

Influences of Surface Shape of Thin Films on Electrical Characteristics of Organic Electroluminescent Devices

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Abstract: Organic electroluminescent devices are looked forward to as devices for next-generation flat panel displays, which will replace liquid crystal displays, and as environmentally friendly light sources, and aggressive research and development on them is being conducted. As organic electroluminescent devices have a multilayer structure in which organic layers are deposited on an ITO electrode, it is surmised that the shapes of the surfaces of the electrode and the organic thin films have influences on electrical characteristics and emission characteristics of the device. In this research, in addition to observation of the shapes of surfaces by AFM images of the ITO electrode deposited by vacuum deposition and sputtering and measurement of the state of element distribution and crystal structure, the shapes of the surfaces of organic films deposited on the electrodes have also been measured and the influence of the shape of the surface of the ITO electrode has been checked. Furthermore, electrical characteristics of organic electroluminescent devices with different states of interface have been measured and the influence of the state of the surface of each layer on the characteristics of the device has been studied.

Key words: Organic Electroluminescence, Surface Roughness, ITO Electrode, Organic Thin Film

1. INTRODUCTION

Research interest has focused on organic electroluminescent (EL) devices as a new next-generation flat panel display solution^{[1]~[2]}. Organic EL devices, however, have been commercialized only on a limited scale because of certain problems mainly in their intensity service life. Because the organic EL devices are structured to have organic layers deposited on a transparent electrode, their characteristics depend significantly on the surface and interface conditions of the electrode and the organic layers^{[3]~[5]}. This research work investigated the possible effects the surface conditions of the ITO electrode and the individual layers have upon organic EL device characteristics by conducting DSC, XRD and other analyses, observing their surface shapes of the organic layers through AFM images, and measuring their light absorbance, followed by measurement of their electrical characteristics.

2. ITO ELECTRODES

Table I lists the film characteristics of two types of ITO electrodes (ITO-S1, ITO-S2) used in our work. Both were deposited in the sputtering method to have a film thickness of 150 to 200 nm and a surface resistance of 10 to 23 Ω for use with organic EL devices.

3. ORGANIC THIN FILM MATERIALS

Alq₃, α -NPD, and CuPc used as organic thin film materials were subjected to thermal analyses as listed in Fig. 1. Alq₃ and α -NPD were confirmed to have their

fusing points at about 410°C and about 280°C, respectively, but no fusing point was located between 30°C and 450°C for CuPc. The material deposition temperature was established on the basis of these findings.

4. RESULTS OF EXPERIMENTATION AND THEIR DISCUSSIONS

4.1 Crystal structures and surface shapes of ITO substrates

Since crystal peaks appeared in both ITO-S1 and ITO-S2, an X-ray diffraction pattern of the ITO-S2 only is shown in Fig. 2. The pattern attested to the crystals' preferential direction (222).

Table I Film Characteristics of ITO Electrodes Used

	ITO-S1	ITO-S2
deposition method	sputtering method	
ITO film thickness [nm]	200	150
average resistance [Ω/\square]	10	20~23
dimensions [mm]	30×30	

Fig. 3 and 4 show the relations between the surface shapes of the ITO electrodes and ion etching time. Up to three cycles of etching were performed under an accelerating voltage of 300 V, each lasting 60 seconds. The ITO-S1, when etched, had its surface shape altered to microscopic blocks, whereas the ITO-S2, when etched, had its surface roughness somewhat increased with its surface detaching. Anyway, the ITO-S2 had a smoother pre-etching surface shape.

4.2 Surface shapes of organic layers

The findings outlined in 4.1 prompted us to use the ITO-S2 deposition electrode. An ITO-S2 electrode on which CuPc had been deposited was observed to have microscopic surface roughness. Organic films were deposited at varying deposition rates to correct their surface shapes. Fig. 5 shows the surface shapes of the individual organic layers. Speeding the CuPc deposition rate of 0.6 nm/sec helped remove the surface roughness of the resultant organic layers, flattening their surfaces, plus the surfaces of α -NPD and Alq₃. Satisfactory interface conditions of the layers were thus presumed.

4.3 Light absorbance of organic thin films

Fig. 6 plots the light absorbance of the ITO-S2 electrode. Light absorption was observed in the UV region at wavelengths of 320 nm or below, evidencing a far-reaching transmitted wavelength region.

Fig. 7 plots the light absorbance of organic layers deposited on the ITO-S2 electrode. Light absorption, not found in the findings of the light absorbance measurement of the electrode alone, was observed around the wavelengths of 265 nm and 340 nm, revealing that Alq₃ influenced the light absorbance. Absorption in the UV region also exerted no effects on the characteristics of the organic EL devices.

4.4 Electrical characteristics

Fig. 8 shows the relations between the surface shapes of the hole injection layers and the electrical characteristics of the resultant organic EL devices, with the device characteristics at a CuPc deposition rate of 0.2 nm/sec in (a) and those at 0.6 nm/sec in (b). Both types of devices demonstrated a current density rise from around 8 V. The deposition rate of 0.2 nm/sec delivered a current density of about 130 mA/cm² under an applied voltage of 15 V, when compared with about 30 mA/cm² at 0.6 nm/sec. Significant differences were also found in the voltage to start light emission, such that light emission was observed under about 14 V for the device deposited at 0.2 nm/sec and about 8 V for the device deposited at 0.6 nm/sec. The higher deposition rate may have smoothed the organic thin film surfaces to facilitate the hole transfer, resulting in a lowering voltage to start light emission.

5. CONCLUSIONS

Depositing hole injection layers on an ITO-S2 electrode, having exceptional surface flatness, at a deposition rate of 0.6 nm/sec may have yielded satisfactory interface conditions between the electrode and the organic layers and also between each organic layer and the next, in addition to making for a uniform application of fields. The resultant widened area of

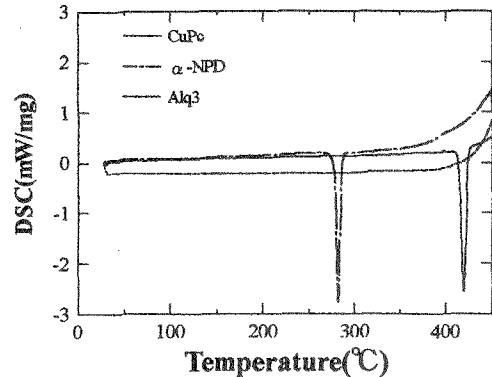


Fig. 1 Thermal Analysis of Materials

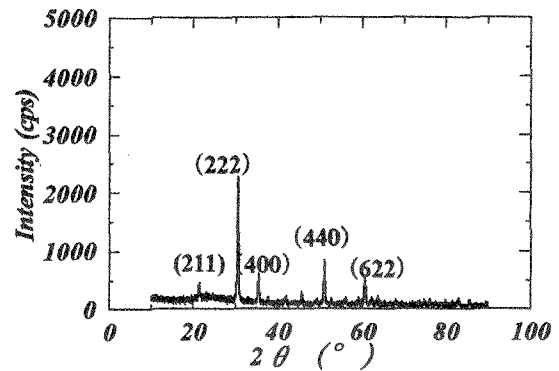


Fig. 2 X-Ray Diffraction Pattern of the ITO-S2 Electrode

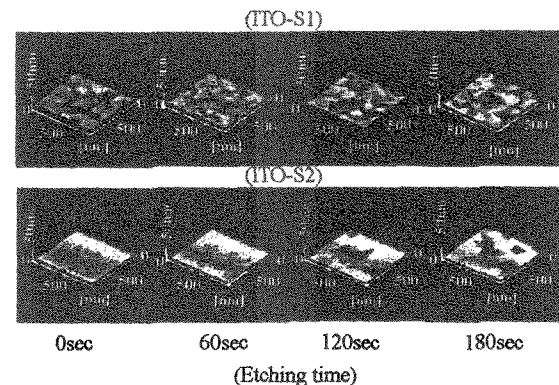


Fig. 3 Surface Shape Changes Relative to Etching Time

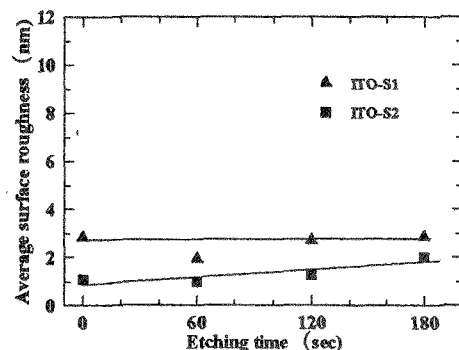


Fig. 4 Etching Time Dependence of Average Surface Roughness

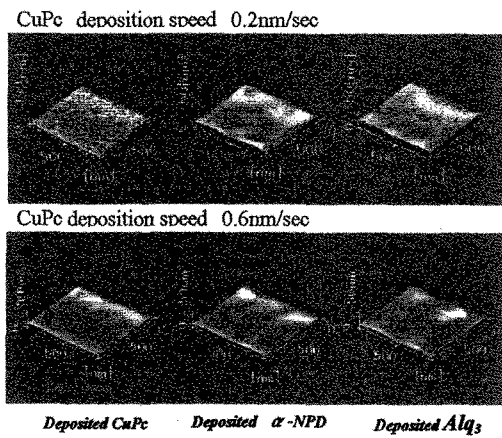


Fig. 5 CuPc deposition rate changes vs. surface shapes of organic films

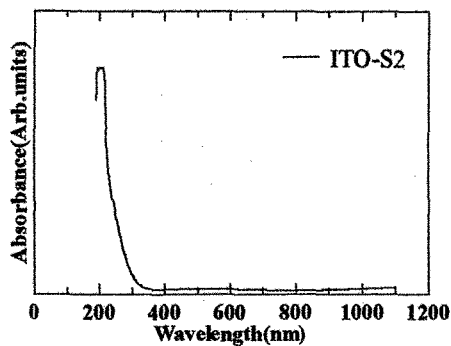


Fig.6 Light absorbance measurement of ITO Electrodes

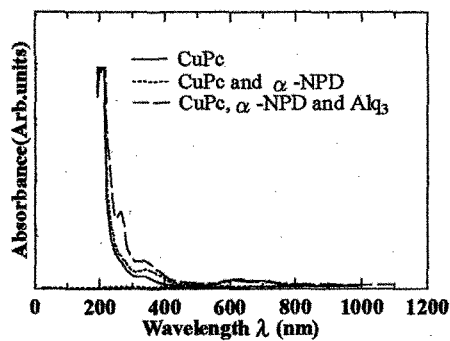


Fig. 7 Comparisons of light absorbance comparisons following organic layer deposition

contact between the electrode and the organic layers has presumably promoted hole injection, resulting in a lowering voltage to start light emission.

6. REFERENCE

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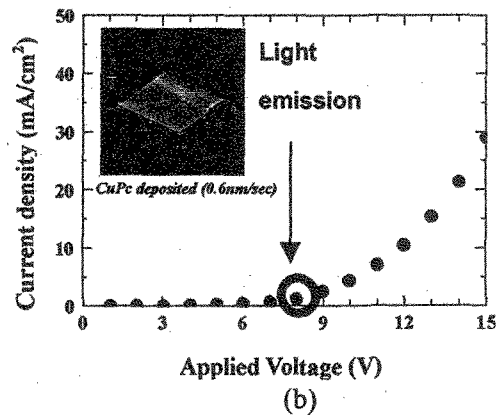
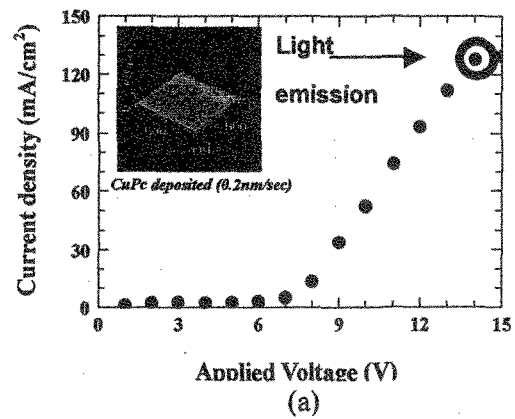


Fig. 8 Surface Shape and Electrical Characteristics of Hole Injection Layers

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