Organic Thin Film EL Device with Plasma-Polymerized *N*-Ethylcarbazole as Hole Transport Layer

Masayuki KURAJOU, Ran ZHAO*, Kenji TANAKA, Yoshiharu MAEKAWA***, Minoru KUSABIRAKI**** and Masao AOZASA*****

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Synopsis

We fabricated an organic EL device with plasma-polymerized *N*-ethylcarbazole(PPCz) as a hole transport layer and 8-hydroxyquinoline aluminum(Alq_3) as an emission and electron transport layer. Optical gap and ionization potential of PPCz and luminance characteristics of the device were investigated.

KEYWORDS: Organic EL device, Plasma-polymerized film

1. Introduction

In the application of organic EL device to flat panel display, the importance of full color capability for its competitiveness with other display technologies has been increasing.[2] Remarkable improvement in efficiency and luminance of organic EL device has been reported .[1] Polymer and ordinary molecule can be used as active layer and carrier transport layer in organic EL device. Polymer EL device have attracted much attention in recent years due to their application to large-area, flexible, and low-cost display. [3] To deposit such polymer thin films, several thin film deposition techniques have been used. One of the important techniques is the plasma-polymerization method.[4]

Plasma polymerziation method has many advantages as follows. It can prepare uniform film with few pinholes at low substrate temperature. The film thickness can be well controlled and many monomers are available.[3] In this study, we fabricated double-layer organic thin film EL device [ITO/PPCz/Alq_3/Al] and single-layer EL device [ITO/Alq_3/Al]. The energy band diagram and luminance characteristics of EL devices were also evaluated.

2. Experimental

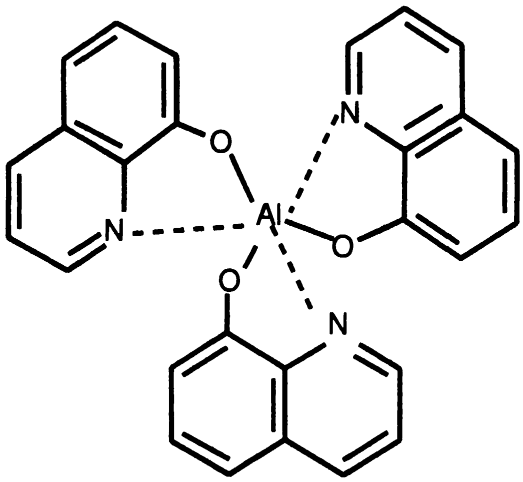
The structures of *N*-ethylcarbazole for hole transport layer and Alq_3 for emission and electron transport layer are shown in Fig. 1. Figure 2 shows the schematic diagram of EL device used in this work for investigating the characteristics. An indium-tin-oxide(ITO) coated on the substrate is transparent electrode, which was typically 300 Å thick with a sheet resistance of about 100 Ω/sq. The ITO coated glass substrate was preliminarily cleaned by scrubbing, sonication, and irradiation in a chamber.

N-Ethylcarbazole monomer which had previously been distilled under reduced pressure was maintained in a reservoir, and all the deposition system was evacuated to the pressure below 10^{-3} Torr. Then the monomer reservoir was warmed and the monomer vapour was introduced into the reaction chamber through a needle valve untill the vapour pressure rose to the predetermined value. A DC discharge was sustained and the PPCz film was formed on the conductive ITO coated glass substrate, which acts as a hole transport layer. Next Alq_3 was deposited as an emission layer which

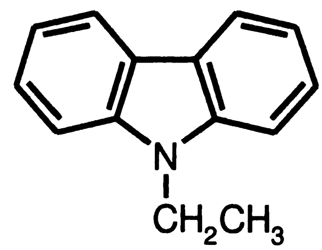
*Student, Master Course of Dept. of Electrical Engineering
**Research Associate, Dept. of Electrical Engineering
***Lecturer, Dept. of Electrical Engineering
****Associate Professor, Dept. of Electrical Engineering
*****Professor, Dept. of Electrical Engineering

simultaneously acts as an electron transport layer. An aluminum electrode was deposited as a top electrode. The emission layer and the aluminum electrode were deposited by conventional vacuum evaporation(10^{-6} Torr) method.

A double-layer EL device was fabricated by the method desercibed above. In order to clarify the characteristics of the double-layer device, Alq_3 single-layer EL device was fabricated.

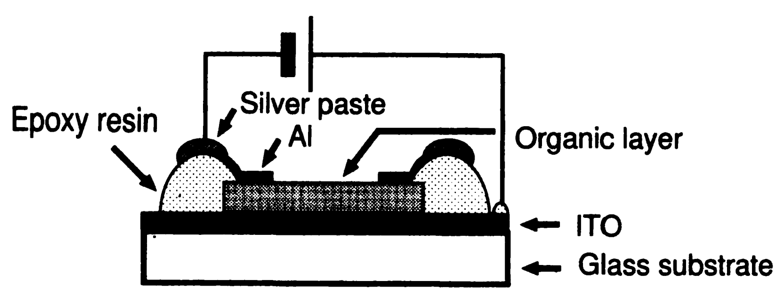


(a) Alq_3



(b) *N*-ethylcarbazole

Fig. 1 Molecular structures



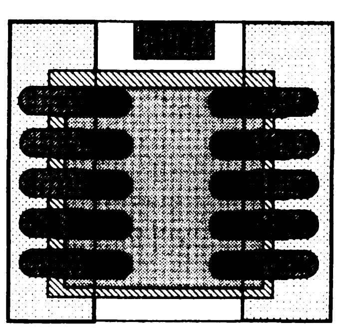


Fig. 2 Structures of organic thin film device

The electronic absorption spectra of the organic compound were determined using a conventional ultraviolet-visible spectrosmeter. Highest occupied molcular orbital-lowest unoccupied molcular orbital(HOMO-LUMO) energy gap values were obtained from the lower energy threshold of electronic absorption spectra.

The top level of the valence band of the organic compounds and work function of ITO and Al were measured by using X-ray photoelectron spectroscopy(XPS). The energy difference between vacuum level and valence band is the ionization potential.

3. Experimental Results and Discussions

3.1 Energy levels of the materials in the EL device

Table 1 shows energy levels of the material in the organic thin EL device in this experiment. Using these data, we can draw an energy band diagram of the double-layer EL device as shown in Fig. 3.

Table 1 Energy Levels

material	I_p(eV)	E_g(eV)	$I_p - E_g$(eV)
ITO	4.8		
Al	4.1		
Alq_3	6.1	2.6	3.6
PPCz	5.6	3.0	2.6

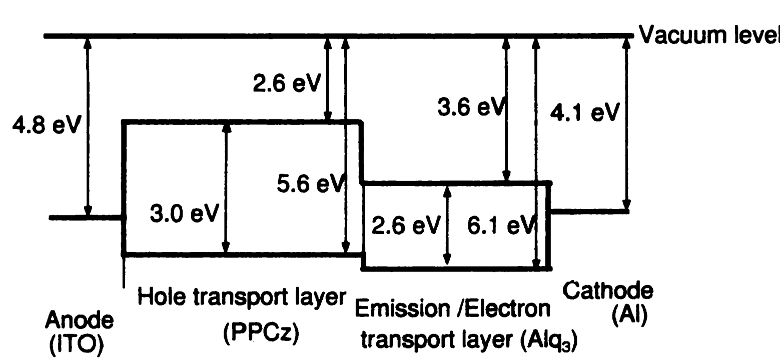


Fig. 3 Energy band diagram of double-layer organic EL device

3.2 Luminance-voltage characteristics

Luminance-voltage characteristics of double-layer EL device with PPCz as a hole transport layer are shown in Fig. 4.

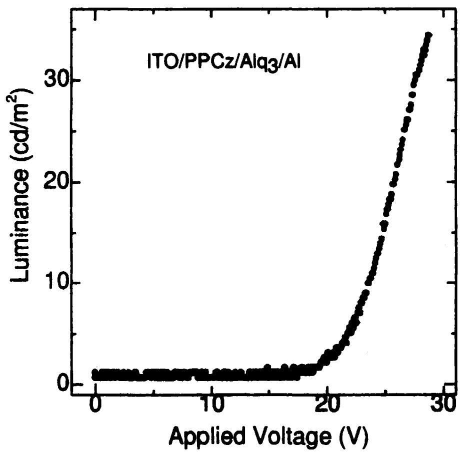


Fig. 4 Luminance-voltage characteristics

Applying the positive voltage to the ITO is called forward bias, and applying the positive voltage to the upper electrod is called reverse bias. Current increased rapidly in the case of forward-bias at 20-25V. On the other hand, the current hardly flew when the reverse-bias was applied. That is, the formed EL device showed rectifying characteristics of diodes.

The rectifying characteristics were also obtained in the single-layer EL device.

3.3 Luminance-current characteristics

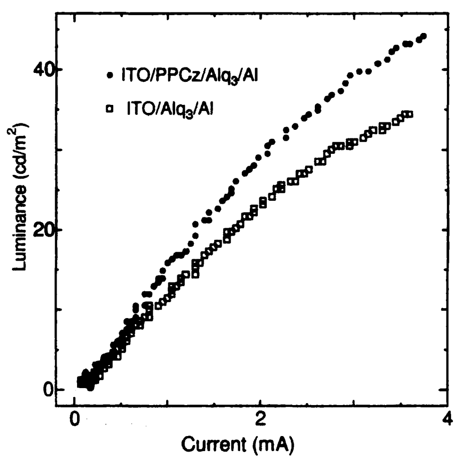


Fig. 5 Luminance-current characteristics

The luminance-current characteristics of double-layer EL device with PPCz as hole transport layer and single-layer EL device are shown in Fig. 5. A concept of hole transport layer has been found effective in a red-emitting device and also in a green- and yellow-emitting ones. [5]. The effect of a hole transport layer is to confine electrons within an emitting layer and to improve recombination probability. Fig. 5 shows that PPCz layer is effective for Alq_3 green-yellow-emitting device. The emission efficiency of the double-layer EL device with PPCz is higher than that of single-layer EL device.

3.4 Luminance decay characteristics

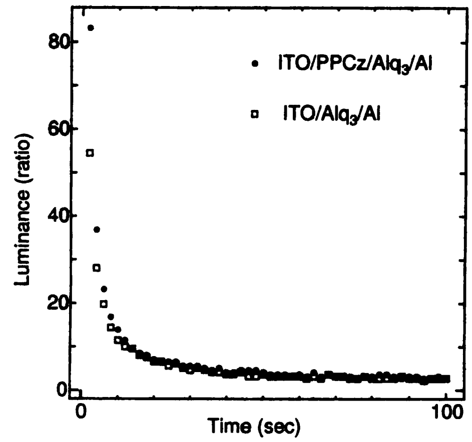


Fig. 6 Luminance-time characteristics

The luminance decay characteristics of double-layer EL device with PPCz as hole transport layer and single-layer EL device are shown in Fig. 6. The stability does not change even if PPCz layer is used.

Conclusions

The conclusions can be summarized as follows :

1. Green- yellow emission could be observed in a double-layer EL device with PPCz.
2. Plasma polymerization method could be utilizated in producting organic EL device.
3. Energy band diagram of the double-layer EL device was drawn from XPS data.

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