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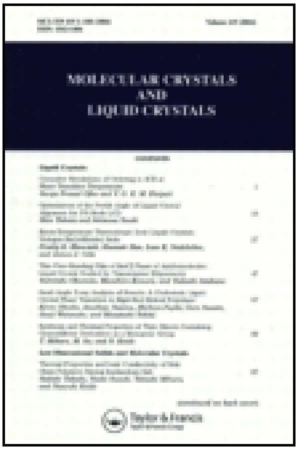

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The morphology change of polymer HTL by thermal treatment is investigated, which affects the performance of organic light emitting diodes (OLEDs). OLEDs are fabricated with the structure of ITO/Polymer HTL/Emitting layer (Alq_3)/Electrode (Al). The polymer HTL layer was treated by heat, which causes the morphology change like the aggregation of polymer HTL. The aggregation of polymer HTL due to the heat affects the turn-on voltage and lifetime of OLED.

Keywords: organic electroluminescence device; morphology; heat; aggregation

INTRODUCTION

For the commercialization of organic electroluminescence devices, two major criteria should be considered, i.e., quantum efficiency and lifetime. In the viewpoint of the importance of the hole mobility and the density in the emitting layer (EML), the number of injected holes from the anode should be balanced to enhance the EL quantum efficiency [1]. It has been considered that humidity and Joule heat would be the crucial factors mainly affecting the degradation process of the devices.

But, the time course behavior or the temperature dependency of the

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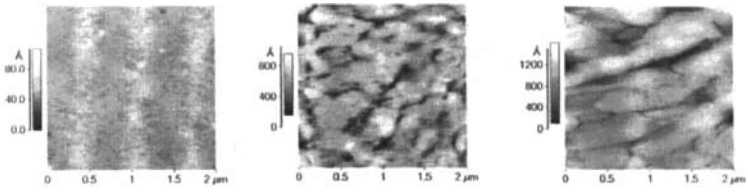
polymer HTL degradation caused by the thermal treatment has not been reported yet. In this study, the degradation processes of Alq_3 and polymer HTL were investigated by the observation of morphology change using atomic force microscopy (AFM) at the different conditions of temperature.

EXPERIMENTALS

Tris(8-quinolinolato) aluminum (Alq_3), used as light-emitting material, was purchased from Sigma Chemical Co. (St. Louis, USA). poly-N-(*p*-(3-methyl diphenylamine) phenyl methacrylamide [PMDPMA] was synthesized and used as a polymer HTL[2]. The OLED consists of ITO / HTL (polymer) / EML (Alq_3) / Electrode (Al). The polymer HTL was prepared onto the pretreated ITO glass by spin coating method. Each polymer HTL prepared onto ITO glass was thermally treated at 55 °C and 95 °C. Maximum temperature in the experiment was 95 °C due to the consideration of local Joule heat [3].

The exposure times to temperature variation of OLED were 7days and 14days. The surface morphologies of the thermally treated polymer HTL were obtained by AFM (Park Scientific Instruments, USA). The Alq_3 (EML) and aluminum electrode were then sequentially deposited onto polymer HTL by vacuum evaporation (10^{-6} torr). The I-V characteristics of the fabricated device were measured using the source measuring unit (SMU 236, Keithley, USA).

RESULTS AND DISCUSSION



(a) (b) (c)

FIGURE 1. Surface morphologies of Alq_3 films. (a) as deposited, (b) after 3days at 55°C, (c) after 3days at 95°C.

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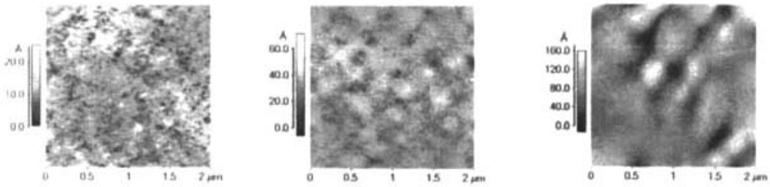
Fig. 1. shows the relationship between the morphology of Alq_3 and the thermal treatment. When the Alq_3 was deposited onto the ITO by vacuum evaporation, the morphology showed a good surface morphology [Fig 1(a)]. But Figs. 1(b) and 1(c) show that the remarkable aggregation of Alq_3 started at 3 days. The surface of the Alq_3 film became distinctive due to partial re-crystallization about 3 days later in thermal treatment.

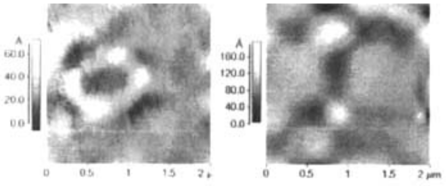
Figs. 2 and 3 show the relationship between the morphology of PMDPMA thin film and the thermal treatment. In the case of the PMDPMA films treated at 55°C, the quality of surface morphology became worse with time as shown in Fig. 2. When the PMDPMA was spin coated on the ITO layer, the PMDPMA film showed a good surface morphology [Fig. 2(a)]. But the size of aggregation became broaden and the difference of height was increased about 7 days later. Fig. 2(c) shows that the difference of height scale was about 160 Å, which means the large aggregation of PMDPMA.



(a) (b) (c)

FIGURE 2. The AFM images of PMDPMA films at 55°C. (a) as deposited. (b) after 7days. (c) after 14days.

Fig. 3. shows the relationship between the morphology of PMDPMA and the time elapse at 95 °C. It was observed that the trend in morphology aggregation at 95 °C was similar to that at 55 °C but the degree of degradation was increased.



(a) (b)

FIGURE 3. The AFM imagies of PMDPMA films at 95°C.
(a) after 7days
(b) after 14days

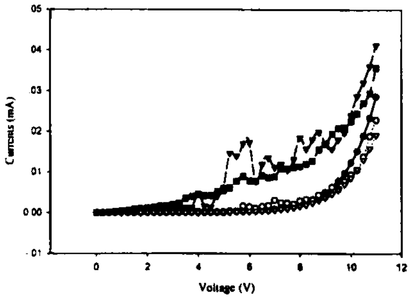


FIGURE 4. The I-V characteristic of ITO/ PMDPMA/Alq$_3$/Al with time [● :first, ○ :7days (at 95 °C), ▼ :14days (at 95 °C), ▼ :7days(at 55°C), ■ :14 days (at 55 °C)]

In Fig. 4, bounces are observed in the I-V characteristics of OLED. These irregularities were related with the thermal treatment conditions such as the variation of exposure time and temperature since the degradation of the polymer HTL would result in the decrease of the effective interfacial area for hole transport which causes the decrease of the effective recombination in light emitting layer. The aggregation of polymer HTL or irregularity of interfacial region by thermal treatment caused the increase of turn-on voltage. (Data are not shown) The turn-on voltage of the OLED which was not treated by heat was about 7V but that of the OLED treated at 95°C for 14 days was about 9.5V.

Based on the surface morphology and I-V characteristics, it could be concluded that the morphological change such as the formation of aggregation in a film is a serious problem in turn–on voltage and lifetime. In the clarification of the thermal degradation or aggregation below the glass transition temperature, the void formation should be investigated.

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