International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 4 Issue 12, December-2015

The Influence of Deposition Conditions on Properties of HgI_2

Ali M. Mousa[1], Jasim Shamki Alikhan[2]

[1]Department of Applied Sciences, University of Technology, Baghdad, Iraq
[2]Department of Physics, University of Al-Mustansiriya, Baghdad, Iraq

ABSTRACT

The effect of deposition conditions on the electrical and structural properties of deposited HgI_2 films were studied .The films were deposited from solution under dark and room light illumination condition. XRD, An increase in the grain size was noticed. The electrical properties revealed a dependence on deposition conditions. Dark resistivity increases to 1.084E+8 (Ω cm) when deposition was carried out in darkness while dark resistivity was 7.32 E+7 at light illumination.

1- INTRODUCTION

Red mercuric iodide (HgI_2) is a wide band gap semiconductor material (E_g=2.13 eV) at 300K with high atomic number (80,53) Due to the low dark current, high stopping power for photon, higher number of charge pair caused by irradiation, higher absorption coefficient for x-ray and gamma-ray detection, It was considered to be of the most promising semiconductor material for room temperature nuclear[1-3] radiation detection and x-ray imaging[4]**.** It is difficult to grow large crystals of HgI_2 with good uniformity; as a result, they are not well suited for applications such as imaging devices which require large surfaces [5–8]. Using thin polycrystalline layer instead of single crystal wafer is an alternative approach to overcome this difficulty which takes advantage of intrinsic properties of mercuric iodide [9–12].Deposition of a layer of HgI_2olycrystalline from solution is a very comfortable and reliable technique [8–11]; the basic principle requires controlled precipitation on substrate in order to form a layer .Hence, the characterization of electrical and structural properties of such layers is of a great concern both for evaluating their ability to fulfill the requirements needed and for improving their preparation. In view of this situation we have investigated the structural and electrical properties dependence of the HgI_2 thin film prepared by solution method on the deposition conditions (including illumination, and darkness) in order to understand the transformation accompanying the growth process.

2- EXPERMENTAL

Substrate used for deposition HgI_2 is borosilicate glass slides with dimensions (1.5*1.5cm),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 days), 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 deionized water, and finally put in ultrasonic agitation with distilled water for 15 min then dried. Deposition of the HgI_2 films The sample studied here were polycrystalline film HgI_2 layers by solvent evaporation. HgI_2 powder (0.3 gm) from (DEHANE radial deform) was dissolved in (50ml) of volatile solvent (acetone) at 25 c˚. The solutions placed inside a beaker with surface area of ($5cm^2$), After that we add an amount of ionized water to the solution equal to that of solvent (50ml), and after about 30 minutes a particles of HgI_2 began to be deposited at the bottom of the beaker ,and after (24 hours) the residual solution have been pulled (most of it is water) from the beaker and keep the sample for (1 hour) to become dry as shown in fig(1) .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 unsoluble 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_2 deposited on the wall of the beake**r.**

2-1 STRUCTURAL MEASUREMENTS

The diffraction spectra of HgI_2 films were obtained by scanning (2Θ) in the range (20-60) The structural properties of the layers were investigated by using X ray diffraction system (Lab X-XRD-6000/Shimadzu) which has the following characteristics: source: radiation of CuKα and with wavelength 1,54 A˚, scanning speed (5 degree/min),. The interplanar spacing is calculated from diffraction Bragg equation:

$n\lambda = 2d \sin\theta$,

where n is a positive integer. d is the interplanar spacing. The average grain size is deduced from Scherer equation :$G.Z = 0.9\lambda/B \cos\theta$,
where λ is the wavelength of X-ray radiation, and B is the full width half max. (FWHM). θ is Bragg diffraction

2-2 OPTICAL MEASUREMENTS

The optical transmission measurement was performed at room temperature between (400-700) nm using phenix-2000 UV-VIS spectrophotometer.

2-3 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 a dc power supplied(0-200 V), and (0- 100mA), and the output current was measured by Keithly Electrometer type 602. The electrical resistivity (ρ) of the deposited films is determined

As $\rho = R\ b\ d/\ l$
where l, b, and d are the length, width, and thickness
of the film respectively. Sample resistivity was measured

3- RESULTS OF DISCUSSION

3-1 X-RAY DIFFRACTION ANALYSIS

From the X-ray diffrograms the planes orientations were determined. Besides, grain size, number of layers (NL), and microstress (σs) of HgI_2 were calculated. Figures (A)– (B) shows the XRD of deposited samples prepared under different conditions. Figures (A)-(B) represent XRD pattern for samples prepared at dark and light .it is clear that strong peaks are observed at (2Θ=14.22,21.54,24.87,29.66,41.87) which corresponds with reflection planes (002), (101), (102) (103) and(200) respectively ,are small intensities are (2Θ=32.31,51.65,59.81) which corresponds with reflection planes(112,213,202). The presence of these reflections indicates that a high degree of crystallization with a preferred orientation perpendicular to the c-axis. XRD showed that the films have polycrystalline tetragonal. Comparisons between our results and those of the JCPDS are showed good agreement and recent researches (13,55,56).

Figures 2 (A(dark), B(light)) reveal x-ray of thick film HgI_2 samples deposited under dark and light conditions. By comparison figures 1(A (light), B(dark)), it is found that the sample prepared at dark has intensity of reflection peaks is higher than that prepared in light, that means the crystallization is better with dark deposition. On the other hand, there is a shifting of the XRD peaks due to the stresses. the sample prepared under dark possessed particle size bigger than particle size of the light sample which leads to minimized the number of layers , the density of dislocations ,and the microstrain will be less and full width half maximum which lead to the best crystallization with dark.

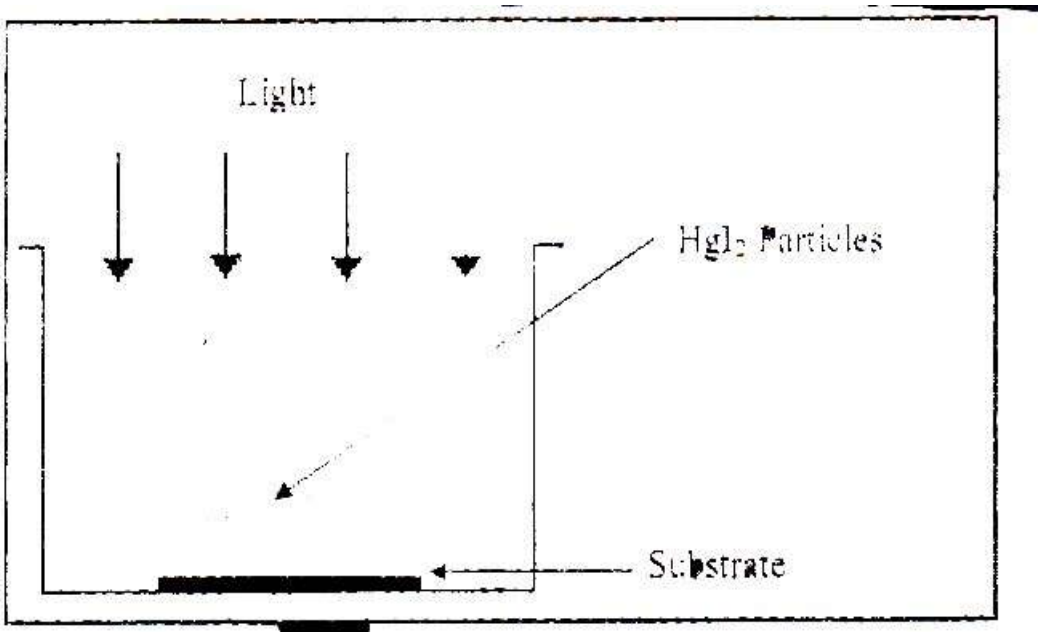

Fig (1): show thick film deposition of HgI_2

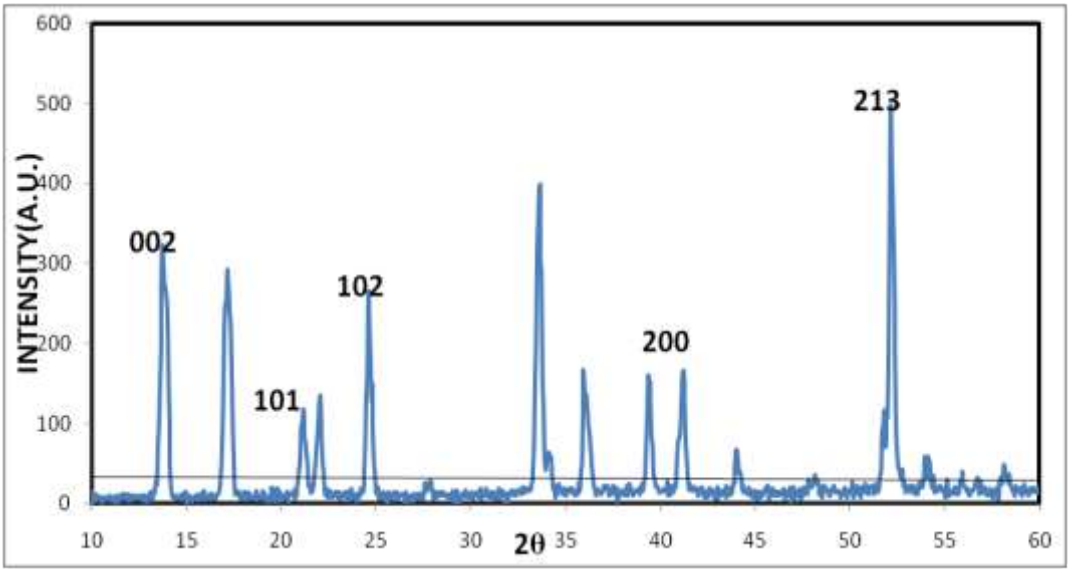

Fig (2-A) XRD patterns of HgI_2 films of light condition

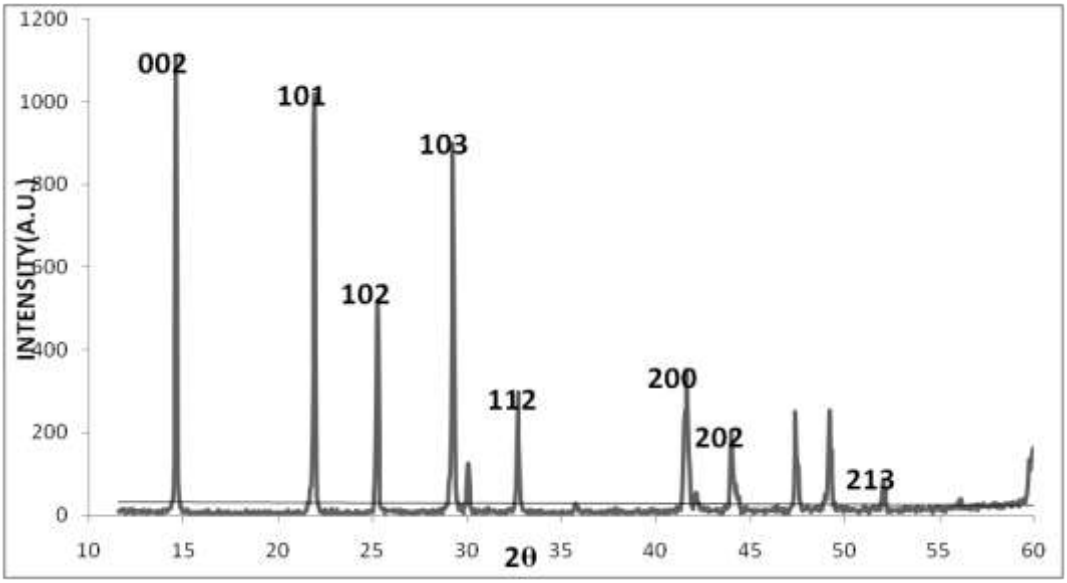

Fig (2-B) XRD patterns of HgI_2 films of dark condition

The lattice constants (a) and (c)of the synthesized films are calculated[table 1] using the following relationships for tetragonal crystal structures: [13]

$$\mathbf{1/d^2 = h^2 + k^2 / a^2 + I^2 / (2.84a^2)}$$

The film prepared at dark it is found causes larger deviation at small angles (002). Causing in turn increasing in parameter lattice (C◦ ,a◦) until larger angles(200) its corresponds to JCPDS. Hence, we think that the samples are under(tensile stress) because its value is smaller than JCPDS .Except preferred orientation(103) under a(compression stress) because its value is larger than JCPDS.

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Table (1) lattice constants of thick film HgI_2 of different deposition

condition	hkl	d_{XRD}	d_{ASTM}	2Θxrd	a_{XRD}	a_{ASTM}	c_{XRD}	c_{ASTM}
	002	6.031	6.223	14.67	4.237	4.369	12.062	12.440

Dark	101	4.035	4.122	22	4.277	4.368	12.178	12.438
	103	3.047	3.009	29.28	4.427	4.371	12.60	12.44
	102	3.517	3.577	25.30	4.298	4.371	12.23	12.44
	200	2.172	2.186	41.53	4.34	4.37	12.35	12.44
light	002	6.369	6.223	13.89	4.468	4.369	12.720	12.44
	101	4.186	4.122	21.20	4.430	4.367	12.613	12.438
	213	1.751	1.768	52.18	4.328	4.370	12.32	12.442
	102	3.605	3.577	24.67	4.405	4.371	12.542	12.445
	200	2.189	2.186	41.18	4.378	4.372	12.46	12.44

Table(2) shown the samples prepared at different conditions(dark, light).we have notice that the grain size of the plane(002) is bigger than other planes. So lowering value of the dislocation density at dark. While the plane(213) is bigger than other planes. So lowering value of dislocation density at light. There is a clear difference in the two values in the two cases. At dark the value is very higher than the value at the light . at Light during the growth process leads to smaller grain size than in the dark, which indicates that the crystal formation might be influenced by the excitation of HgI_2 molecules. Our guess is that during light, high energy photons are absorbed by the HgI_2 molecules. Somehow, crystal nucleation and growth are enhanced when the molecules are not excited. According to our knowledge, this effect has never been studied for any semiconductor material except HgI_2,pbI_2[14].

Table 2 analysis of the XRD of thick HgI_2 film under different conditions

condition	hkl	G.S(n)	σ_S	ε	N_L	δ
light	**213**	**39.807**	**0.939**	**0.000528**	**291**	**6.31062E+14**
	002	**18.574**	**2.395**	**0.004019**	**623**	**2.89853E+15**
	102	**18.874**	**0.777**	**0.002274**	**614**	**2.80714E+15**
dark	**002**	**94.5**	**3.085**	**0.00076**	**209**	**1.11745E+14**
	103	**78.0**	**1.263**	**0.00047**	**254**	**1.6435E+14**
	101	**161**	**4.036**	**0.00029**	**122**	**3.81673E+13**

3-2 OPTICAL PROPERTIES

Shows the spectral transmittances for film deposited at different conditions, In figure(2), sharp increasing starts around (≈550-580nm). show that the transmittances of film deposited in dark having lower transmission and this due to the bigger grain size, Optical band gap value was deduced from the extrapolated intercept of $(\alpha\ h\nu)^2$ versus $(h\nu)$. Absorption coefficient (α) was calculated from the transmission spectra using Beer-lamberts law [15]. $\alpha = 1/d \ln 1/T$ Where α: the absorption coefficient d: film thickness T: transmission of the film.

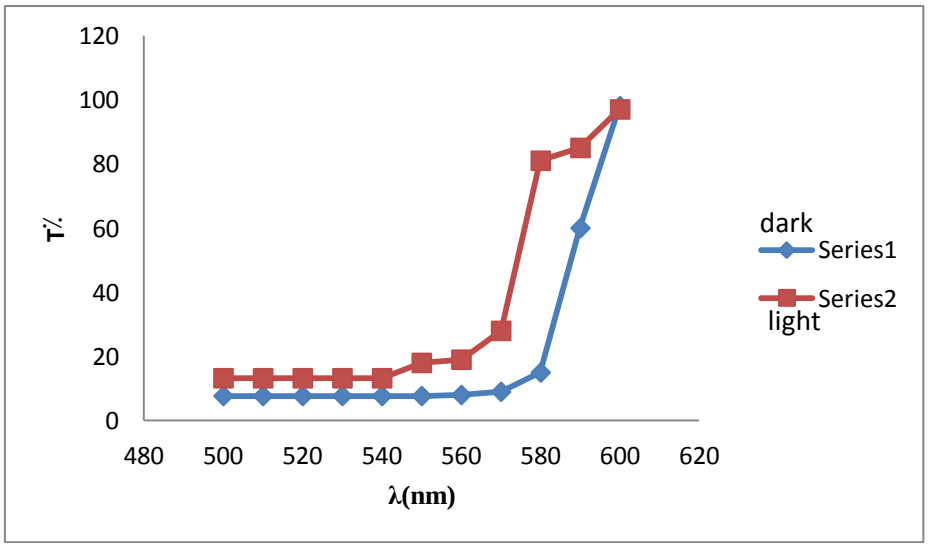

Fig (3) spectral transmittances for film HgI_2deposited at different conditions .

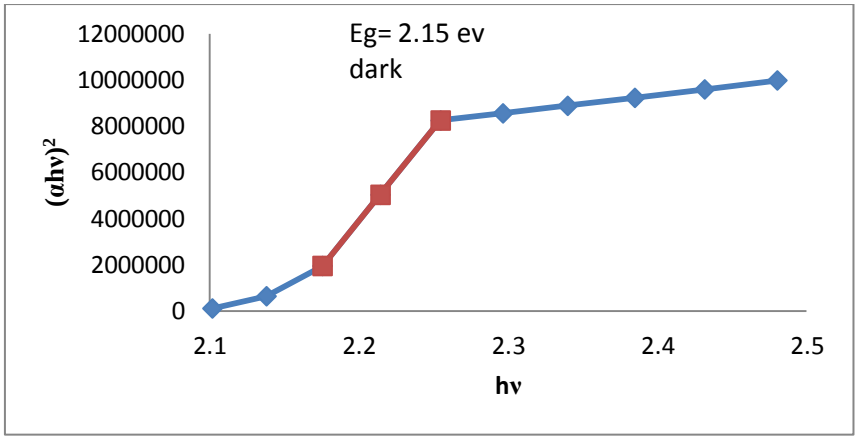

Fig (4) represent $(\alpha h\nu)^2$ versus (hν)

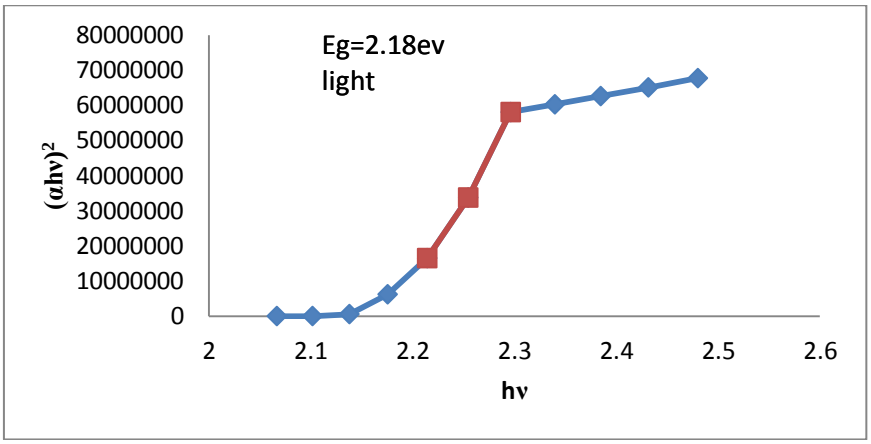

Fig (5) represent $(\alpha h\nu)^2$ versus (hν)

Electricity conductivity

The electrical conductivity was calculated from the measured electrical resistivity through the current – voltage characteristic. (Figure7-8) shows ohmic behavior of samples. The dark current of both deposition (dark, light) increased linearly with applied voltage. These currents are influenced by different factors as such as material purity and by the deposition method [16]. The presence of defects and impurities in the starting material severely affect the device performance [17][18]. It is concluded that the dark current is lower for the sample deposited in dark, while deposition under illumination gives higher dark current. The low current value for samples deposited under dark is probably due to the influence of grain boundaries. The grain size was found bigger under dark .hence the density of their grain boundaries is lower.

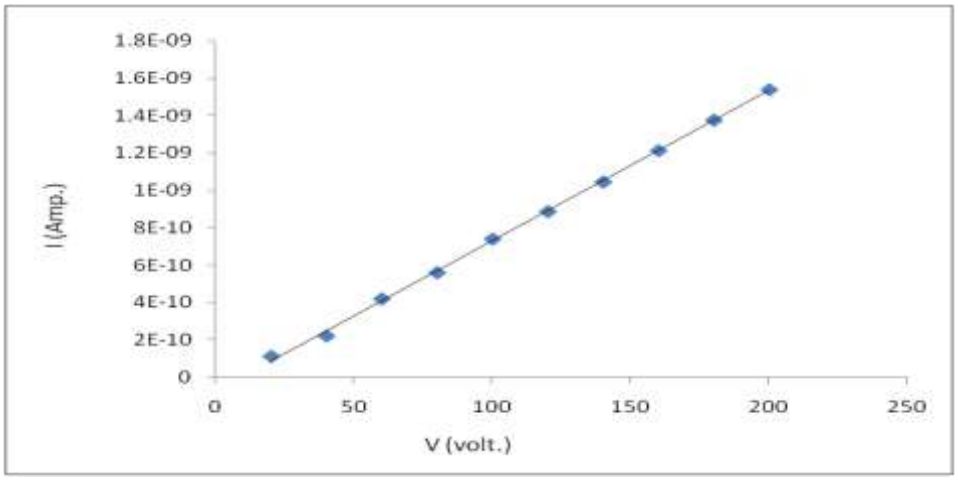

Figure (7): I-V characterization of HgI_2 thick film under light

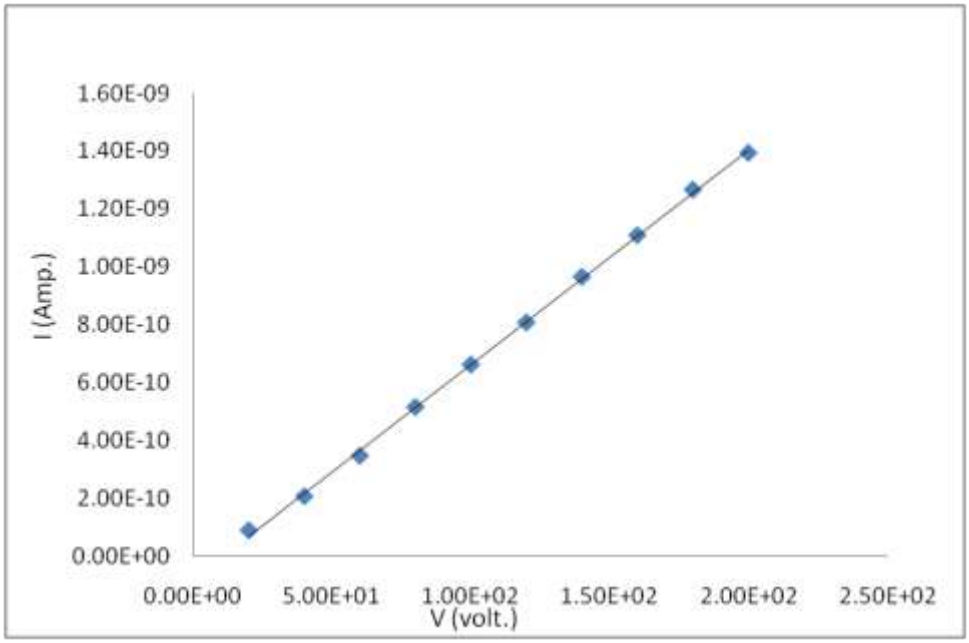

Figure (8): I-V characterization of HgI_2 thick film under dark

Table (3): The value of electrical properties of samples of thick film HgI_2

DEPOSITION	DARK RESISTIVITY(Ω. cm)	DARK CONDUCTIVITY(Ω.cm)$^{-}$
DARK	1.084E+8	9.229E-9
LIGHT	7.323E+7	2.323E-8

CONCLUSION

It has been shown that polycrystalline mercuric iodide layers with interesting properties can be prepared by means of a simple solution growth methods. All XRD patterns had the same peaks approximately. The grain size increases when deposition is carried out in darkness. The illumination impact on the chemical reaction rates had strong consequences on the resulting layer characteristics, dark resistivity at darkness is higher than at illumination, dark current is less at dark than illumination.

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