

OPTICAL PROPERTIES OF $\text{CH}_3\text{NH}_3\text{PbI}_3$ BY SPRAY PYROLYSIS WITH MOVING NOZZLE

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Abstract— Organic-inorganic perovskite based solar cells are a promising material in recent research. It is characterized by its high light absorbance regarding to other technologies. In recent research perovskite solar cells have an exponential evolution in power conversion efficiency which have reached more than 20%. In this paper we try to get optical and electrical properties for the $\text{CH}_3\text{NH}_3\text{PbI}_3$ perovskite fabricated based on spray pyrolysis method. Obtained results shows that optical properties can be enhanced using specific molarity of 2 moles and processing temperature of 100 °C.

Keywords— Perovskite $\text{CH}_3\text{NH}_3\text{PbI}_3$, Spray pyrolysis, Post-annealing, IV

I. INTRODUCTION

Recently the hybrid perovskite $\text{CH}_3\text{NH}_3\text{PbI}_3$ remains the most studied [1-3] because of its applications in deferent knowledge fields such as solar cell technology [4]. The solar absorption threshold of hybrid perovskite $\text{CH}_3\text{NH}_3\text{PbI}_3$ is compatible with solar radiation which makes them a good material for photovoltaic applications.

Several methods are used in manufacturing $\text{CH}_3\text{NH}_3\text{PbI}_3$ nanomaterials, which can be generally classified as physical and chemical methods. The $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin film can be deposited by several techniques such as pulsed laser evaporation [5, 6], physical vapor deposition [7] and spray pyrolysis method [8, 9]. Chemical-based synthesis methods are mostly adopted due to low production cost and high yield. Studies have shown that these substances are affected by several factors : the outside environment conditions, concentration, including sedimentation temperature, annealing and used method [10, 11].

Spray with amoving nozzle (SPMN) is used to uphold the heat of substrate during the elaborating period. The aim of this work is to synthesize and study physical properties of $\text{CH}_3\text{NH}_3\text{PbI}_3$, to determine the effect of the molar ratio between the concentration of iodine and methylamine iodide and to investigate the effect of temperature.

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II. EXPERIMENTAL DETAILS

A. Thin films preparation

We prepared the thin film using two ways.

In the first way, perovskite solution is prepared with mixing 0.6 ml of Dimethylformamide (DMF) and PbI_2 with different molar ratios $[\text{CH}_3\text{NH}_3\text{I}] / [\text{PbI}_2]$ according to Table 1.

Table 1: Constitution of the different perovskite solutions realized

Molar ratio [$\text{CH}_3\text{NH}_3\text{I}$]/[PbI_2]	The weight of the reactants (g)	
	$\text{CH}_3\text{NH}_3\text{I}$	PbI_2
0.5	0.05	0.286
1	0.098	0.286
2	0.196	0.286

In the second way perovskite solution is prepared according to the figure 1, in which we used deferent processing temperatures in the thermal processing step.

B. Thin films characterization

The band gap energy has been calculated through the optical transmittance spectrum using (UV-VIS spectrophotometer Shimadzu, Model 1800) operating in the wavelength 300-900nm range.

III. RESULTS AND DISCUSSION.

A. Optical properties: the band gap

Fig. 2.shows the variation of the transmittance as a function of the wavelength for three layers developed with a three molar ratio 0.5M, 1M, and 2M see table 1, the transmittance measurements were have been made in the wavelength range 250-850 nm. In the region between 600 and 850 nm, the transmittance of deposited films is in the order of 43%, 34%, and 26% respectively. Low permeability values can be

attributed to the dispersion of light from crystal defects, Tauc's relation is used:

$$\alpha h\nu = A(h\nu - E_g)^n \quad (1)$$

where α , h , ν , and E_g are the absorption parameter, Planck constant, the photon frequency and gap energy respectively. A is a constant and n is taken 1/2 in based consideration that perovskite has a direct gap. The optical absorption data was used to generate plots of $(\alpha h\nu)^2$ vs $h\nu$.

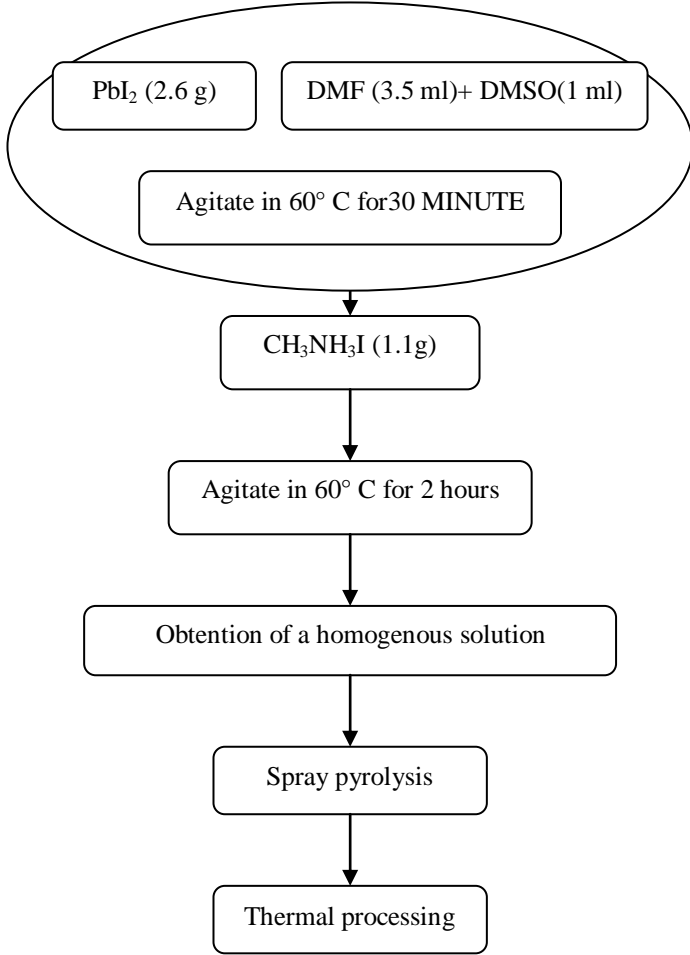


Fig. 1. Perovskite deposition in method.

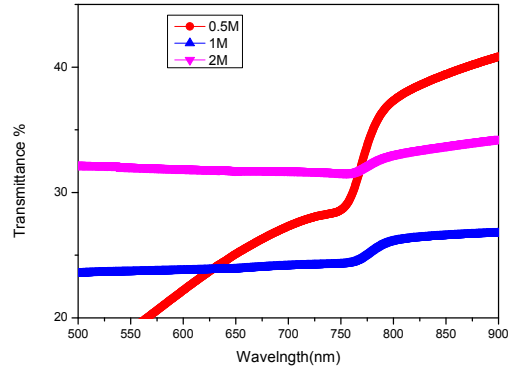
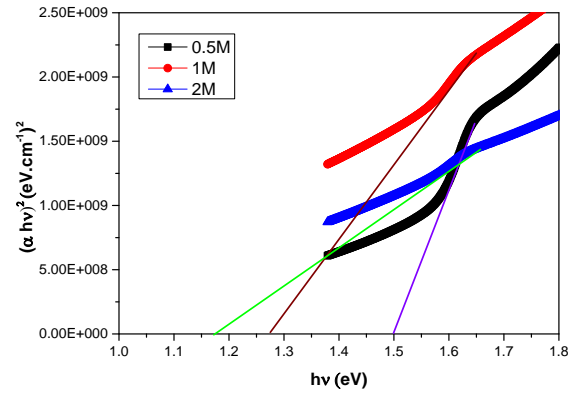


Fig. 2. Spectra of perovskite transmittance of the three films.

The band gap value increases with processing temperature increased.

Fig. 3. Curves presenting the variation of $(\alpha h\nu)^2$ in



function of $h\nu$ and direct band gap deduction for different concentrations

Photodynamic data were used to generate pieces of $(\alpha h\nu)^2$ vs $h\nu$, as shown in Fig. 3, resulting in 1.5eV bandgap voltage of the deposited film and 1.46eV, 1.54, for the first film in the first part. These values are consistent with many previous works.

B. Optical properties: Energy of Auerbach

Urbach energy E_u is a principal optical characteristic of thin film layers, it is calculated using equation (2) :

$$\ln(\alpha) = \ln(\alpha_0) + \frac{h\nu}{E_u} \quad (2)$$

From the curve drawing of a variation of $\ln(\alpha)$ in function of $(h\nu)$ we can obtain the reverse Auerbach energy using the value obtained in the straight line intersection with the abscise line.

We can conclude from table 2 that Auerbach energy decreases with processing temperature increasment, which means that the high-temperature processing gives a crystalline

stricter with fewer defects. It has a significant effect on the value of the energy separator and thus we obtain several $[\text{CH}_3\text{NH}_3] / [\text{PbI}_2]$ Note that the molar ratio of applications of the change of these properties as well as the energy of Auerbach was a small value when the molar ratio is equal. So we get well-developed slices.

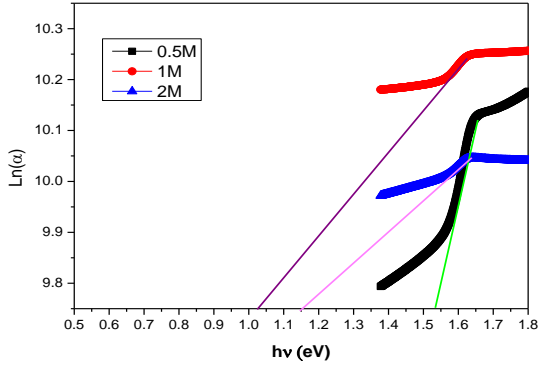


Fig. 4. curve presenting $\ln(\alpha)$ in function of (hv) and deduction of Auerbach energy values deferent Concentration

Table 2. Urbach energy, Bandgap, of as-deposited and annealed samples.

Molar ratio [CH ₃ NH ₃]/[PbI ₂]	Optical gap E_g (eV)	Urbach energy E_u (meV)
0.5M	1.50	970
s1M	1.54	869
2M	1.46	653

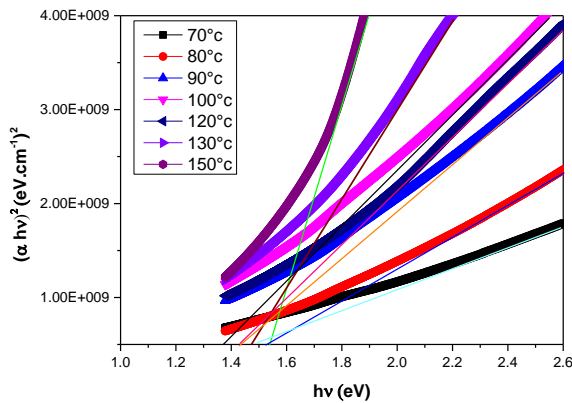


Fig. 5. Band gap (E_g) for as sprayed perovskite and annealed thin films.

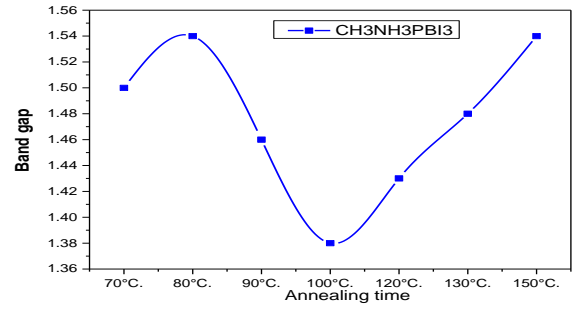


Fig. 6. Variations of energy separation in terms of energy separation in terms of temperature

Table 3., Urbach energy, the transmittance of as-deposited and annealed samples.

Annealing time	Optical gap E_g (eV)
70°C	1.50
80°C	1.54
90°C	1.46
100°C	1.38
120°C	1.43
130°C	1.48
150°C	1.54

From Figure 5, we observe that the value of the separator increases from 70°C to 80°C from 1.5 eV to 1.54 eV and then decreases to 1.38 eV at 120°C degrees and then increases to 1.54 eV at 150 eV degrees. Explain the reason for the increase in the first stage lack of crystalline defects. As for the second phase, the ratio of crystalline defects to crystallization is considered, or the third stage, we notice an increase in the value of the energy separator to 1.54 eV, which indicates that there is a relative deformation on the crystal.

IV. 4. CONCLUSIONS

Using the spray pyrolysis deposition method we can conclude from the first way processing that the better molarity concentration that gives lower energy of Auerbach is 2 Moles. Concerning temperature processing, it is concluded that the 100°C gives butter crystalline structure.

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