Transactions of the Materials Research Society of Japan 30[1] 253-256 (2005)

Influence of the Preparation Process on Characteristics of Organic Electroluminescent Devices

Yuichiro Kikuchi* and Shigetaka Fujita
Department of Electrical and Electronic Engineering, Hachinohe Institute of Technology
88-1, Myo Ohbiraki, Hachinohe 031-8501, Japan
Fax: 81-178-25-1430, e-mail: m03204@hi-tech.ac.jp

The next-generation flat panel display devices which are the subject of much current research contain organic EL devices. However, there are problems with the luminance and lifespan of these organic EL devices, so only some are in practical use. Because organic EL devices have a structure in which organic layers are deposited on a transparent electrode, it is believed that the surface and interface conditions of the electrode and organic layers have a significant influence on the characteristics of the devices. In this study, we paid attention to the aluminum electrode formation process to improve the characteristics of the device. Because of the structure of the device, an aluminum electrode must be deposited after the deposition of the organic layers, meaning that the organic layers have to be exposed to the air for a period of time. By improving the device, we succeeded in depositing the aluminum electrode in the same vacuum. The electric and luminance-time characteristics were compared between organic layer samples exposed and not exposed to the air. Thus, we changed the aluminum electrode formation process and fabricated devices through both the conventional and changed processes. Their electrical and luminance-time characteristics were measured to ascertain the superiority of devices fabricated in the same vacuum as the organic layers.

Key words: organic electroluminescence, organic thin films, ITO electrode, luminance, electrical properties

1. INTRODUCTION

The next-generation flat panel display devices which are the subject of much current research contain organic EL devices[(1)-(2)]. However, there are problems with the luminance and lifespan of these organic electroluminescent(EL) devices, so only some are in practical use. Because organic EL devices have a structure in which organic layers are deposited on a transparent electrode, it is believed that the electrode/organic layer and organic layer/organic layer interface conditions have a significant influence on the characteristics of the devices. In this study, we examined what influence the surface conditions of the electrode and organic layers have on the characteristics of the organic EL device. For this purpose, we carried out raw material analysis using a differential scanning calorimeter (DSC), to observe the surface shape, electrical characteristics and luminance-time characteristics of the devices, and other investigations[(3)-(7)]. In this study, the aluminum electrode formation process was altered. Because of the current structure of the device, the aluminum electrode is deposited after the deposition of the organic layers, meaning that the organic layers have to be exposed to the air for a period of time. By improving the device, however, we succeeded in depositing the aluminum electrode in the same vacuum as the organic layers. The electric and luminance-time characteristics of that device were measured.

2. THE ITO ELECTRODE

The characteristics of the indium-tin-oxide(ITO) electrode film used in this study are shown in Table I. The film was formed by sputtering, and an ITO electrode with a film thickness of 95 nm and a surface resistance of 29 Ω/□ was used. The surface shape of the ITO electrode is shown in Fig. 1. The X-ray diffraction pattern and absorbance of the ITO electrode are reported elsewhere[(3)-(4)].

Table I. Film characteristics of the ITO electrode used.

Film formation method	sputtering
ITO film thickness [nm]	95
Mean resistance [Ω/□]	29
Dimensions [mm]	30×30

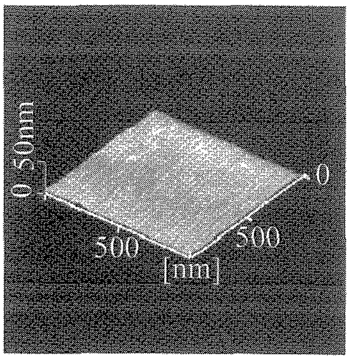

Fig. 1. The ITO electrode surface shape.

3. RAW MATERIALS FOR ORGANIC THIN FILM

Alq_3、α-NPD and CuPc were used as raw materials for the organic thin film. The formulae for their chemical structures are shown in Fig. 2. Fig. 3 shows the comparative absorbance characteristics of the various deposited organic layers. Since optical absorbance was seen near 265 and 340 nanometers, it was found that Alq_3 has an effect on absorbance. It was also found that since absorbance occurs in the ultraviolet region, it has no influence on light emission by the organic EL device. An organic thin film was fabricated based on these data. The conditions for the formation of the film are shown in Table II.

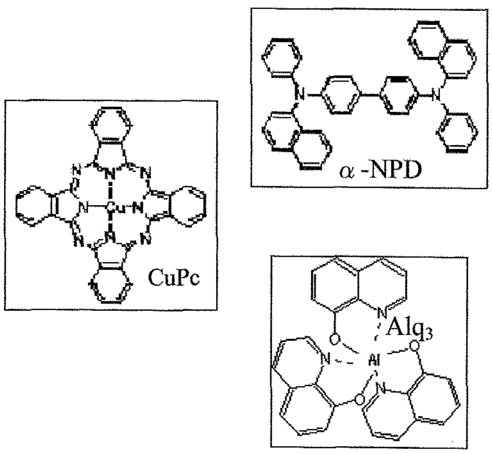

Fig. 2. Chemical formulae of organic raw materials.

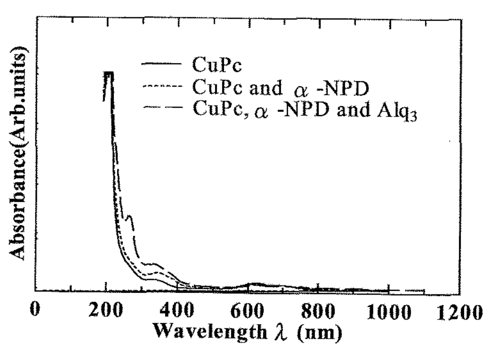

Fig. 3. Comparative absorbance after the various organic layers are deposited.

Table Ⅱ. Fabrication conditions for organic thin film.

Organic name	CuPc	α-NPD	Alq_3
Melting point (℃)	-	280℃	420℃
Film thickness (nm)	15	50	50
Deposition rate(nm/sec)	***0.1~0.3***		
	0.01~0.03		

4. DEVICE STRUCTURE

Figs. 4 and 5 show the structure and shape of the device used in this study. An ITO electrode was used for the anode and aluminum was used for the cathode, and a positive hole injection layer, a positive hole transport layer and an electron transporting light emitting layer were sandwiched between them. The anode and cathode intersected with each other, the intersecting portions being light emitting surfaces. The light emitting area was 255 mm^2. For the devices fabricated at deposition rates of 0.01 to 0.03 nm/sec, film formation control for the organic layers was exercised more precisely than for other devices. Table III shows the differences in the aluminum electrode formation process. A large difference is: for Type (a)

Table III. Aluminum electrode fabrication process.

	Type(a)	Type(b)
Fabrication method	vacuum deposition	
shape	Foil	Powder
weight [mg] /thickness [nm]	- / 0.055	150 / -
purity	99.50%	99.99%
fabrication equipment	ULVAC . Inc VPC-260F	ULVAC . Inc VPC-1100
presence/absence of film thickness gauge	absent	present
fabrication process	exposure to the air, aluminum electrode fabrication by changed fabricating equipment	aluminum electrode fabrication in the same vacuum as the organic layers

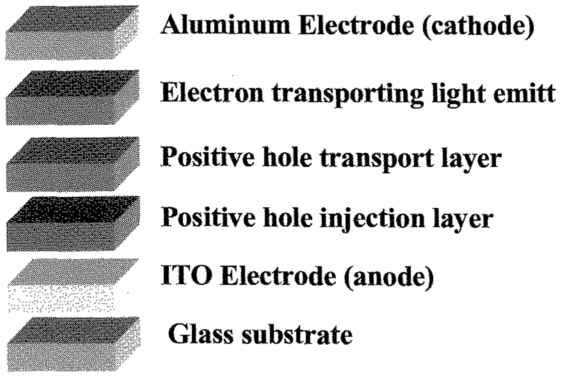

Fig. 4. Device structure.

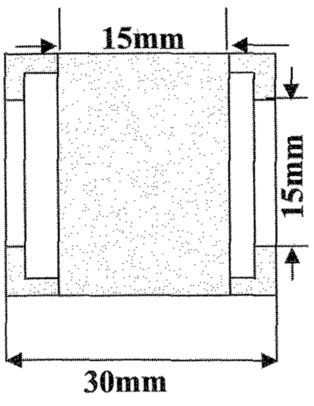

Fig. 5. Device shape.

electrodes, the organic layer sample was exposed to the air for a time when changing equipment for the deposition of the aluminum electrode, while for Type (b) electrodes, the sample was not exposed to the air because the deposition took place in the same vacuum as the organic layers.

5. EXPERIMENT RESULTS AND DELIBERATION

5.1 ORGANIC LAYER SURFACE SHAPE AT VARIOUS DEPOSITION RATES

Fig. 6 shows the organic layer surface shape at the various deposition rates. The deposition rate of the organic layer was varied, and deposition at 0.1 ~ 0.3 nm/sec and 0.01 ~ 0.03 nm/sec yielded a comparatively smooth surface. It is thought that forming a smoother surface yields good organic layer surface conditions.

5.2 ELECTRICAL CHARACTERISTICS

Fig. 7 shows the electrical characteristics for the various deposition rates. For every device, a peak of conduction current was ascertained at about 8 volts, and the manner in which the current density varied was almost the same for all deposition rates. On the devices at 0.1 to 0.3 nm/sec, device failure occurred

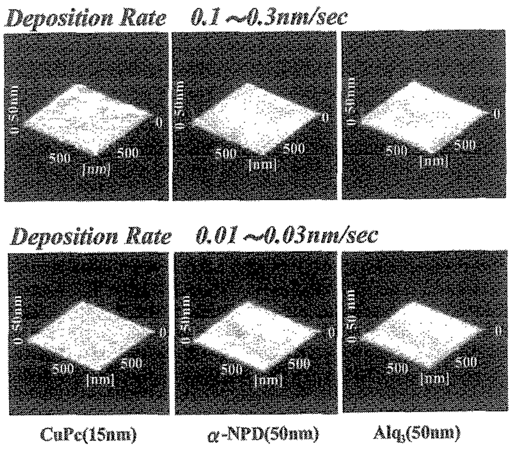

Fig. 6. Organic layer surface shape when the deposition rate is changed.

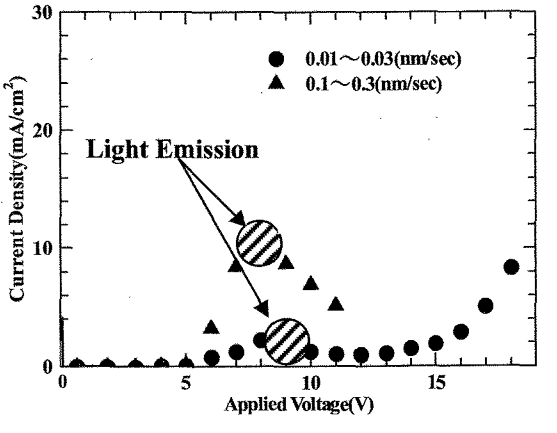

Fig. 7. Electrical characteristics when the deposition rate is changed.

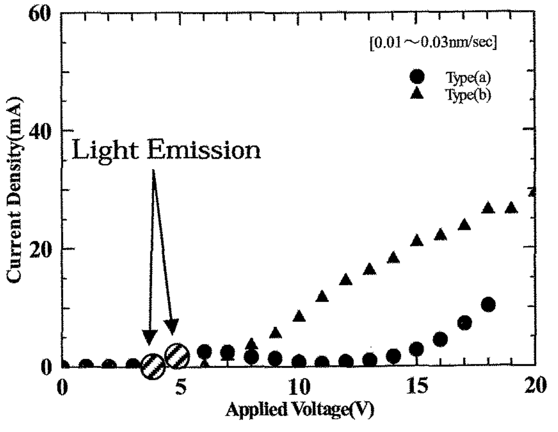

Fig. 8. Electrical characteristics when the aluminum electrode fabrication process is changed.

near 11 volts, while on the devices at 0.01 to 0.03 nm/sec, it occurred near 19 volts. It was observed that the initial emission voltage tends to increase as the deposition rate decreases. Fig. 8 shows the electrical characteristics for the device fabricated with the altered aluminum electrode formation process. It was ascertained that the initial emission voltage was lower for the device whose aluminum electrode was fabricated in the same vacuum as the organic thin layers. It is thought that if the organic layers are exposed to the air at the time of aluminum electrode fabrication, they are deteriorated by the moisture in the air.

5.3 LUMINANCE CHARACTERISTICS

The luminance-time characteristics at the various deposition rates are shown in Fig. 9. The devices at 0.01 to 0.03 nm/sec fabricated under finer film formation control than other devices showed a higher luminance than the other device. For the devices at 0.1 to 0.3 nm/sec, the luminance variations versus voltage were small, and the difference in luminance was large when compared with other devices. From the results of Fig. 9, one can derive the luminance-time characteristics of the device at 0.01 to 0.03 nm/sec fabricated with the altered aluminum electrode formation process. The results are shown in Fig. 10. The devices with an aluminum electrode fabricated in the same vacuum showed a higher luminance.

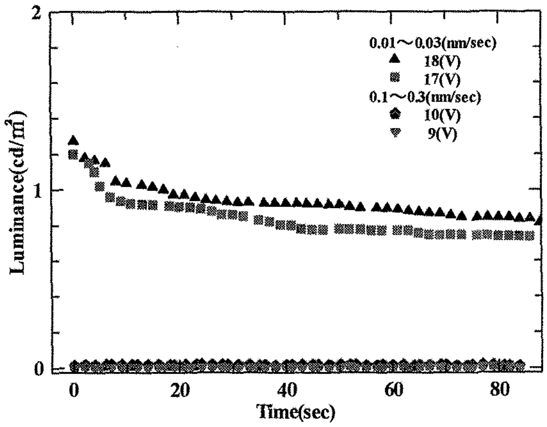

Fig. 9. Luminance-time characteristics when the deposition rate is changed.

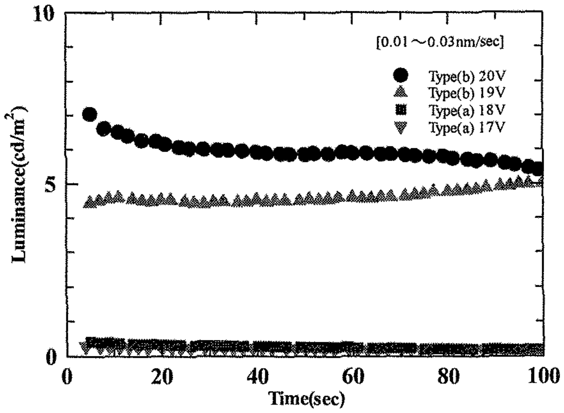

Fig. 10. Luminance-time characteristics when the aluminum electrode fabrication process is changed.

6. CONCLUSION

A high-quality organic multilayer film can be formed that is suitable for positive hole and electron movement if fine film formation control is exercised at the time of film fabrication. As a result, it is possible to apply an electric field uniformly. Therefore, injection of holes and electrons takes place efficiently. It is thought that varying the deposition rate and finer film formation control caused the differences in luminance and in the initial emission voltage. By forming the aluminum electrode in the same vacuum as the organic thin film, an organic thin film of good quality was fabricated that was not affected by the moisture in the air.

REFERENCES

[1] J. shi and C.W. tang; Appl. Phys. Lett, 70, p1665 (1997).

[2]C. Hosokawa, M. Eida, M. Matsuura, K. Fukuoka, Y. Nakamura, and T. Kusumoto; Synth. Met., 91, pp.3-7 (1997).

[3]Y. Kikuchi, K. Tanaka, and S. Fujita; Transactions of the Materials Research Society of Japan, Vol.29, No.3, pp. 1001-1003 (2004).

[4] Y. Kikuchi, K. Tanaka, and S. Fujita; Proceedings of International Conference on Electrical Engineering, Vol.1, pp.686-689 (2004).

[5]Y. Kikuchi, K. Tanaka, and S. Fujita; Abstracts 1 of IUMRS-ICAM2003, p.160 (2003).

[6] K. Tanaka and S. Fujita; Journal of IEED-J, Vol.45, pp.71-74 (2002).

[7] K. Tanaka and S. Fujita; Proc. of IDW'02, pp.1211-1214 (2002).

(Received December 24, 2004; Accepted February 2, 2005)