OLED Micropatterning by Plasma Etch

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Keywords: Micropatterning, Plasma etch

ABSTRACT

The micropatterning of OLED by plasma etch was investigated. The luminescence of patterned OLED micropixels was evaluated when the pixels were fabricated by photolithography and plasma etch. It was confirmed that the OLED micropixels could be fabricated by plasma etch if there is no damage on the organic material. The damage of organic material was caused by oxygen and ozone during the process. In this study, we proposed a novel method of OLED micropatterning that could be applied to fabrication of an OLED panel.

1 INTRODUCTION

Organic light-emitting diode (OLED) has a high luminous efficiency, adaptability to flexible substrates. OLED pixels can be fabricated by fine metal mask (FMM) and evaporation. This method has a problem of maskbends with a large size. It causes shadow in OLED panel. We decided to investigate a new method to fabricate OLED pixels that could be applied to large area OLED display fabrication. Plasma etch fabrication method can be better at OLED stability than other methods because the OLED materials are encapsulated before the etch process. The objective of this study is to investigate the electroluminescence and photoluminescene of micropixels to evaluate whether OLED material is damaged.

2 EXPERIMENT

To fabricate OLED micropixels OLED and cathode material were deposited on ITO glass by thermal evaporation. The structure of OLED was HATCN 60 nm, NPB 50 nm, Alq_3 40 nm, Liq 1.5 nm. Aluminum 100 nm was used as cathode. Then the layers were encapsulated by atomic layer deposition (ALD) Al_2O_3 and plasma polymer. The substrate temperature was maintained at 90 °C in ALD process and the Al_2O_3 growth rate per cycle was 1.2 Å. The plasma polymer layer was deposited in Ar plasma using n-hexane and the deposition rate was 20 nm/min. We made patterns on the encapsulation layer by photolithography. Positive photoresist (PR) GXR-601 was used for photolithography process. We used spin coater to make 1 ㎛ of coated PR. The size of each square pixel was from 10㎛/10㎛ to 100㎛/100 ㎛ that can be used for commercial OLED television. The distance of pixels was from 5 ㎛ to 100 ㎛. By changing the size and distance of pixels we could evaluate the resolution of the process. The layers on the ITO anode were etched sequentially. We used capacitive coupling plasma (CCP) type reactive ion

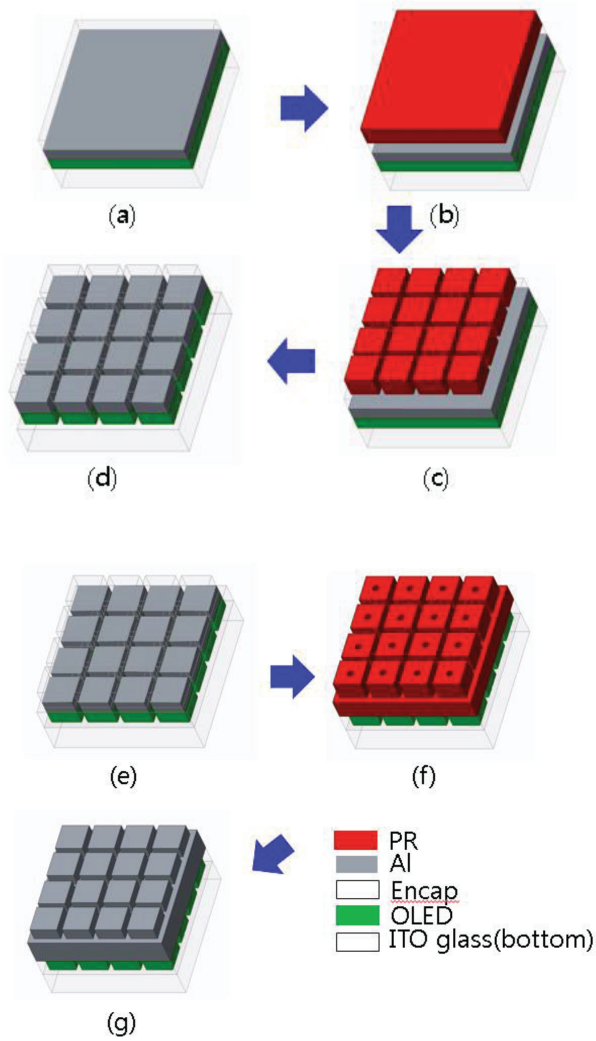

Fig. 1. Schematic fabrication process of OLED micropatterning pixels. (a) OLED, cathode deposition and encapsulation; (b) PR coating; (c) PR patterning by photolithography; (d) Etching of encapsulation, cathode, OLED layers; (e) Sidewall insulation by plasma polymer; (f) Hole patterned by photolithography; (g) Etching and second cathode deposition.

Table 1. Etch gases and conditions for each layer.

Layer materials	Film thickness	Etchant	Etching conditions
Polymer	240 nm	Ar	50 W
OLED	150 nm		30 sccm
Al	100 nm	BCl3 +	70 W
Al2O3	20 nm	Cl2	20 / 5 sccm

etch (RIE) system. Plasma polymer and OLED material were etched by Ar plasma. Al_2O_3 and Al were etched by BCl_3 / Cl_2 mixing gas plasma. The temperature of etcher was maintained at 21 °C. To emit light from the device, we needed second cathode to make an electrical contact. We insulated the device to prevent short in the second cathode deposition process by plasma polymerization. 120 nm of n-hexane polymer was deposited for insulation. With the insulation we could protect OLED layers from the environment. To make contact between first cathode and second cathode, we used photolithography. The size of each hole was 5㎛/5㎛. Then the layers on the first cathode were etched sequentially. Finally, second cathode was deposited by thermal evaporation. Electroluminescence was evaluated by optical microscope in a dark room. Photoluminescence could be evaluated without second cathode using uv lamp and optical filter having 450 nm cut-on wavelength.

3 RESULTS

Optical images were gained by optical microscope for each step. We could recognize each layer was etched vertically.

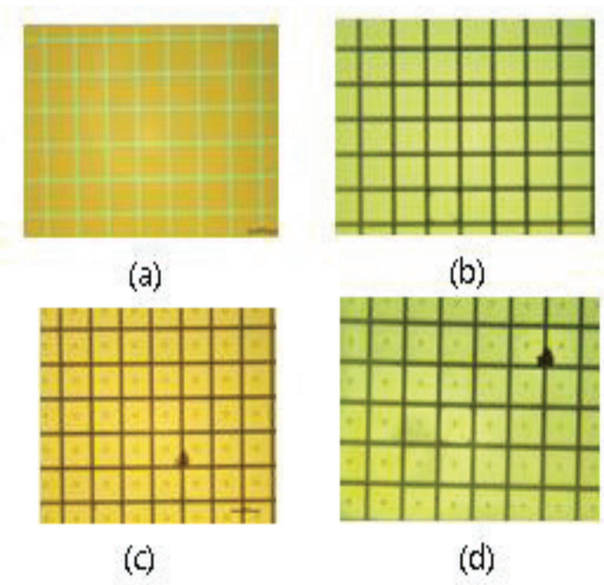

Fig. 2. Optical images of OLED micropatterning pixels. (a) PR patterning by photolithography; (b) Etching of encapsulation, cathode, OLED layers; (c) Hole patterned by photolithography; (d) Hole etching.

We used focused ion beam (FIB) and scanning electron microscope (SEM) to confirm whether first and second cathodes were electrically connected. Hole region was etched by FIB. First cathode and second cathode were connected along the SEM images.

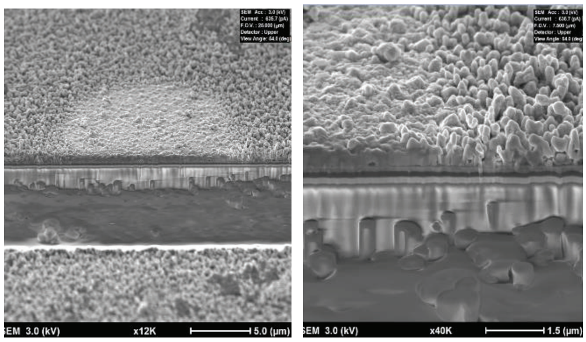

Fig.3. Cross-section images of micropixel and hole.

Electroluminescence was confirmed by optical microscope in a dark room. Pixels fabricated by plasma etch emitted green light. Based on the results, we concluded anode and second cathode were insulated. However the light emitting area was smaller than that of pixels we thought. According to optical images of each step, patterning and etching of metal cathode were conducted well and OLED materials might be damaged from the etching process.

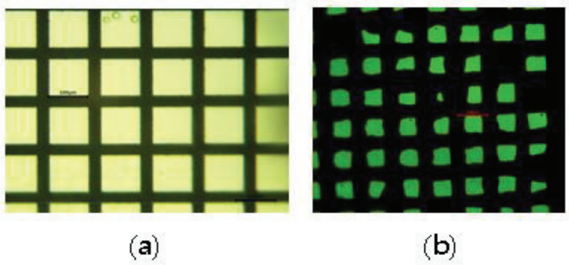

Fig. 4. (a) Optical image of cathode; (b) Optical image of electroluminescence.

4 DISCUSSION

The organic materials were damaged during the fabricating process. The damage seemed to be caused by oxidization. Oxygen was not used as an etchant in the etching process. The oxidization could be caused by ozone in ALD process and oxygen in the environment. ALD process using ozone can be replaced with SiN_x encapsulation. Environment problem can be solved when using a globe box in nitrogen atmosphere. By eliminating the effect of oxygen we would evaluate of the process again. Photoluminescence was evaluated by uv lamp. Because light intensity of uv lamp was too strong, the photoluminescence of micropixels was not captured by optical microscope. Optical filter that blocks light whose wavelength is under 450 nm would make the evaluation possible. With the evaluation, we would confirm the damage of OLED materials in the process easily.

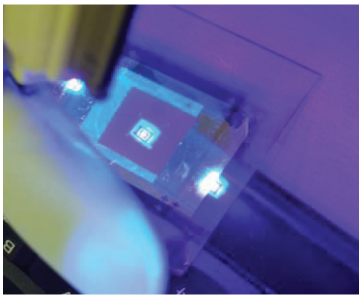

Fig.5. Photoluminescence image of micropatterned blue fluorescence OLED.

5 CONCLUSIONS

From the above results, we concluded OLED micropatterning by plasma etch is possible. Cathode connection and electrode insulation were formed well. Etch profile seemed vertical. However OLED materials were damaged during the process. The fabricating process should be conducted very carefully. Some modification in the process is also needed. By solving the problems above, the micropatterning method could be applied to large area OLED panel fabricating process. With the OLED etching method, we would be able to make OLED tile device.

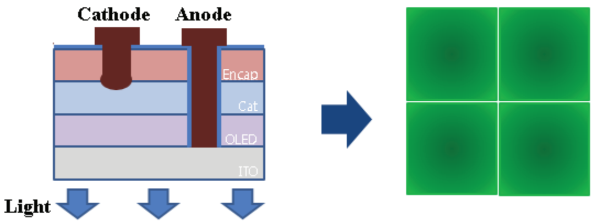

Fig.6. Concept of OLED tile device.

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