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Effect of Magnetic Field on Physical Properties of HgI_2 Thick Films during Deposition

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Abstract
A deposited layer of HgI_2 deposited on glass substrate (1.5 x 1.5 Cm^2) using solution evaporation technique under the effect of magnetic field shows good properties in compare to that deposited without any effect of magnetic field. The band gap energy and type of optical transition were determined from transmission spectra, And an optical band gap of Eg =2.12 eV for direct transition was estimated. X-ray diffraction of HgI_2 to film shows a preferential orientation of peaks (002) and (101).

1- Introduction

Semiconductor material represents one of the most important materials, because it is largely use in manufacturing all electronic components. By improved purification of starting material and growth technique it give a good inhensement of properties and application of semiconductor compound.

Mercuric iodide has a wideband-gap (2.1 eV), high atomic numbers (53 for iodine, 80 for mercury), and a high density (6.4 g/cm3), low dark current, a high stopping power for photons of ionizing radiation, and electrical resistivity of the order of 10^{12} Ω cm lead to a large ratio of the photo to dark currents even at room temperature as desired for a good photo detector, [*R.Turchetta (1999), A.Zuck (2004), M.Schieber (2006), M.Schieber (1998)*]. So Mercuric iodide (HgI_2) considered being of the most promising semiconductor material for room temperature nuclear radiation detection from astrophysics [*R.Ahhuja (1996), M.Schieber (2000), E.R.Mancel (1999), T. Takahashi (2001)*], and HgI_2 thick films X-ray medical imaging detector [*A.Zuck (2004), R. A. Street (2002), Marcelo Mulato(2011)*]. The major advantages in using HgI_2 it does not need any liquid nitrogen for cooling process as in most commercially available system [*Zhong Sa (2005)*]. One of the methods of preparation: the screen print (SP) technology [*M.Schieber (1998), J.C.Ugucioni (2006)*].The SP method in the current Integration mode gives reduced sensitivity but has a much lower dark current. Much greater sensitivity can be obtained for X-ray imaging by using polycrystalline HgI_2 detectors produced by direct physical vapor deposition (PVD), [*A.Zuck(2004), Hong Du(2008)*]. Poly-HgI_2 films with an average small grain size of about 50μm can be obtained on ITO substrates by ultrasonic wave-assisted vapor deposition method whose deposition temperature can be as low as 40 ^oC [Hong Du (2008)].

And by solvent evaporation technique which has the lower fabrication cost for large area, [*Lei Nie (2011*)]. It does not require any vacuum system. The requirement of this technique is the solution which is composed of HgI_2 powder and a volatile solvent either ethanol, or acetone.

J.C. Ugucioni says that the optimized composite film might be better candidate for uses X-ray detector forms medical imaging, in place of the single HgI_2 crystalline device [*S.L.Sharma (2002*)].

Su *et al* say that polycrystalline HgI_2 have low effective work function WEFF ~5 eV, WEFF which defined as the average amount of absorbed x-ray energy required to generate one unit of detected pixel charge [*J.C. Ugucioni (2010)*].

Zentai *et al* compeer the result of HgI_2 signal per unit of absorbed x-ray energy with that of the α-Se photoconductors currently used in commercial direct detection devices. He concluded that a higher signal can get from HgI_2 films [*Su Z (2005)*].

2-Experimental 2-1 Substrate preparation

Substrate used for deposition HgI_2 is borosilicate glass slides with dimensions (1.5x1.5cm),which were first cleaned in distilled water in order to remove the impurities and residuals from their surfaces, followed by rinsing in chromatic acid(for two-day), to introduce functional groups called nucleation and/or epitaxial centers, which formed the basis for layer films growth. Then the samples were washed repeatedly in deionizer water, and finally put in ultrasonic agitation with distilled water for 15min then dried.

2-2 Deposition of the HgI2 films

The sample studied here were polycrystalline film HgI_2 layers by solvent evaporation. HgI_2 powder (1.2gm) from (DEHANE radial deform) 99%puriuty was dissolved in (100ml) of volatile solvent (acetone) at 25^oC using

magnetic stirrer for 30min. The solutions of(25ml) placed inside a beaker(75ml) with surface area of ($5cm^2$) putting on magnets with different magnetic field intensities (1000,2000,3000G), At different time, after that we add an amount of ionized water to the solution equal to that of solvent(25ml), and after about 30 minutes a particles of HgI_2 began to be deposited at the bottom of the beaker, after (48 hours) we pulled the residual solution (most of it is water)from the beaker and keep the sample for (1hour) to become dry. The deposition of HgI_2 happened because the density of acetone is less than that of water, so the acetone atoms moved toward the surface of solution while the insoluble HgI_2 atoms in water will be separate from the solution and deposited at the bottom of the beaker, with a very little amount of HgI_2deposited on the wall of the beaker.

2-3 Thickness measurements

Film thickness is measured by weight method because the thickness of the layer is greater than 1μm.Sensitive electrical balance of Metler AE-160 was used, with preciseness reaches 10^{-4} gm. The following mathematical relationship is adopted

$$Thickness = \Delta m / pf \, x \, A f$$

Δm: represents the deposited thin film weight, which is equal to the difference between weight of the glass slide after and before the deposition process.
pf: density of film.
A f: the film area.

2-4 Structural measurements

The diffraction spectra of HgI2films were obtained by scanning (2Θ) in the range (20-60) using cu-kα (PhilipsPW 1840) which has the following characteristics: the CuKα with (1.540A) wavelength and scanning speed: (3 degree/min).

2-4-1 Grain size (*D*) of the polycrystalline material can be calculated from the X-ray spectrum by means of Full Width at Half Maximum (FWHM) method (Scherer relation) [*Zentai G(2007)*].

$$D = \frac{0.94\,\lambda}{\beta \cos\theta}$$

Where $\boldsymbol{\beta}$ is the full – width at half maximum of the XRD peak appearing at the diffraction angle.

2-4-2 Dislocation density σ

From the value of grain size we can determine dislocation density [*B.D. Cullity (2001)*].

$$\sigma = 1 / D^2$$

2-4-3 Strain Ɛ

The strain could be calculated by the formula [*G.B.williamson (1956)*].

$$\beta = \left(\frac{\lambda}{D\cos\theta}\right) - \varepsilon \tan\theta$$

2-5 Optical measurements

The optical transmission measurement was performed at room temperature between (400-700) nm using phenix-2000 uv-vis spectrophotometer. Optical band gap value was deduced from the
Extrapolated intercept of $(\alpha\ h\upsilon)^2$ versus $(h\upsilon)$. Absorption coefficient (α) was calculated from the transmission spectra using Beer-lamberts law [*R.A.street (1996)*].

$$\alpha = \frac{1}{d} \ln \frac{1}{T}$$

Where: d is the thickness of thin film and T is the transmission.

The absorption coefficient (α) and optical band gap (Eg) are related by [*H. Reiss (1988) 25 N. F. Mott (1979)*].

$$\alpha h\nu = A(h\nu - Eg)^n$$

where : ***A*** is constant depending on transition probability, ***h*** is Plank's constant, ***υ*** is the frequency of the incident photon, Eg is the band gap of the material and n has different values depending on the nature of the absorption

process. The plot of $(\alpha h \upsilon)^2$ versus $(h\upsilon)$ gives the best fit results, by extrapolating the liner part down to $\alpha = 0$, the value of Eg could be determined.

2-6 Extinction coefficients (K)

The extinction coefficient calculate from the relationship [*26 K.L Chopra (1969)*]

$$K = \frac{\alpha \lambda}{4\pi}$$

2-7 the contacts

In order to study the electrical properties, we used ohmic contac tsrespectively. They were obtained by using the graphite spray material manufactured by (Rc Industries, France)through mask made from(AL)foil designed to give two metals contacts of dimensions($2x8mm^2$)and (3mm)inter electrode distance.

2-8 Electrical measurements

Electrical measurements were carried out by using the planar structure to measure the electrical Current-Voltage curves were measured with the use of ac power supplied (0-350 V), and (0-100mA), and the output current was measured by Keithly Electrometer type 602. The illumination source used was a white light lamp with power of 100W located about 15 cm from the sample.

3- Result and discussion

Fig (1) illustrate the diffraction curve for HgI_2 samples deposited under the effect of magnetic field (1000, 3000, 5000G), and without magnetic field. These curves show a preferentially oriented in the (002), (101), (102) directions. We can see that the peak intensity of the levels at (5000G) is greater than that of (3000G) and (1000G), the lower intensities observed on the diffraction pattern of sample deposited without magnetic field. This may be according to the inhensiment the grain size at increases magnetic field intensity. Also there are little shifted in the diffraction angles, because of the mistake in the atomic packing according to the defect or impurities at deposition process. This variation in behavior is due to the compressive stresses that produced in the sample as a result to the deposition process, this stresses play an important role in changing the peaks position or according to residual stresses which may lead to residual defects that causes deformations.

Fig (2) illustrated that at increasing magnetic field intensity lead to increase the preparation crystal size according to the absorption of energy from the magnetic field that led to increase the excitation of deposited crystals and braking the boundaries between it, this lead to decrease the dislocation density of HgI_2 films as in Fig(3). Also it will decrease the strain of the films with increasing magnetic field intensity Fig (4).

From Fig (5) which represent the relationship of HgI_2 films transmittance at wavelength range (400 – 800nm), we can see a large increase in transmittance value with increasing wavelength (500 – 520nm), then the transmittance will saturate at wavelength above (520nm) which means that HgI_2 film have a large transmittance value at wavelength (550nm).There is a little difference in transmittance values for HgI_2 films deposited at different magnetic field intensities.

Fig(6) represent the absorption coefficient oh HgI_2 films, we notes that the absorption edge is very sharp, and the absorption coefficient increase for films deposited at (1000G) than (3000&5000G).

Fig (7) shows a direct transition with direct energy gap with clearly change in energy gap for HgI_2 deposited at (1000, 3000, 5000G), which means that magnetic field intensity affected the optical properties of HgI_2 films.

Fig (8) represents the extinction coefficient for HgI_2 films at different magnetic field intensities. The extinction coefficient represent the quantity of energy that absorbed in the film, which means the quantity of extinction for electromagnetic wave inside the material and depend on free electrons density and structure defects. The extinction coefficient for HgI_2 films deposited at (5000G) is much less than that deposited at (3000&1000G).

Fig (9) The I-V characteristic curve for HgI_2 films. The lowest value of dark current is for samples deposited without magnetic field according to increases the density of grain boundary which reduce the mobility of charge carrier, and changing the grain size that lead to affect the charge acclomaration efficiency and the sites and number of charge capture at the grain boundary which effect the reaction of magnetic field with electric field inside the HgI_2 films lead to affected the net movement of charge particles inside crystal structure that means net effects of charge cloud inside the crystal body.

Acknowledgment.

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Conclusion

The HgI_2 thick films deposited by solution evaporation technique on magnetic field have better performance compared to that deposited without magnetic field.

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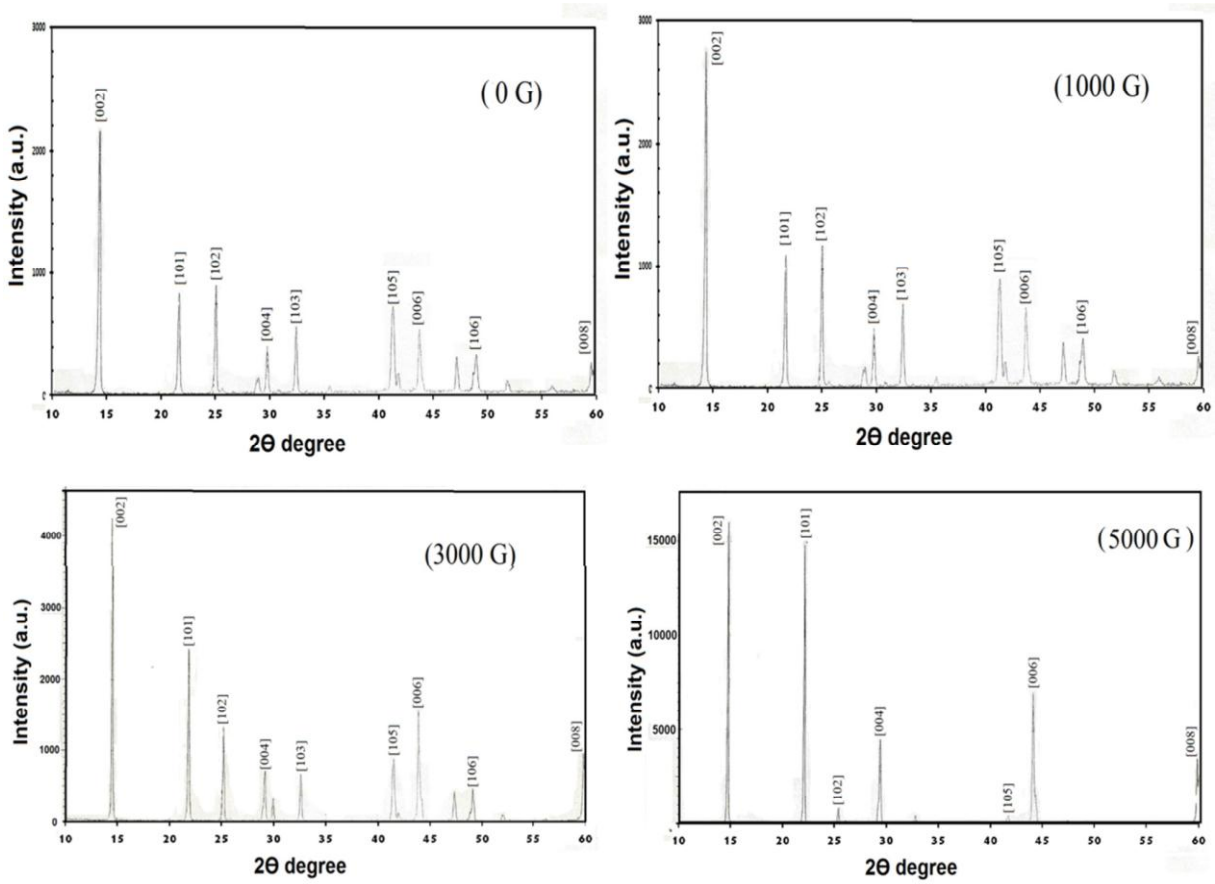
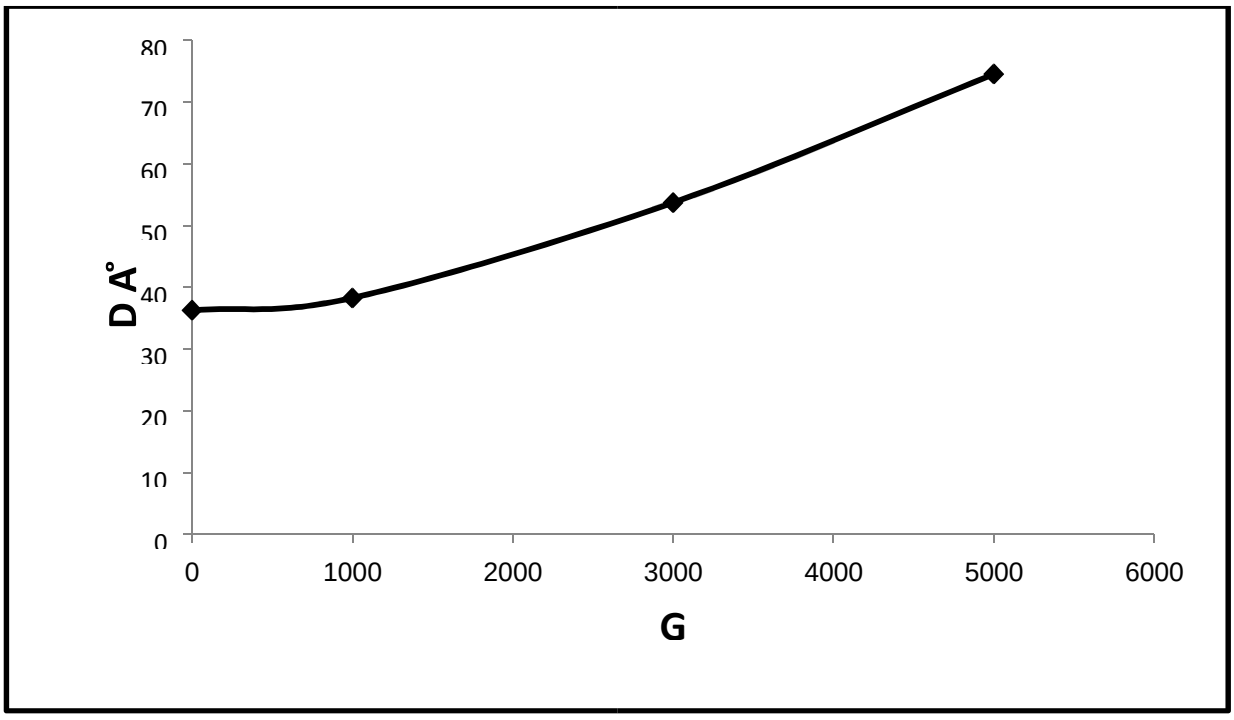
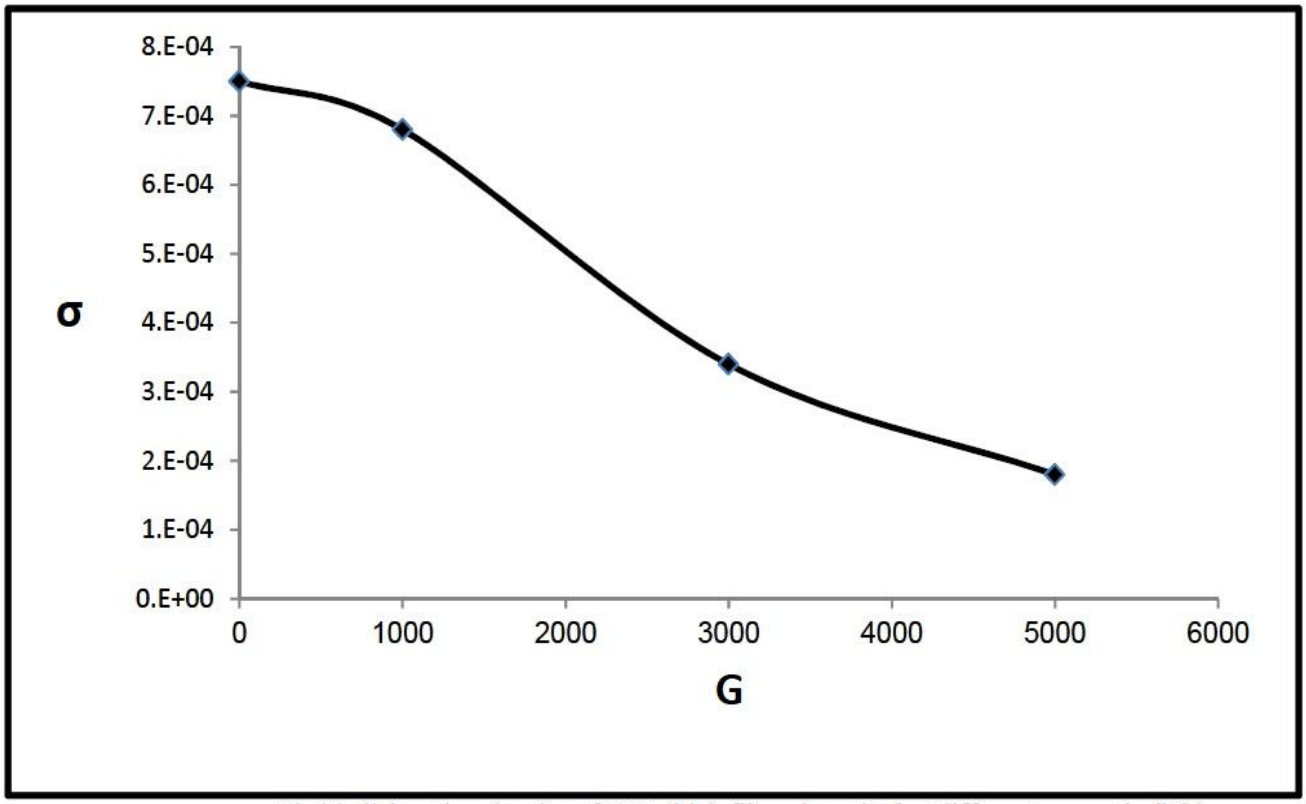


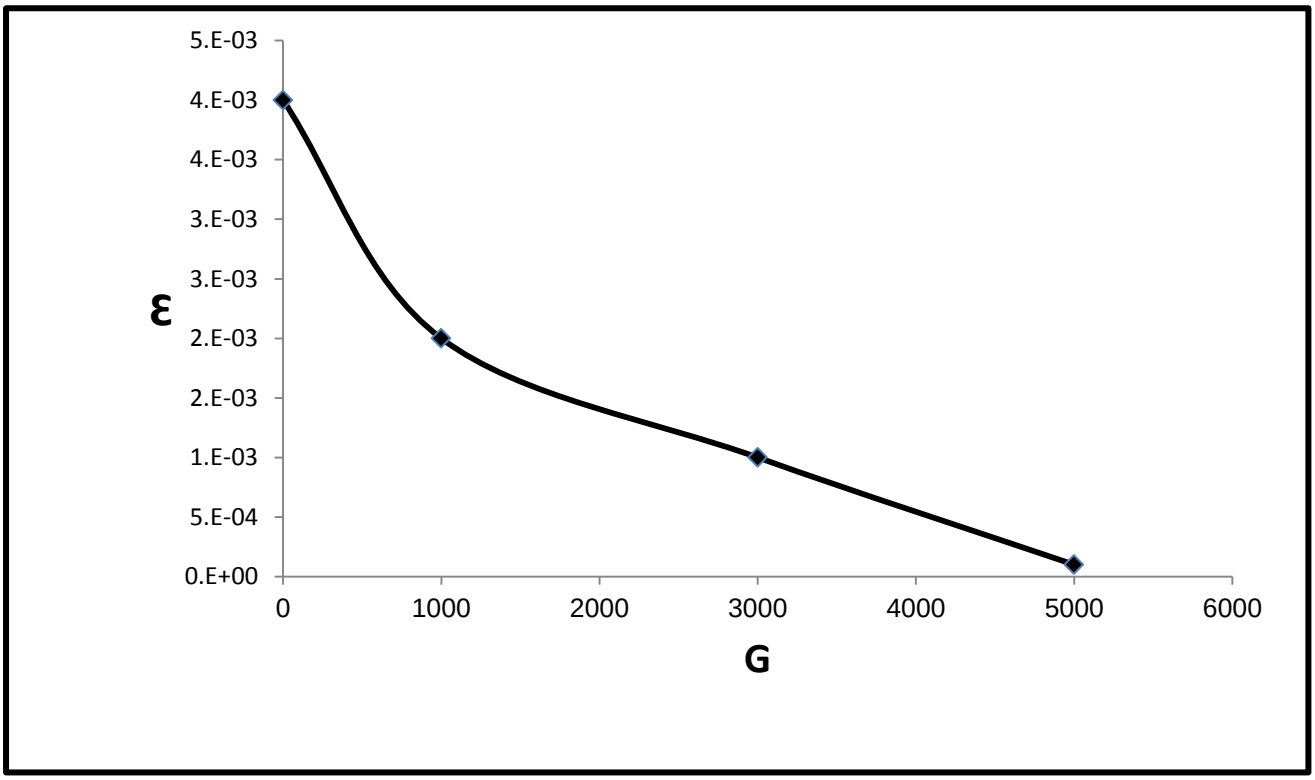
Fig (1) X-Ray Diffraction of HgI_2 Thick Films Deposited at different magnetic field.



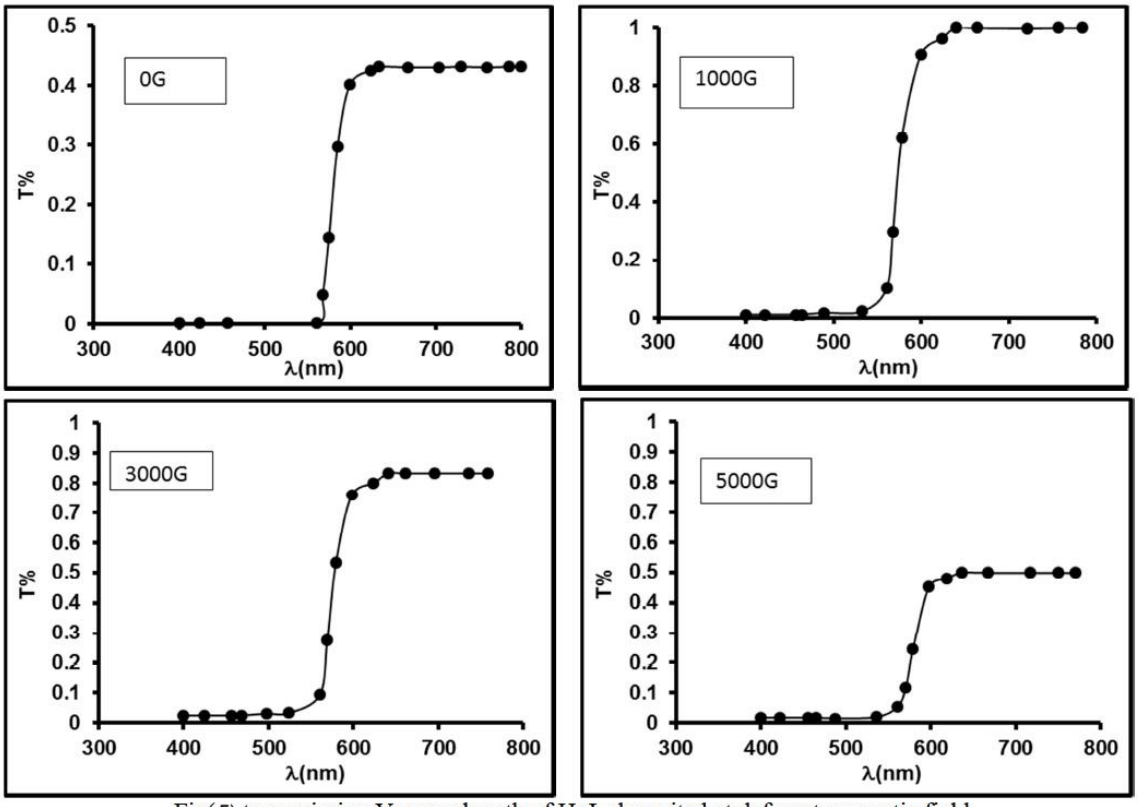
Fig(2) Grain size of HgI_2 thick films deposited at different magnetic field



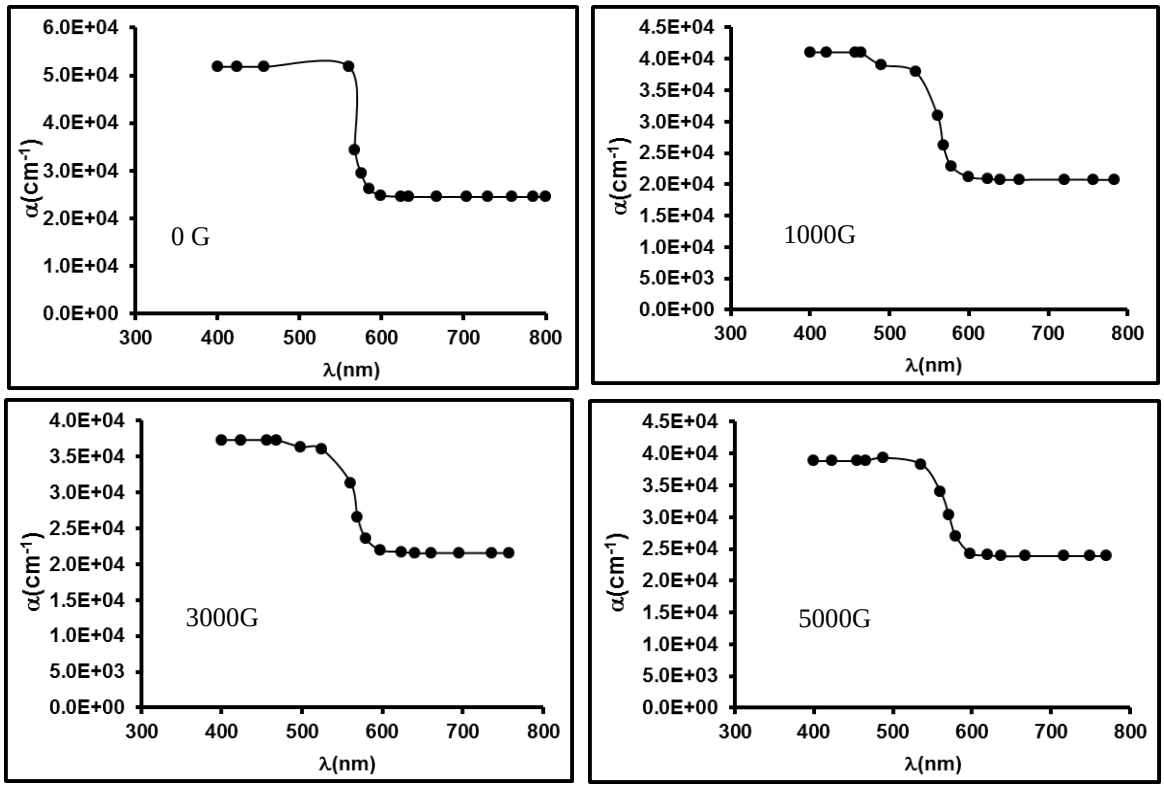
Fig(3) dislocation density of HgI_2 thick films deposited at different magnetic field



Fig(4) strain of HgI_2 thick films deposited at different magnetic field



Fig(5) transmission Vs wavelength of HgI_2 deposited at deferent magnetic field



Fig(6) absorption coefficient Vs wavelength of HgI_2 deposited at deferent magnetic field

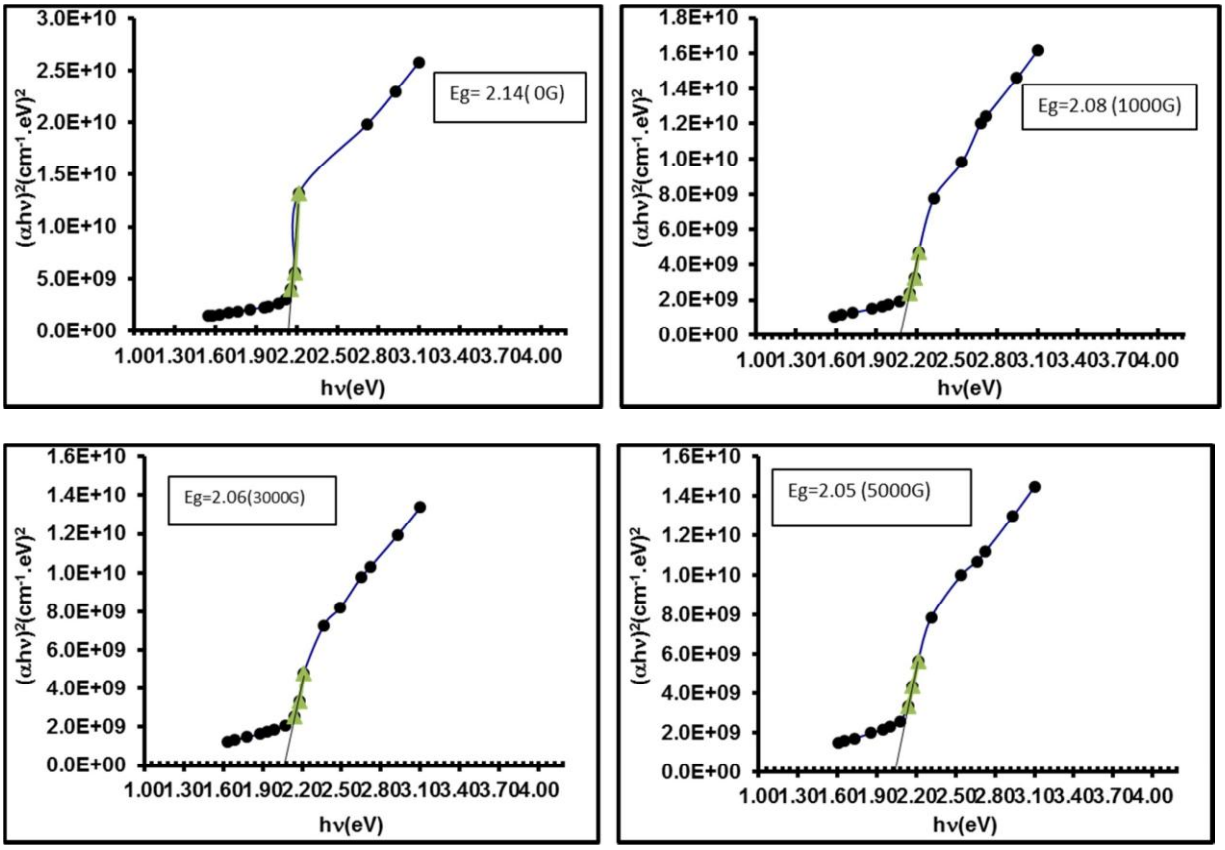


Fig (7) energy Gap of HgI_2 deposited at deferent magnetic field

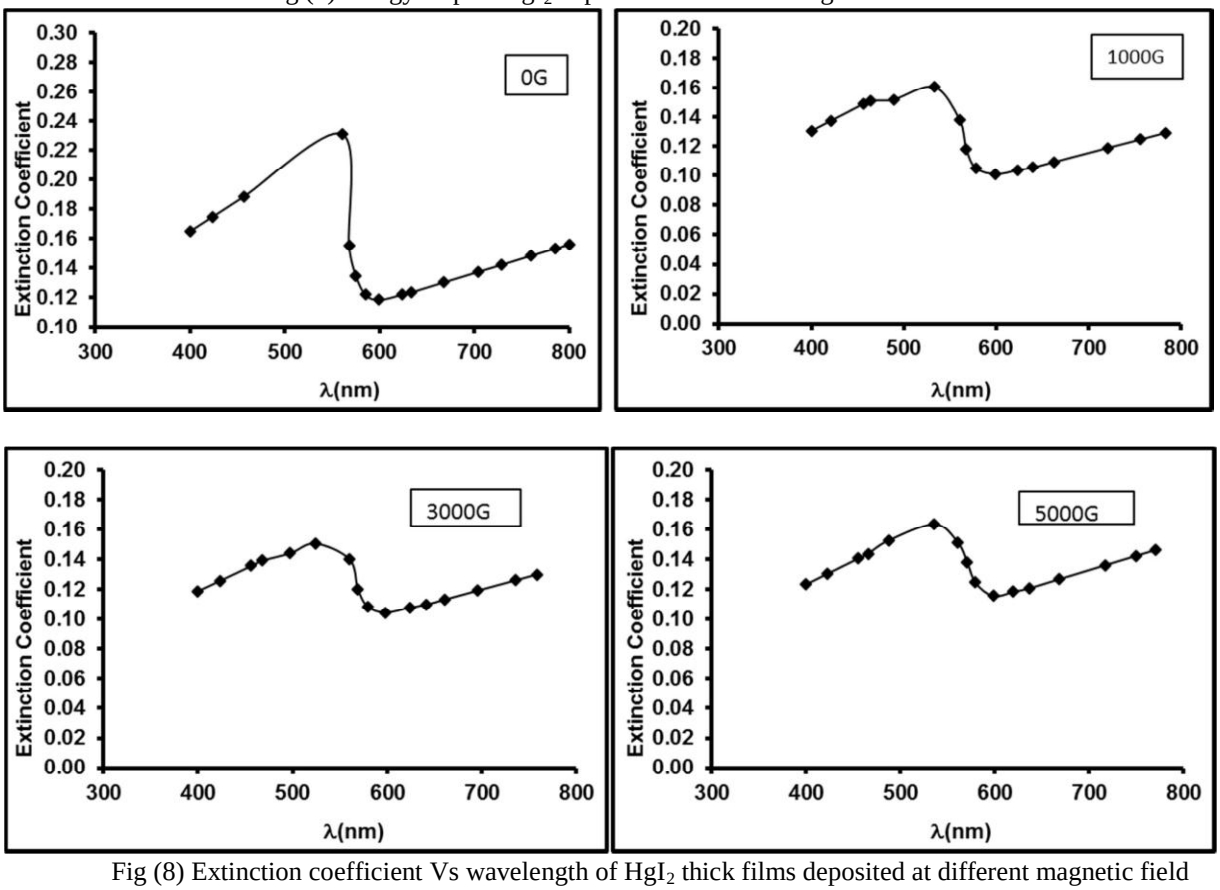


Fig (8) Extinction coefficient Vs wavelength of HgI_2 thick films deposited at different magnetic field

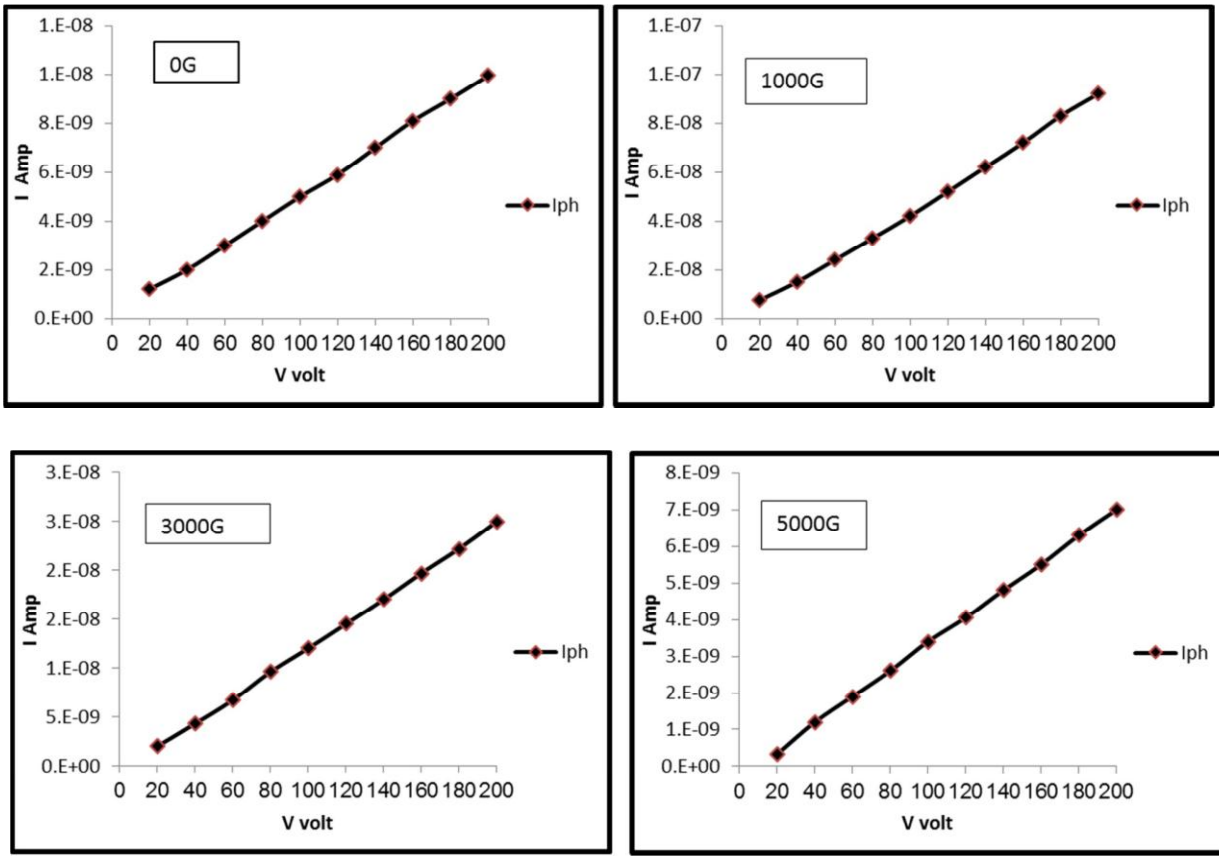
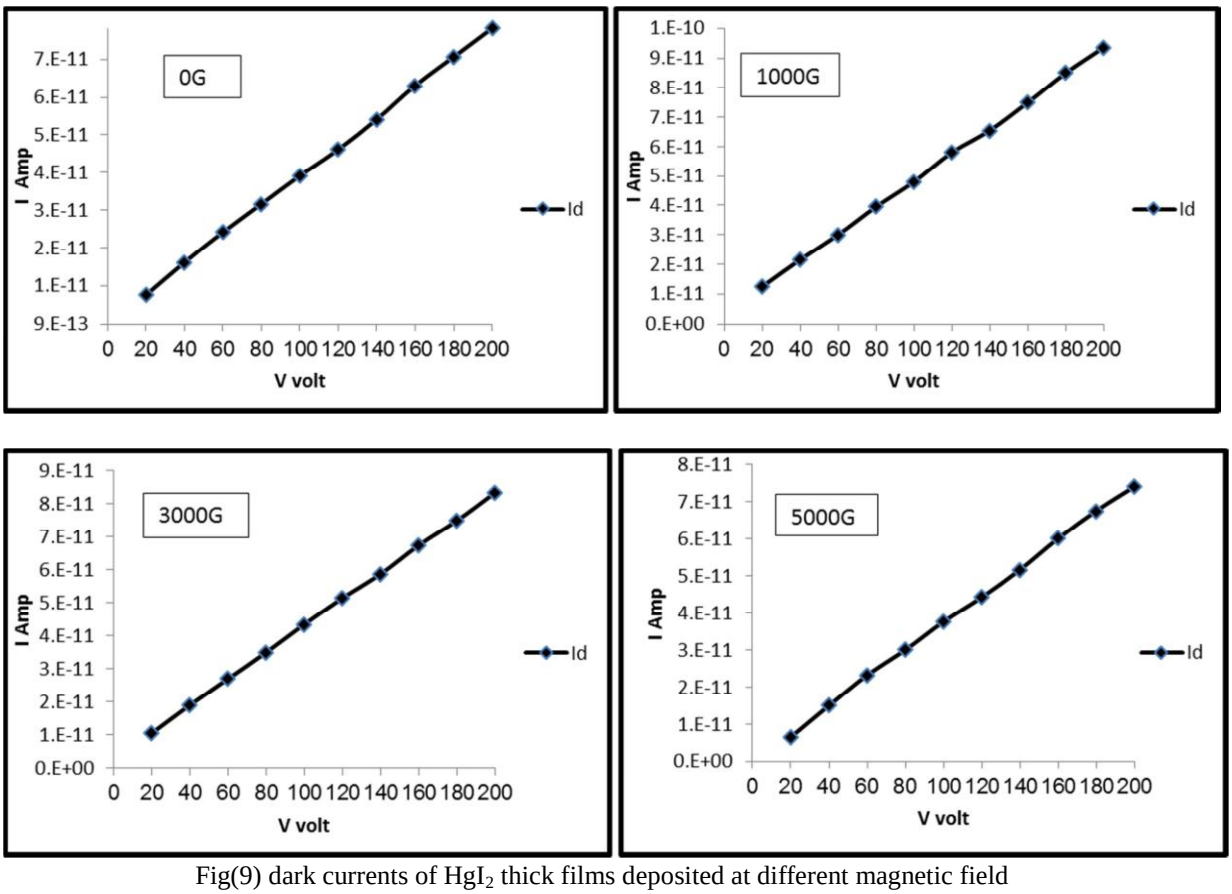


Fig (9) photo currents of HgI_2 thick films deposited at different magnetic field



Fig(9) dark currents of HgI_2 thick films deposited at different magnetic field

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