

Variation in Characteristics of Organic Electroluminescent Devices Caused by Changes in the Film Thickness of the Organic Layer

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Organic electroluminescent (EL) devices recently have been attracting attention primarily as elements in flat panel displays, replacing liquid crystal. Features of organic EL displays include the following: they are low power devices, because they emit light themselves, they are suitable for displaying moving pictures because of their quick response, and it is possible to make them on flexible substrate because they are thin and lightweight. However, they have problems, such as their short lifespan and low luminance, and they are still under development. In this study, we examined the thickness of the electron-transporting, light-emitting layer. We examined the changes in electric and luminescence characteristics of this layer as its thickness was varied. The results showed that the characteristics of the device are influenced by the thickness of the organic layer. We also confirmed that a certain thickness is more suitable for the structure of devices.

Key words: Organic Electroluminescence, Organic Thin Film, Electrical Properties

1. INTRODUCTION

Organic electroluminescent (EL) devices recently have attracted attention primarily as elements in flat panel displays, taking the place of liquid crystal [1]. Features of organic EL displays include the following: they are low power devices because they emit light themselves; they are suitable for displaying moving pictures because of their quick response; and it is possible to make them on flexible substrate because they are thin and lightweight. However, they have problems, such as their short lifespan and low luminance, and they are still under development. In this study, we examined the changes in the characteristics of organic EL devices when the thickness of the film of the organic layer was changed, in order to make the devices more effective.

2. PRINCIPLES OF LIGHT EMISSION

Organic EL devices are made by layering organic thin film on glass or plastic substrate [2]. They emit light under a low voltage direct current when an electric field is applied. The process by which light is emitted is as follows.

The electrons and holes which come in from an external electrode move to opposing electrodes. Excitons are generated by carrier recombination inside the organic thin film. Light is then emitted due to the transition energy produced when excited electrons and holes return to a stable state.

3. METHOD OF EXPERIMENT

A glass substrate with indium-tin-oxide (ITO) deposited on it was cut to 30 mm square, and an ITO electrode was made to the required size by chemical etching. An organic EL device was made by accumulating each of the organic layers on this electrode

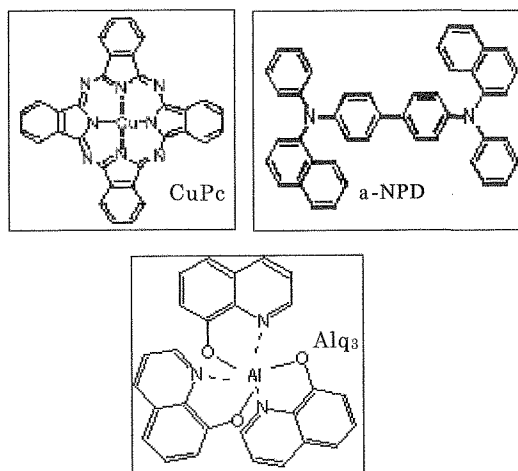


Fig. 1. Chemical structure of organic raw materials.

using vacuum deposition. In this study, we used three organic layer structures. The components of the organic layers were a positive hole injection layer (CuPc), a positive hole transport layer (a-NPD) and an electron transporting light emitting layer (Alq₃). Figure. 1 shows the chemical structures of these layers. In the structure of an organic EL device, organic layers are placed between a transparent electrode (ITO), which acts as an anode, and an aluminum electrode, which acts as a cathode. The structure and shape of the device are shown in Fig. 2 and Fig. 3. Each layer was deposited using a VPC-1100 High Speed Vacuum Coater (ULVAC KIKO Inc.). It is possible to deposit layers in the same vacuum without interfering with the state of the vacuum, because the VPC-1100 has five sources of

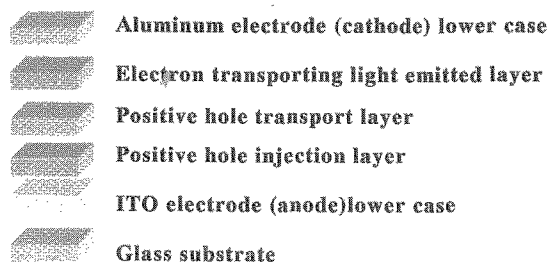


Fig. 2. Structure of the device.

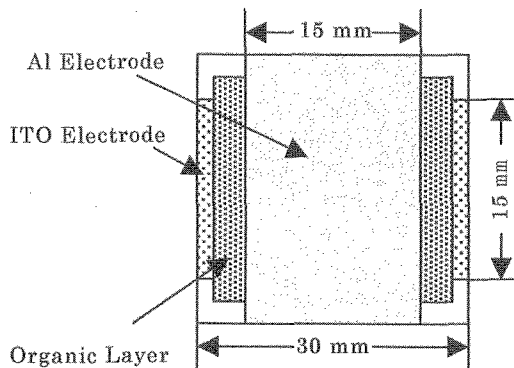


Fig. 3. Device shape.

deposition. It is possible to observe the deposition rate and the thickness of thin film using a crystal oscillator in real time. The degree of the vacuum when the organic material was deposited was about 1.0×10^{-3} Pa, and the substrate temperature was room temperature.

4. RESULTS AND DISCUSSION

Generally, organic molecules are readily influenced by atmospheric moisture. Before the preparation process was improved, the aluminum electrode was exposed to the atmosphere when it was added to the other apparatus, after the deposition of the organic layers. The organic molecules used in this study form a very thin film, so moisture is likely to have a large influence on them. We therefore used an improved process, adding the aluminum electrode in the same vacuum as was used for the deposition of the organic layer [3]. As a result, the luminance and lifespan of the device whose aluminum electrode was made in the same vacuum improved

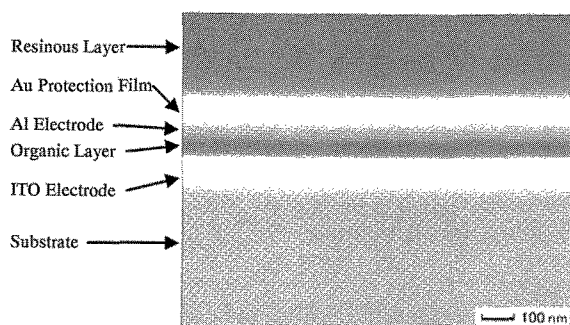


Fig. 4. A cross section of a device where aluminum electrode was deposited in the same vacuum.

significantly in comparison with devices made by exposing them to the atmosphere. Figure 4 shows a cross section of a device where the aluminum electrode was deposited in the same vacuum. It is possible to see that the surface between the electrode and the organic layer is in good condition.

Generally, in the structure of organic EL devices, each organic layer is deposited on the ITO electrode, and therefore it is necessary to examine the adhesion

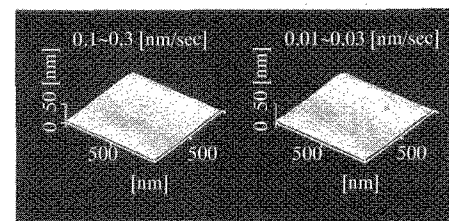


Fig. 5. Surface state of different deposition rates.

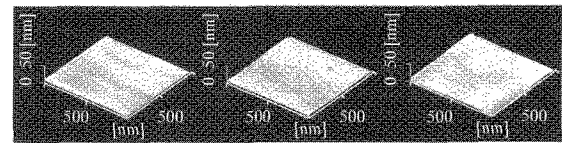


Fig. 6. Surface state of different thicknesses of the Alq₃.

between an electrode and an organic layer, and the adhesion between two layers. We therefore changed the deposition rate of the organic layer, and observed their surface using an AFM image. Figure 5 shows the surface image of the organic layer with deposition rates of 0.1 - 0.3 nm/sec and 0.01 - 0.03 nm/sec. The results showed there was little difference in the state of the surface when the deposition rate was changed. Figure 6 shows images of the Alq₃ surface produced by changing the thickness with a deposition rate of 0.01 - 0.03 nm/sec. It is possible to see that the thicker the surface is, the smoother it is.

It is thought that the Alq₃ layer influences electric and luminance characteristics. We therefore compared the characteristics of Alq₃ layers of different thicknesses. Figure 7 shows the electric characteristics of the Alq₃ layer of different thicknesses. Figure 8 shows the

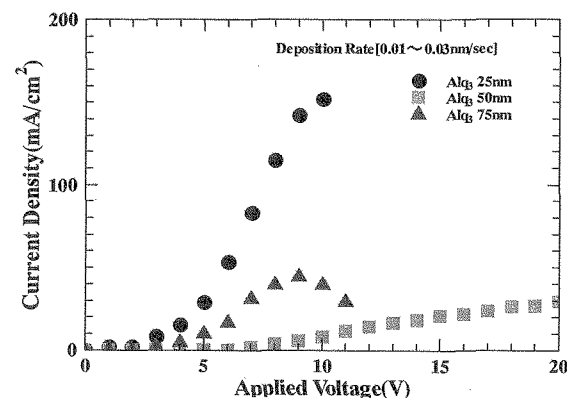


Fig. 7. Voltage-current characteristics.

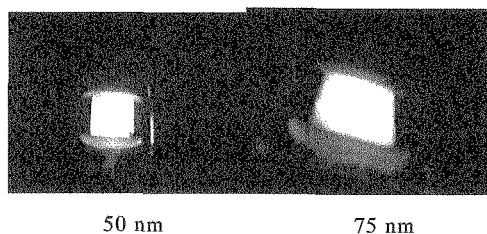


Fig. 8. Appearance of luminescence.

luminescence with thicknesses of 50 nm and 75 nm. When the thickness of Alq₃ was 25 nm, the current density increased with increases in voltage but no light emission was observed. When the thickness was 75 nm, light was emitted with a voltage of about 8 V, but current density decreased after a peak of 9 V. Good characteristics were produced at a thickness of 50 nm.

Figure 9 shows the relationship between the applied voltage and electric field strength at different thicknesses. The voltages at which luminescence was

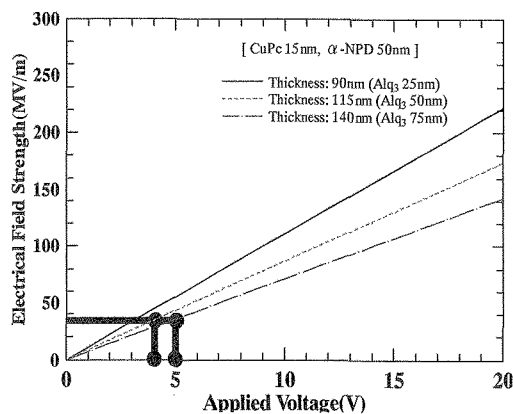


Fig. 9. Applied voltage-electric field strength.

first produced by Alq₃ layers with thicknesses of 50 nm and 75 nm were 4 V and 5 V respectively, but the electric field strength was the same. The current density increased immediately after emission began.

Figure 10 shows the characteristics of luminescence over time with different thicknesses. The lifespan of the Alq₃ layer was shorter when it had a thickness of 75 nm

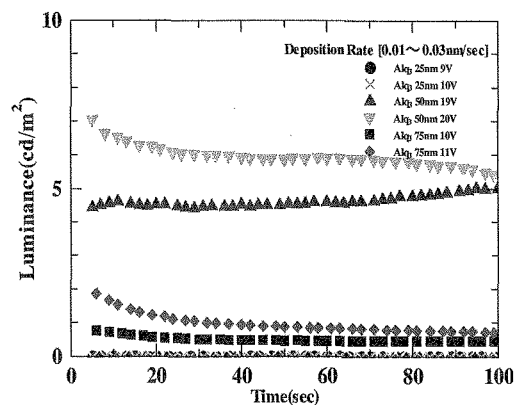


Fig. 10. Luminescence-time characteristics.

and it produced less luminescence than a layer of 50 nm. The voltage at which luminescence began was higher for 75 nm than for 50 nm. On the other hand, when the thickness was 25 nm, luminescence was not produced. From these results, it is thought that when the thickness of Alq₃ is 50 nm, electrons and positive holes recombine efficiently. It was confirmed that in a device with an Alq₃ layer with a thickness of 75 nm, luminescence began when voltage was applied to short-circuited elements after the device had been made. It is thought that this is due to the device returning to an insulating state, because the electrode in the short-circuit gave off Joule heat when voltage was applied.

5. CONCLUSION

In this study, we changed the thickness of the organic layer (Alq₃) of organic EL devices, to give them a higher luminance and longer lifespan. We were able to confirm that a smoother surface state was produced with greater thicknesses. Based on an evaluation of the characteristics of the device, we confirmed that the recombination of electrons and positive holes was influenced by the thickness of the organic layer.

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(Received December 21, 2005; Accepted January 31, 2006)