بررسی الکترولومینسانس دیودنورگسیل پروسکایتی

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در این مقاله بکارگیری ساختار پروسکایتی آلی-معدنی بعنوان ماده نورزا دیودهای نورگسیل و صفحات روشن مورد بررسی قرار گرفته است که برای نیل این منظور خواص اپتیکی این ساختارهای آلی-معدنی بررسی می‌شود. پروسکایت $CH_3NH_3PbCl_3$ با استفاده از روشهای شیمیایی سنتز شدهو بر روی یک زیرلایه شیشهو ایندیم تین اکساید لایه ای نازک از پروسکایت $CH_3NH_3PbCl_3$لایه نشانی می‌شود تا ساختار یک دیود نورگسیل حاصل شود. تمامی مشخصات اپتیکی این دیود از جمله طیف جذب نور مرئی، طیف الکترولومینسانس و طیف فتولومینسانس فیلم نازک و طیف فتولومینسانس پودر پروسکایت نیز بررسی شده است. همچنین منحنی مشخصه ولتاژ-جریان آن مورد مطالعه قرار گرفته است.

کلیدواژه: هالید هیبریدی- پروسکایت- ایندیم تین اکساید- طیف نور مرئی- طیف الکترولومینسانس- طیف فتولومینسانس- فیلم نازک

Electroluminescent Characteristics of Perovskite Light-Emitting Diode

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Abstract- In this article, organic/inorganic hybrid perovskite asLight Emitting Diode (LED)is investigated. For this aim, optical properties of this materialshould be studied. First, we synthesize the $CH_3NH_3PbCl_3$ perovskite by chemical method and the obtained material is deposited on an ITO-glass substrate to fabricate a LED.UV Absorption, electroluminescence, and photoluminescence of perovskite powder and photoluminescence of perovskite thin film are studied.Also, the I-V characteristic of the synthesized thin film is obtained.

Keywords: Hybrid halide- Perovskite- Indium tin oxide- UV absorption spectrum- Electroluminescence spectrum- Photoluminescence spectrum- Thin film.

1. Introduction

Because of significant benefits of organic/inorganic hybrid materials such as tunable optical band gap from visible to infrared regions, easy and low-temperature solution-processing, high absorption coefficient, organic/inorganic hybrid perovskites (OIHPs)have been found different applications in optoelectronic devices, recently [1-4].

Generally, OIHPs have a three-dimensional $CH_3NH_3PbX_3$ (X=Br, I, Cl)structure [5]. OIHPs can also be a choice to usual inorganic quantum dot (QD) emitters and organic emitters [1]. Already, these perovskites have been used to construct light-emitting diodes (LEDs) [1].

Electroluminescence (EL) phenomenon (which is the consequence of radiative recombination of holes and electrons) in semiconductor structures has been the subject of several researches to characterize the emission spectra of the structure [6,7]. However, despite of numerous studies on perovskites photoluminescence (PL), the EL properties have not been fully investigated yet [1-4].

EL was presented at very low temperatures firstly, then by including an organic emitter also at room temperature [6].

Recently, it was described that 3D OIHPs show high photoluminescence quantum yield (PLQY) at strong excitation intensity [2]. It has also been shown that a device in which the OIHPs layer is sandwich in among an organic electron and hole layer results in a high photovoltaic efficiency [8].

By regulating the bandgap by replacement the cations, anions and ligand, the emission spectrum can be adjusted easily [1].

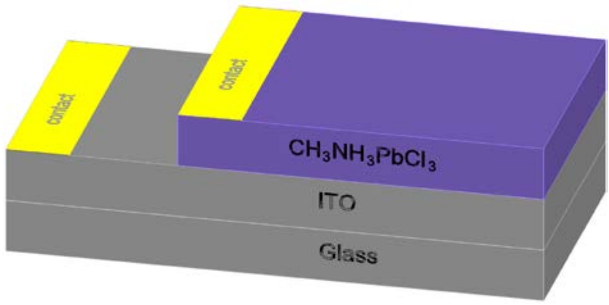

Figure 1.Device schematic considered for OLED based on $CH_3NH_3PbCl_3$perovskite

The structure of our fabricated device has been schematically presented in fig.1 which includes an ITO layer grown on the glass substrate. The $CH_3NH_3PbCl_3$ layer has been deposited on top of the ITO layer, then. The device was accomplished using Ag electric contacts [6].

In this research, we focus on the absorption, PL and EL spectra and I-V characteristic of thin film and powder-type $CH_3NH_3PbCl_3$ perovskite. Section 2 of this report includes the synthesis method of the introduced structure and the obtained results are presented in section 3.

2. Synthesis Method

Organic/inorganic perovskite of CH3NH3PbCl3 hybrids was prepared by solution-processedsynthesis method. For the synthesis of $CH_3NH_3PbCl_3$ perovskite, we first synthesized CH_3NH_3Cl by reacting 1.536mL of hydrochloric

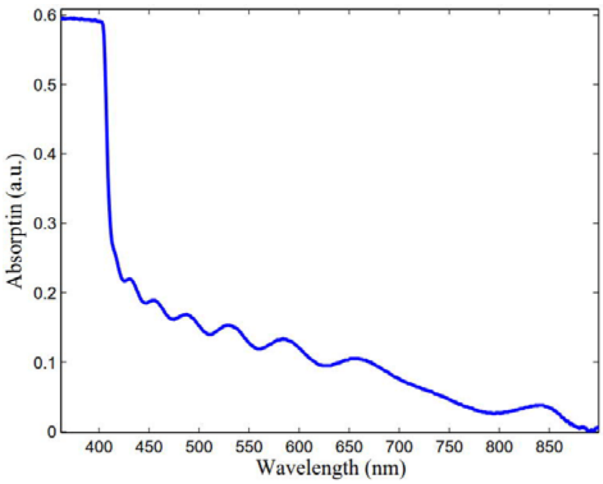

Figure 2.Absorption spectrum of $CH_3NH_3PbCl_3$ perovskite.

acid fuming (HCL, 37% extra pure, Merck) and 1.175mL of Methylamine (CH_3NH_2, 40% solution in water, Merck) in a 250-mL round-bottom flask (RBF) at 0°C (to remove reaction temperature) for 10min while stirring.We added 2.492gr of lead(II) chloride($PbCl_2$,Merck-Schuchardt) to the solution and then, let it to dry at room temperature in watch glass for 24h. The solution was thermally annealed at 60°C for a week. Finally, organic/inorganicperovskite ($NH_3CH_3PbCl_3$) was formed.

The next stage, is to deposit a layer of $CH_3NH_3PbCl_3$ perovskite on the top of the substrate. ITO-coated glass substrate was sonicated four times in soap water, distilled water, ethanol,and acetone for 20 min each and dried in the oven. After these steps, $CH_3NH_3PbCl_3$perovskite was coated on the substrate by electron beam evaporation technique at a base pressure of 10^{-5}Torr.

The UV-visible optical absorption, emission spectraof $CH_3NH_3PbCl_3$ perovskite thin film was measured using (Shimadzu UV-2450) spectrophotometer in range of 300-900 nm, and (JASCO FP-6200) spectrofluorometer at room temperature, respectively.

3. Experimental Results

Fig. 2 depicts the absorption spectra of the demonstrated $CH_3NH_3PbCl_3$thin film. Furthermore, the absorption spectra consists of a huge region of the UV zone of solar spectrum.

The electroluminescence spectra of $CH_3NH_3PbCl_3$perovskite thin film at room temperature isdemonstrated in Fig. 3. The electroluminescence spectrum has a strong peak at ~530 nm.

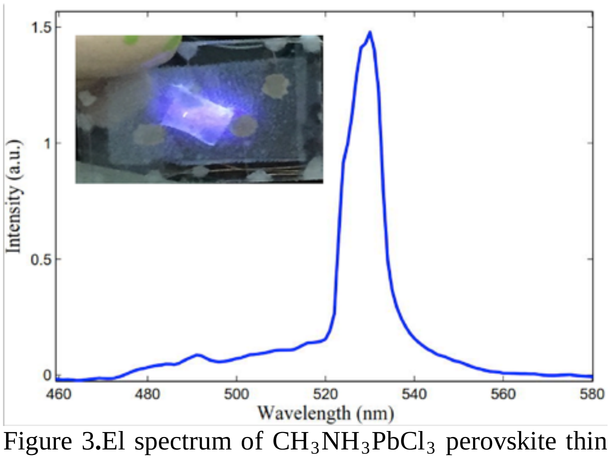

Figure 3.El spectrum of $CH_3NH_3PbCl_3$ perovskite thin film. Inset illustrates the violet electroluminescence of fabricated $CH_3NH_3PbCl_3$ LED.

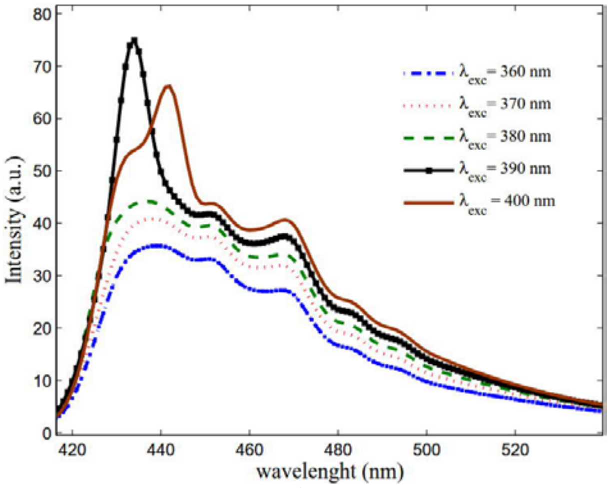

Figure 4. PL spectrum of $CH_3NH_3PbCl_3$ perovskite powder

Theconsiderable dielectricconstant distinctionbetween organic and inorganic layers results in high color purity due to the exciton restriction in the inorganic layer. The inset of fig. 3 representsshows the brightly violet light emitting diode (LED). This luminescence emission can be observed with naked eye at room temperature.

Fig.4 displays PL spectrum of $CH_3NH_3PbCl_3$ perovskite powder at different excitation wavelengths at room temperature. The PL spectrum have a broadpeak at the range of ~415 nm till ~550 nm.

The PL spectrum of thin film $CH_3NH_3PbCl_3$ perovskite at room temperature at several excitation wavelength is demonstrated in fig.5.

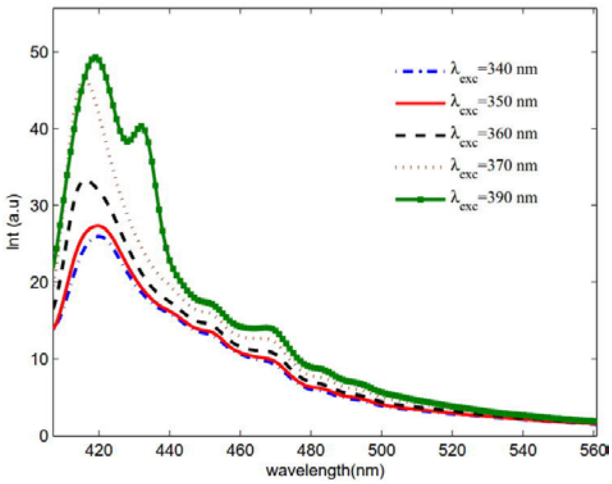

Figure 5.PL spectrum of CH3NH3PbCl3 thin film

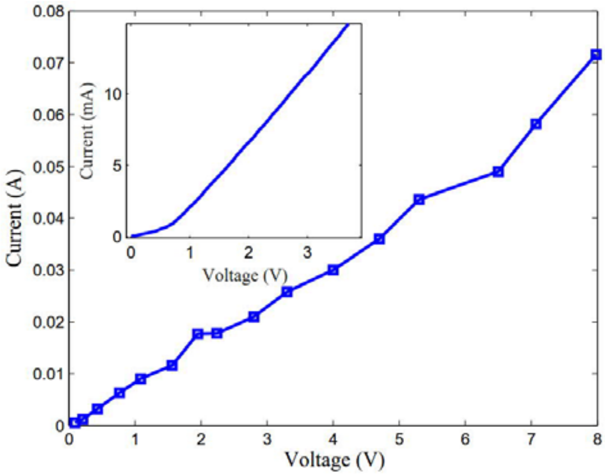

Figure 6.I-V characteristic of $CH_3NH_3PbCl_3$ perovskite thin film

The current-voltage (I-V) characteristic of CH3NH3PbCl3 perovskite thin film has been displayed in fig. 6. As I-V curve demonstrates, the $CH_3NH_3PbCl_3$perovskite thin film behaves like light emission diode (LED). The inset image is I-V characteristic of $CH_3NH_3PbCl_3$ measured by Electrical characterization system (IVM 10.15.50).In conclusion, we produced Perovskite LEDs by adopting a very careful $CH_3NH_3PbCl_3$ layer deposition. The advantages are: i) The ability to reducing the turn-on voltage (~1v), ii) sharp, color-pure emission from the Perovskite LED (FWHM~25 nm) due to a larger hole injection barrier. The improvement obtained, makes these Perovskite LEDs highly appealing for display applications.

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