

# Photoelectric properties of a multifunctional mixed ligands 8-hydroxyquinoline aluminum complex

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Green organic light-emitting diode and photovoltaic diodes were fabricated based on a mixed ligands 8-hydroxyquinoline aluminum complex. The maximum luminance was 2504 cd/m<sup>2</sup> and current density was 460 mA/cm<sup>2</sup> at 10 V. This complex is sensitive to the ultraviolet irradiation. In the optimized ultraviolet photovoltaic diode, the open-circuit voltage ( $V_{OC}$ ), short-circuit current density ( $J_{SC}$ ), fill factor (FF) and power conversion efficiency (PCE) were 1.56 V, 19.5  $\mu$ A/cm<sup>2</sup>, 0.26 and 1.99%, respectively.

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## 1. Introduction

Organic light-emitting diodes (OLEDs) have attracted much attention in recent years due to their advantages of making low-cost, flexible, lightweight, full color display and solid state lighting applications possible [1-3]. 8-hydroxyquinoline aluminum (Alq<sub>3</sub>) as a kind of electroluminescent (EL) material was widely used in OLEDs owing to its high EL efficiency and luminance, good film performance, high glass transition temperature and simple synthesis. Based on Alq<sub>3</sub>, many efforts were directed to the research of aluminum complex with mixed ligand [4-6]. Xu group synthesized a mixed ligands 8-hydroxyquinoline complex (Alq<sub>2</sub>A) (A = acetylacetone) which possesses higher electron mobility, fluorescence efficiency and good film-forming than Alq<sub>3</sub> [4]. Yuki Iwama et al. reported bis(2-methyl-8-quinolinolato)-4-phenylphenolate (BALq) as host material for OLED [5]. Lim et al. obtained white OLEDs consisting of a single light emitting layer of blue-emitting bis(2-methyl-8-quinolinolato) (triphenyl-siloxy)aluminium (III) (SAlq) doped with red-emitting 4-dicyanomethylene-2-methyl-6-[2-(2,3,6,7-tetrahydro-1H,5H-benzo [i,j] quinolizin-8-yl)vinyl]-4H-pyran) (DCM2) [6]. In the present study, we investigate the EL and ultraviolet photovoltaic performances of a mixed ligands 8-hydroxyquinoline aluminum complex (Alq<sub>2</sub>DBM) (DBM=1,3-Diphenyl-1,3-propanedione). The emission peaks of photoluminescence (PL) located at 530 nm, EL emission peak of Alq<sub>2</sub>(DBM) was also monitored around 530 nm showing green emission. The maximum luminance was 2504 cd/m<sup>2</sup> and current density was 460 mA/cm<sup>2</sup> at 10 V. In addition, this complex was utilized as an electron acceptor in ultraviolet (UV) photovoltaic (PV) diodes due to its strong absorption in UV region and

electron transport property. In the optimized UV-PV diode, the open-circuit voltage ( $V_{OC}$ ) of 1.56 V, short-circuit current density ( $J_{SC}$ ) of 19.5  $\mu$ A/cm<sup>2</sup>, fill factor (FF) of 0.26 and power conversion efficiency (PCE) of 1.99 % were obtained, respectively.

## 2. Experimental

Alq<sub>2</sub>DBM was synthesized according to the reported procedure [7]. 4,4',4''-tris(3-methylphenylphenylamino)-triphenylamine (*m*-MTDATA), N,N'-di-1-naphthyl-N,N'-diphenyl-benzidine (NPB) and 4,7-diphenyl-1,10-phenanthroline (Bphen) were purchased and used without further purification. OLED (D1) has the structure of ITO/m-MTDATA(15 nm)/NPB(40 nm)/Alq<sub>2</sub>(DBM)(50 nm)/Bphen(15 nm)/LiF(0.5 nm)/Al(200 nm). UV-PV diodes having the structure of *m*-MTDATA(30 nm)/Alq<sub>2</sub>(DBM) (20-40 nm)/LiF(1 nm)/Al(200 nm) with different Alq<sub>2</sub>(DBM) layer thicknesses of 20, 30 and 40 nm for D2, D3 and D4 were also fabricated. ITO was cleaned with the standard oxygen plasma treatment. Organic layers were deposited onto a precleaned ITO glass substrate by thermal evaporation in vacuum at  $5 \times 10^{-4}$  Pa. The evaporating rates were kept at 0.1–0.2 nm/s for organic layers, 0.1 nm/s for LiF and 1 nm/s for Al in the same vacuum run. Active area of each device were 2×3 mm<sup>2</sup>. All devices were tested in air ambient.

## 3. Results and discussion

The chemical structure was shown in Fig. 1. The electrochemical property of Alq<sub>2</sub>(DBM) was studied by cyclic voltammetry (CV) in dichloromethane solutions

with Ag/AgCl as reference electrode [8]. The highest occupied molecular orbital (HOMO) energy level of Alq<sub>2</sub>(DBM) was estimated to be 5.5 eV (HOMO =  $E_{ox}^{onset} + 4.4$  eV). The lowest unoccupied molecular orbital (LUMO) energy level of Alq<sub>2</sub>(DBM) was estimated to be 2.5 eV. The proposed energy-level diagram of D1 was depicted in Fig. 2.

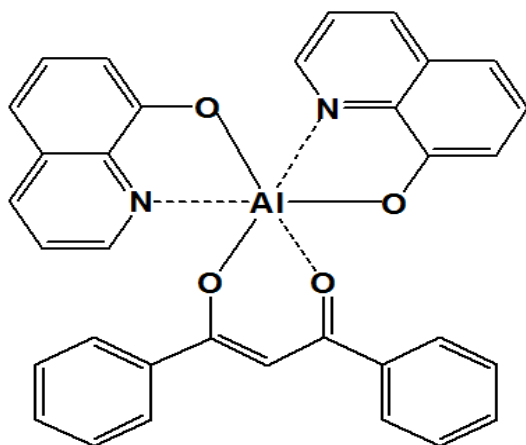


Fig. 1. Chemical structure of Alq<sub>2</sub>(DBM).

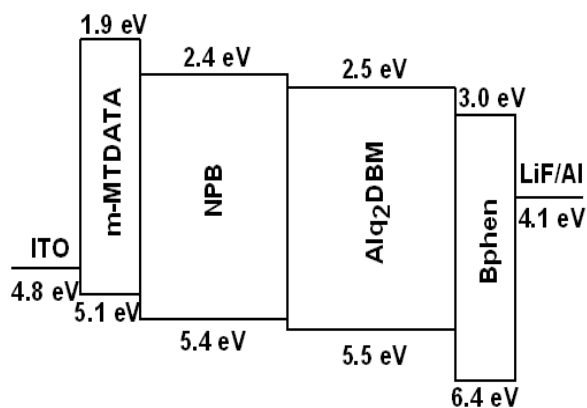


Fig. 2. Schematic energy level of D1.

The solid film of Alq<sub>2</sub>(DBM) shows green emission peaking at 530 nm, as shown in Fig. 3. Fig. 4 plots the EL spectra of D1 under various voltages and the emission peaks are also located around 530 nm in accordance with PL emission. With increase of voltage, more electrons were injected. So, the recombination zone shifted from Alq<sub>2</sub>(DBM) to NPB leading to some blueshift of EL emission peak in D1.

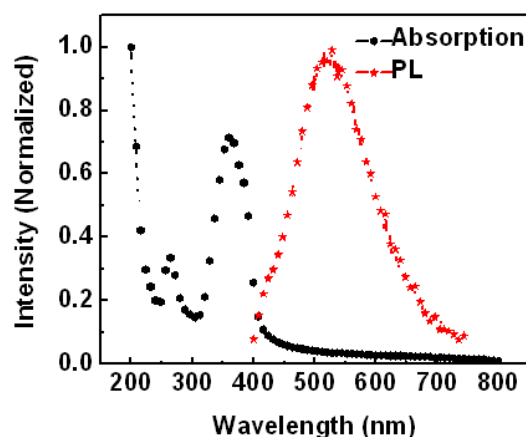


Fig. 3. Absorption and PL of Alq<sub>2</sub>(DBM) film.

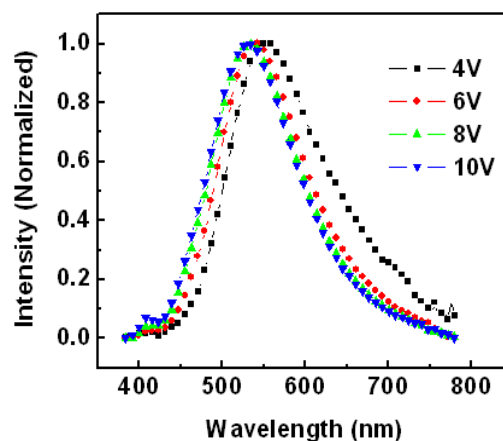


Fig. 4. The Normalized EL spectra of D1 under various volages.

Fig. 5 demonstrates the luminance and current density as a function of voltage of D1 which exhibited moderate EL performances with a low turn-on voltage of 4 V and a maximum luminance of 2504 cd/m<sup>2</sup> at 10 V.

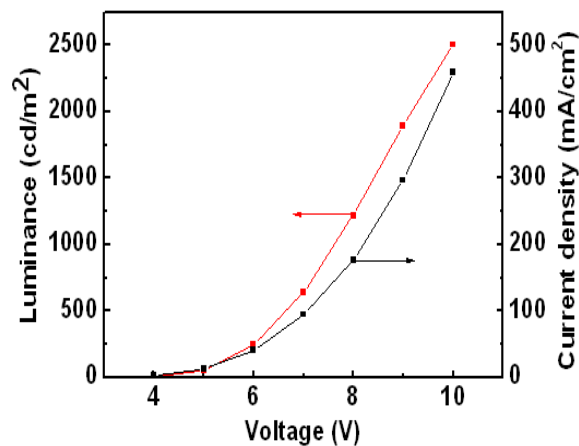


Fig. 5. The current density–voltage–luminance characteristics of D1.

Owing to strong absorption in ultraviolet (UV) zone and electron transport property of  $\text{Alq}_2(\text{DBM})$ , it could be used as an electron acceptor material of UV-PV diode. m-MTDATA was chosen as the electron donor in our study due to its low ionization potential, high hole mobility and feasible level alignment with  $\text{Alq}_2(\text{DBM})$ . The proposed energy-level diagram of UV-PV diode based on  $\text{Alq}_2(\text{DBM})$  was shown in Fig. 6. Fig. 7 depicts I–V characteristics of these three UV-PV diodes. The optimized UV-PV diode (D3) exhibited the VOC of 1.56 V, JSC of  $19.5 \mu\text{A}/\text{cm}^2$ , FF of 0.26 and PCE of 1.99%, showing moderate PV responses.

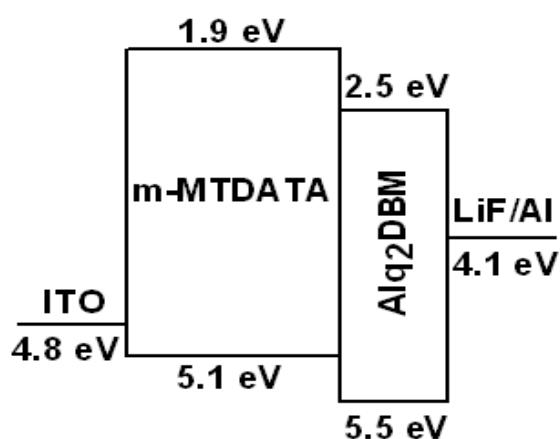


Fig. 6. Energy-level diagram of UV-PV diode based on  $\text{Alq}_2(\text{DBM})$ .

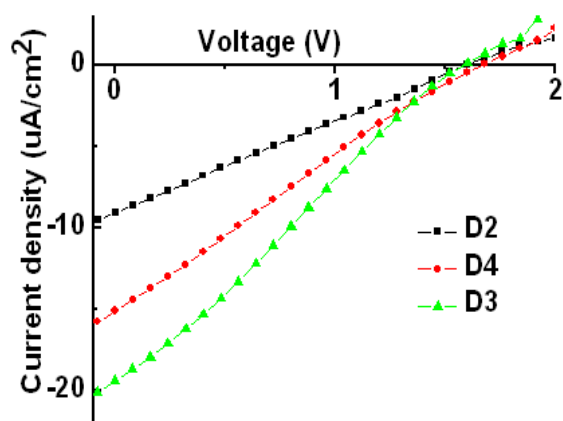


Fig. 7. I–V characteristics of the D2, D3 and D4 under irradiation at 365 nm at an incident light density of  $0.426 \text{ mW}/\text{cm}^2$ .

## 4. Conclusions

We fabricated and demonstrated green OLED and UV-PV diodes based on a mixed ligands 8-hydroxyquinoline aluminum complex. Green OLED exhibited a low turn-on voltages of 4 V and the maximum luminance of  $2504 \text{ cd}/\text{m}^2$  at 10 V. In the optimized UV-PV diode, VOC, JSC, FF and PCE were 1.56 V,  $19.5 \mu\text{A}/\text{cm}^2$ , 0.26 and 1.99%, respectively. The present results indicate that  $\text{Alq}_2(\text{DBM})$  exhibit excellent EL performance and UV-PV responses. This can offer  $\text{Alq}_2(\text{DBM})$  potential useful building block for multifunctional molecular organic UV photonic integrated circuits.

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