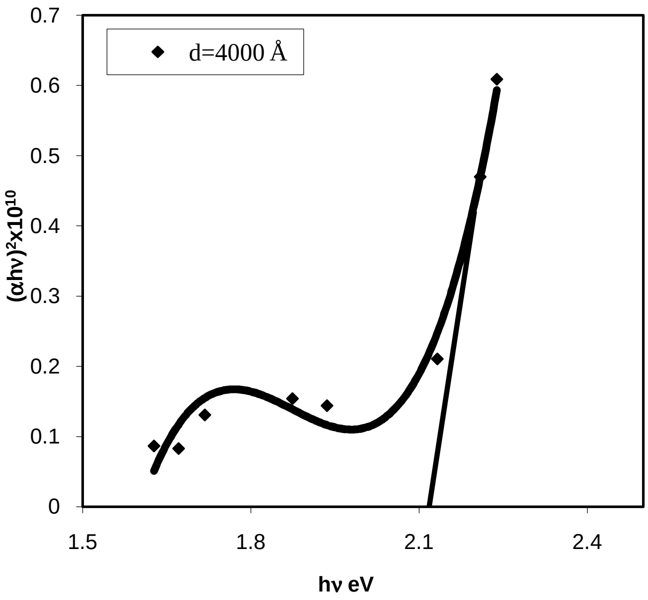

Fig. 2 Plot of $(\alpha h\nu)^2$ versus hν (Al-doped)

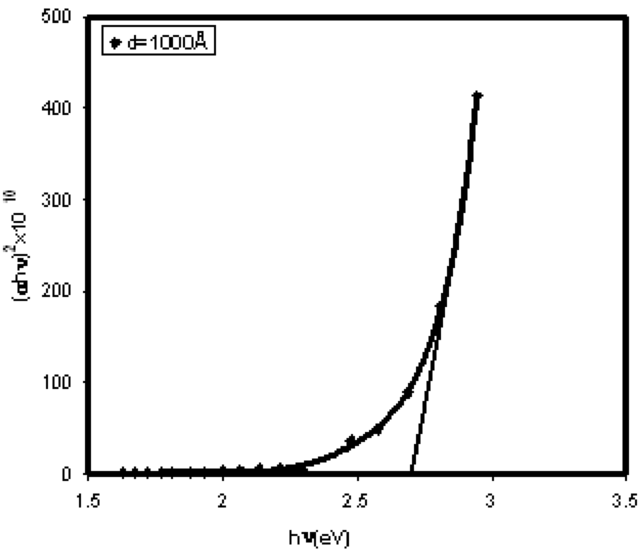

Fig. 3 Plot of $(\alpha h\nu)^2$ versus hν (Zn-doped)

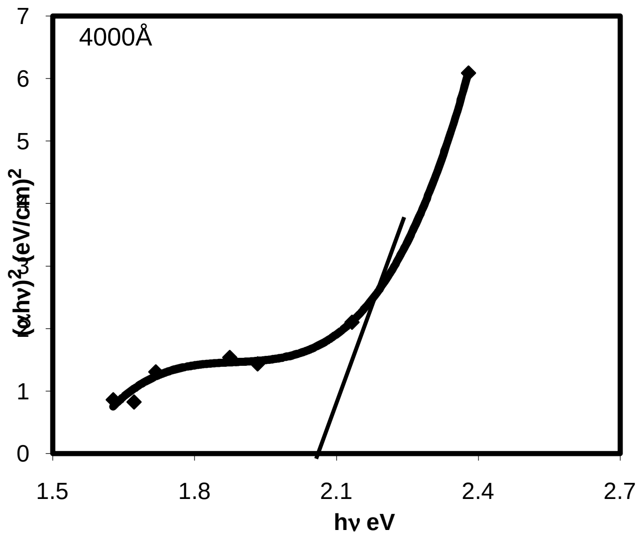

Fig. 4 Plot of $(\alpha h\nu)^2$ versus hν (Zn-doped)

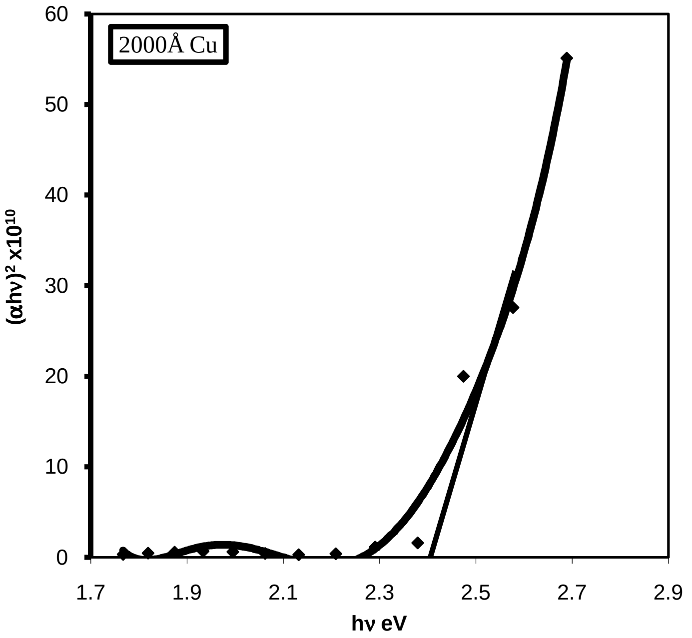

Fig. 5 Plot of $(\alpha h\nu)^2$ versus hν (Cu-doped)

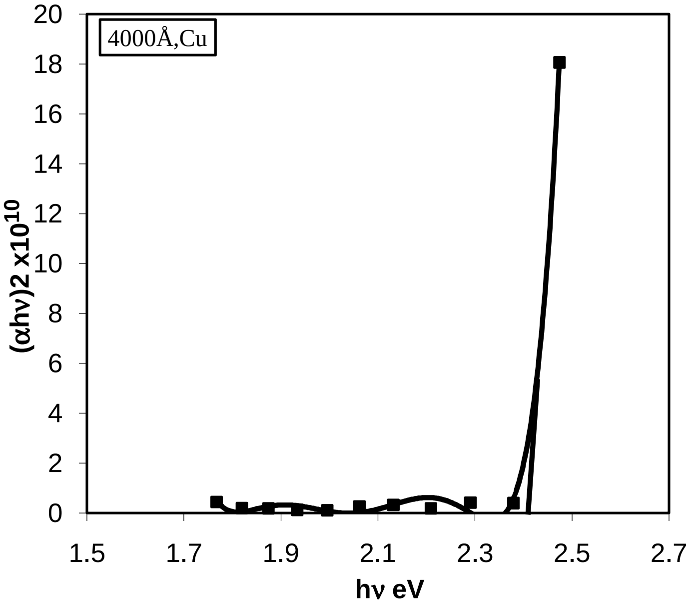

Fig. 6 Plot of $(\alpha h\nu)^2$ versus hν (Cu-doped)

CONCLUSION

1) Lead Iodide crystals successfully grown by gel technique.
2) The lattice parameters are well matching with the ASTM data of the Lead Iodide.
3) The structure of the crystals are hexagonal and polycrystalline in nature.
4) It is established that the growth has been taken placed by two-dimensional nucleation mechanism and by spreading and pilling of growth layers.

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