

Research Article

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Optical Properties of Perovskite Thin Film

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Abstract

Methyl-ammonium lead tri iodide ($\text{CH}_3\text{NH}_3\text{PbI}_3$) perovskite thin films have been prepared by solution processing. Thin film after deposited in the laboratory ambient conditions by drop casting, it prepared by two step method PbI_2 and $\text{CH}_3\text{NH}_3\text{I}$ at the glass substrate. The analysis provides: the absorption coefficient, extinction coefficient, refractive indices, real and imaginary components of the dielectric constant of the $\text{CH}_3\text{NH}_3\text{PbI}_3$ films, energy gap. Energy gap of perovskite thin films is reached 1.8 that is very important for solar cell application.

Keywords: Optical properties, Perovskite, Drop casting, Two step method.

الخلاصة

تم تحضير الغشاء الرقيق لميثيل امونيوم ثلاثي ايوديد الرصاص $\text{CH}_3\text{NH}_3\text{PbI}_3$ بعملية الاذابة. بعد تحضير الغشاء تحت الظروف المختبرية بطريقة drop casting وعلى مرحلتين لمادتي PbI_2 و $\text{CH}_3\text{NH}_3\text{I}$ على القواعد الزجاجية. اجريت التحليلات للفحوصات البصرية: معامل الامتصاص، معامل الأسترخاء، معاملات الانكسار، المركبات الحقيقية ولخيالية لثابت العزل الكهربائي وفجوة الطاقة لأغشية $\text{CH}_3\text{NH}_3\text{PbI}_3$. وتم الحصول على فجوة طاقة تصل الى 1.8 إلكترون فولت والتي تعتبر مهمة جدا لتطبيقات الخلايا الشمسية.

Introduction

Organic-inorganic perovskite of $\text{CH}_3\text{NH}_3\text{PbX}_3$ ($\text{X}=\text{Cl}, \text{Br}, \text{I}$) families have attracted extreme attention as light-harvesting materials in solar cells. Within past nine years, power conversion efficiency of perovskite solar cells has been enhanced from 3.8% [1] to 20.1% [2], which is the fastest increasing rate in the history of Solar Cells (SCs). The impressive photovoltaic efficiency of perovskite SCs attribute to their unique optical and electrical properties, such as an appropriate band gap (1.50 eV) [2] [3], high absorption coefficient [2] [4], high open-circuit voltages (1.3 V) [5], long hole-electron diffusion length (~100 nm) and excellent carrier transportation [6]. Solution-processed deposition of a thin film of perovskites may be performed using various casting methods, such as spin coating, dip-coating, doctor blading, spray coating, inkjet printing, screen printing, drop casting, slot-die coating, etc. [7]. Graetzel and co-workers have demonstrated the use of

the two-step deposition technique as a powerful technique for achieving highly efficient perovskite solar cells [8]. The two-step deposition enables better control over the perovskite crystallization by separating the perovskite deposition into the two precursors (two-step). Density Short Current (J_{sc}) is ultimately controlled by the optical absorption in the solar cell absorber layer. Accordingly, determination and interpretation of $\text{CH}_3\text{NH}_3\text{PbI}_3$ optical properties are of critical importance for the further development of $\text{CH}_3\text{NH}_3\text{PbI}_3$ solar cells. It is known well that $\text{CH}_3\text{NH}_3\text{PbI}_3$ is a direct transition semiconductor [9]. In particular; the reported absorption coefficient (α) of $\text{CH}_3\text{NH}_3\text{PbI}_3$ differs significantly in a range from $2.5 \times 10^4 \text{ cm}^{-1}$ [10] to $8.7 \times 10^4 \text{ cm}^{-1}$ [11] at 2.0 eV. Light penetration through the absorber layer and the resulting carrier generation are depends entirely on α of the absorber material [12]. An addition for perovskite SCs, organic-inorganic

perovskite are also promising materials for light-emitting diodes [13], lasers [14] and thin film electronic devices [15]. For designing thin-film optoelectronic devices, optical parameters such as absorption coefficient, extinction coefficient, refractive index, optical band gap and dielectric coefficient are very important parameters. So far, the optical and dielectric properties of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin film have been little studied. Stefaan De Wolf *et al.* [16] found a high absorption coefficient with particularly sharp onset by photo-thermal deflection and photocurrent spectroscopy. Xie Zhang *et al.* [17] fabricated the $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films by dual-source evaporation technique and studied the refractive index and extinction coefficient of $\text{CH}_3\text{NH}_3\text{PbI}_3$ layer by spectroscopic ellipsometry in the range of 300-2000 nm, the refractive index of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin film is of 2.8-3.4, respectively, in the visible range, and almost a constant (2.6) in near-infrared range. Philipp Loper *et al.* [18] investigated the complex refractive index of planar $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films at room temperature by variable angle spectroscopic ellipsometry and spectrophotometry. In the visible range, the refractive index of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin film is 2.5-2.8, and in near-infrared range, the refractive index is 2.3-2.6. Qianqian Lin *et al.* [19] achieved the refractive index and extinction coefficient in the visible to near-infrared wavelength range by a combination of spectroscopic ellipsometry, total transmittance and near-normal incidence reflectance measurements.

Materials and Methodology

Synthesis of Organic Perovskite Materials (OPM) reported in Ref [20]. Methylamine Iodide ($\text{CH}_3\text{NH}_3\text{I}$) is prepared by reacting Methylamine, 33% of weight in Ethanol (BDH-LTD), with Hydro-Iodic acid (HI) 57% of weight in water (BDH-LTD) under ice bath stirring for 2 h. Typical quantities employed are 24 ml of Methylamine, 10 ml of HI, and 100 mL of Ethanol then stirrer at 100 °C, a transparency solution is formed.

Results and Discussion

Figure 1 is explained the band gap of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films were obtained by extrapolation to zero the band gap is estimated (1.75 eV) of perovskite films which are measured in the wavelength range (400-800) nm using a (SPECTRO UV/VIS Double Beam (UVD-3500) Labomed, Inc.) and glass substrates as reference samples.

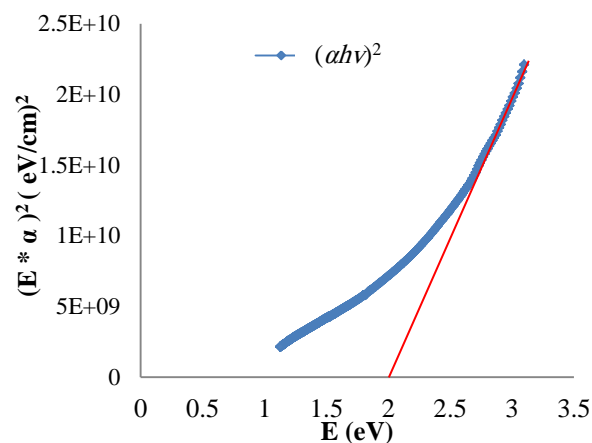


Figure1: explain energy gap of the $\text{CH}_3\text{NH}_3\text{PbI}_3$ films.

Plots inset of $(ahv)^2$ versus photon energy ($h\nu$) for perovskite layers on glass substrates are illustrated in Figure 1 a direct optical band gap energy (E_g) for perovskites material $\text{CH}_3\text{NH}_3\text{PbI}_3$ [21] [22]. The optical band gap value is obtained by extrapolating the linear part of the curve $(ahv)^2$ as a function of photon energy, $h\nu$, intercept the $(h\nu)$ axis at $\alpha=0$. The absorption coefficient α of $\text{CH}_3\text{NH}_3\text{PbI}_3$ is in a range from $4.1 \times 10^2 \text{ cm}^{-1}$ [10] to $4.8 \times 10^2 \text{ cm}^{-1}$.

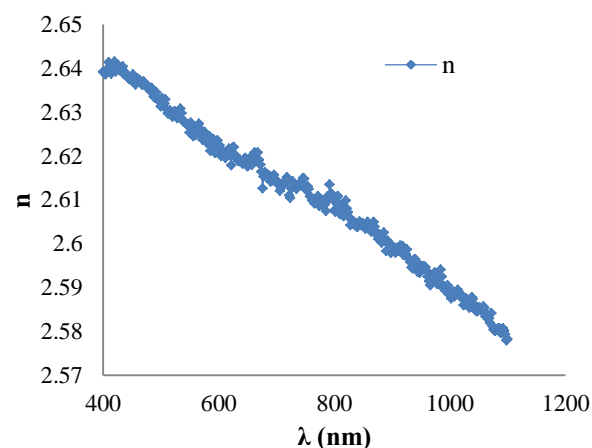


Figure 2: Refractive index curves of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films.

Figure 2 shows the dependence of refractive indices on the wavelengths. The curve of the refractive indices slowly change peak near to 2.9 is at 554 nm. The refractive indices increase from 2.56 to 2.84 at 550 nm. From 556 nm to 670 nm, the refractive index is almost a constant around 2.9, the refractive index of $\text{CH}_3\text{NH}_3\text{PbI}_3$ films imply that it is an ideal antireflection coating for silicon SCs.

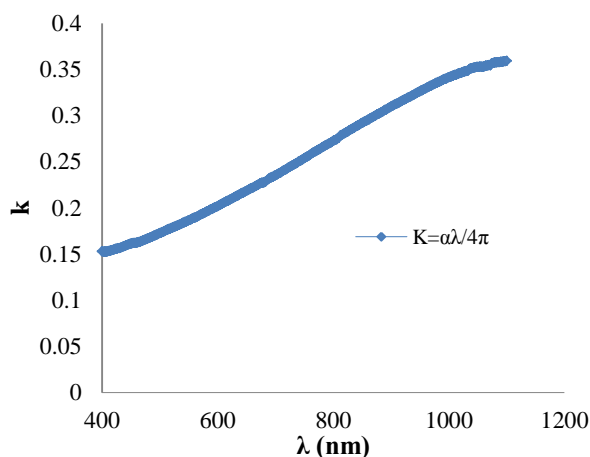


Figure 3: Extinction coefficients curve of the $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films.

Figure 3 shows the curves of extinction coefficient of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films the values of $k(\lambda)$ in the visible regions, from (400 nm to 800 nm), $k(\lambda)$ increase with wavelengths (0.15 at 400 nm to 0.27 nm at 800 nm).

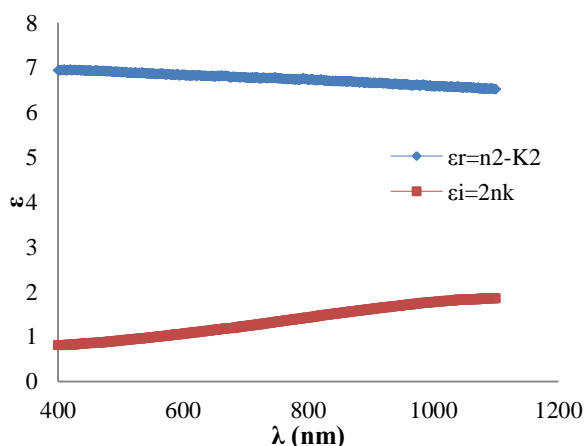


Figure 4: Real components and imaginary components of complex dielectric constant of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films.

Figure 4 shows the real and imaginary components of the complex dielectric constants of $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films. The real components follow the same pattern as the refractive indices changing with wavelengths

(Figure 3). There is a sharp peak at 350 nm. In the region of 400 nm, the real components ϵ_r increase from 4 to 9.0, then decrease to 6.18 at 400 nm. In the region of 400-530 nm, ϵ_r increase from 6.94 to 8.62. After 530 nm, ϵ_r is almost a constant near to 8.81. Our result for the real components of the complex dielectric constants is in good agreement with [22] obtained the dielectric constant of 6.5 in visible range at temperature of 4.2 K. For the imaginary component ϵ_i , slow increase from 0.8 to 1.59 in the range from 400 to 800 nm.

Conclusions

In this work, $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films with thicknesses about 1 μm were prepared. The optical properties of the films were characterized by UV-Vis absorption and transmittance spectra. The optical constants including in absorption coefficient, extinction coefficient, refractive indices. The band gap of the films is 1.7 eV which is very important to the solar cell application as harvesting layer.

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