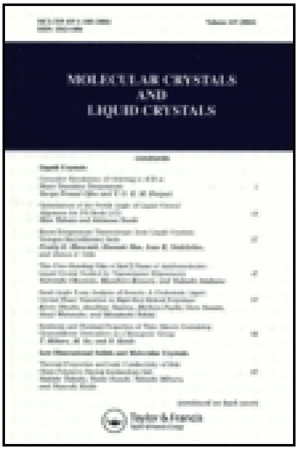

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LONGEVITY OF ORGANIC LIGHT-EMITTING DEVICES BY MEANS OF POLYACRYLATE PASSIVATION LAYERS FORMED BY USING SPIN COATING METHOD

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LONGEVITY OF ORGANIC LIGHT-EMITTING DEVICES BY MEANS OF POLYACRYLATE PASSIVATION LAYERS FORMED BY USING SPIN COATING METHOD

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We fabricate organic light-emitting devices with polyacrylate passivation layers formed by using spin coating method and compare the rate of degradation to an organic light-emitting device without the passivation layer. The fabrication process of passivation layer did not influence the electrical and the emissive properties of the device. Polyacrylate passivation layers enhanced the longevity of the device than that of the non-encapsulated device, and its behavior was dependent on the polyacrylate film thickness.

Keywords: Encapsulation; life time; passivation layer; polyacrylate

INTRODUCTION

Since organic light-emitting device (OLED) was first reported in 1987 [1], much attention has been paid to OLEDs due to their possible use in a wide range of display applications [2–6]. However stability of OLED is still a major problem, which should be overcome in order to realize the practical use of OLED. There have been many research efforts aimed at understanding the degradation mechanism in unencapsulated OLEDs [6–10]. The lifetime of OLED is remarkably limited in the presence of moisture and oxygen. Therefore, to achieve longevity of OLEDs, it is very important to protect OLEDs from diffusion of moisture and oxygen into the cathode electrode and the organic layers.

Among various encapsulation methods [10–14], a hermetic encapsulation technique using a glass or metal lid and ultra-violet (UV) cured epoxy

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*Corresponding author. E-mail: kimgh411@etri.re.kr seal has been extensively explored. However, this method is very expensive to fabricate and require extensive labor to assemble. Further, this is large and heavy, which severely limit applications of OLEDs. Therefore there is a need for simple and efficient encapsulation of OLEDs, which is required without the use of a glass or metal lid. In this study, we report a flexible and transparent passivation layer for OLEDs by using spin coating method. Encapsulation method based on wet process, which is obviously advantageous for various display applications because of its simplicity and reliability in handling, has hardly been performed.

EXPERIMENTAL

To explore the effect of our passivation layer, small molecular light-emitting device was fabricated by mean of the vacuum deposition method and the configuration of the device was glass/ITO/4,4′,4″-tris(N-3(3-methylphenyl)-N-phenylamino)triphenyl amine (MTDATA, 20 nm)/N,N′-biphenyl-N,N′-bis(1-naphenyl)-[1,1′-biphenyl]-4,4′-diamine (NPB, 40 nm)/Alq3(60 nm)/LiF(1.2 nm)/Al(100 nm).

The acrylate monomer chosen for study was a mixture (trade name, PETIA) of pentaerythritol tri-acrylate and pentaerythritol tetra-acrylate. Photopolymerization was initiated with HSP-188. All materials were supplied by SK ucb Co. and used without further purification. Chemical structure of the monomer is shown in (Figure 1). The photopolymerizable

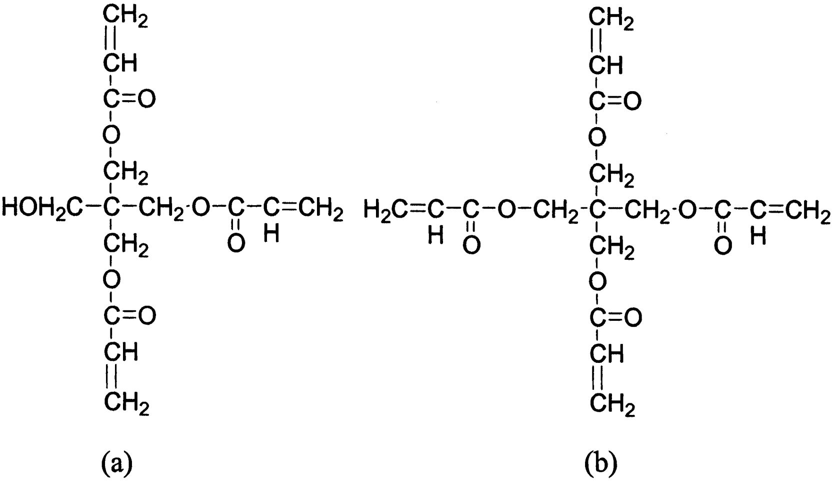
(a) (b)

FIGURE 1 Chemical structures of pentaerythritol tri-acrylate (a) and pentaerythritol tetra-acrylate (b).

blends were prepared with initiator concentration approximately 10-wt % of the total monomer concentration.

In order to form a passivation layer, the photopolymerizable blend was spin-coated onto the device and the obtained film was subsequently irradiated with UV light to form 14.5 μm-thick cured passivation layer. Light-induced polymerization of the blend was performed using a high pressure mercury (Hg) lamp at 365 nm (exposed light energy, 1260 mJ/cm^2). Figure 2 shows a schematic diagram of the device with the passivation layer.

The electrical characteristics of the fabricated devices were measured on a programmable electrometer having current and voltage sources (source measure unit, model 238, Keithley) and the brightness was measured with a luminance meter (trade name, LS-100) supplied by Minolta Co., Ltd.

Water vapor transmission rate of the polyacrylate films were evaluated at 37.8°C and 100% relative humidity (RH) with MOCON detection instruments (MOCON, PERMATRAN-W® 3/31 MA). UV-visible absorption spectra of the films were measured at ambient temperature in air using a spectrophotometer (Hitachi U-3501).

RESULTS AND DISCUSSION

Typical physical properties of the polyacrylate film are given in Table 1. The film exhibits good adhesion for the device and makes a smooth surface on the relatively irregular surface of the device. In addition, the polyacrylate has a high light transmission and is insoluble to common organic solution.

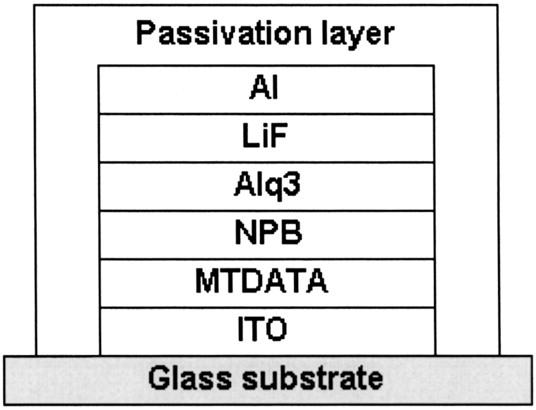

FIGURE 2 Schematic diagram of organic light-emitting device with a polyacrylate passivation layer.

TABLE 1 Physical Properties of the Polyacrylate Film

Items	Unit	Results
Thickness	μm	14.5
Light transmittance ($\lambda = 550\,\text{nm}$)	%	99
Water vapor permeability	g/m^2/day	39.0
Cross-linking density	%	98.9
Swelling index		0.23
Conversion	%	91

We investigated the influence of wet process encapsulation on the EL characteristics of the device. The luminance-voltage (L-V) characteristics were examined to compare the electrical properties of the devices before and after forming the passivation layer. As shown in (Figure 3), it was observed that with increasing dc applied voltage, the luminance remained unchanged until ~8 V and then increased steeply. We also measured the L-V characteristic of the encapsulated device. The L-V characteristic of the encapsulated device slightly shifted to low voltage and a luminance of ~100 and 21600 cd/m^2 was achieved at 8.0 and 15.6 V, respectively. However, we could not observe substantial variations in electrical properties for both

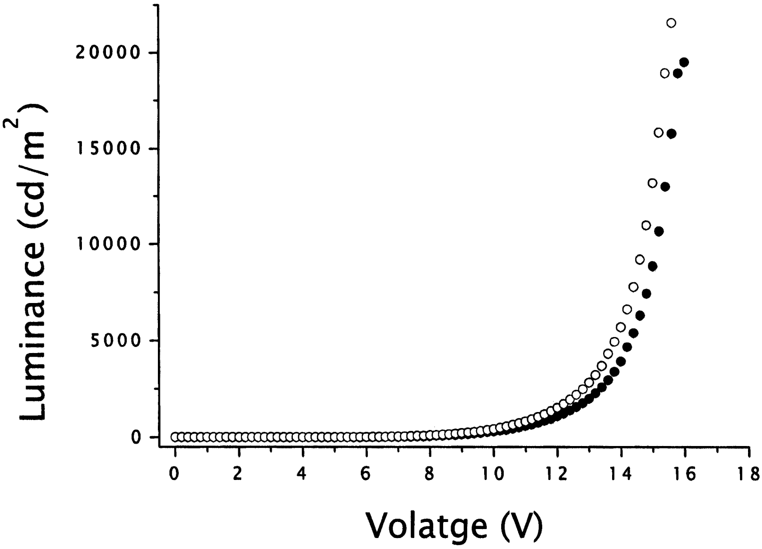

FIGURE 3 Luminance-voltage characteristic of organic light-emitting device at room temperature. ● without the passivation layer; ○, with the polyacrylate passivation layer (thickness, 14.5 μm).

devices. These results indicate that the fabrication process of the passivation layer induced no appreciable photochemical reaction on the cathode surface and/or the organic layers and did not influence the electrical and the emissive properties of the device.

In order to explore the rate of degradation, the lifetime of the fabricated devices were measured at an initial luminance of 170 cd/m^2 and a dc constant current of 0.039 mA/mm^2, as shown in (Figure 4). These measurements, which are one of acceleration test, were carried out under air at 40°C and 60% RH. Figure 4 shows a typical plot of normalized luminance versus driving time for the devices. We defined the lifetime as the time necessary to reduce the luminance to 50% of the initial luminance value, which resulted from the degradation of the device. The encapsulated device resulted in a half time of 7.4 h, while that of the non-encapsulated device was 2.3 h.

We next explored the dependence of the polyacrylate film thickness on the stability of the encapsulated device. We measured the lifetime as previously stated. As shown in (Figure 5), the lifetime of the encapsulated devices gradually increased as the polyacrylate film thickness increased. The lifetime of three devices are 7.3 h (thickness, 12 μm), 7.4 h (thickness, 14.5 μm), and 9.6 h (thickness, 29 μm). Water vapor transmission rate of

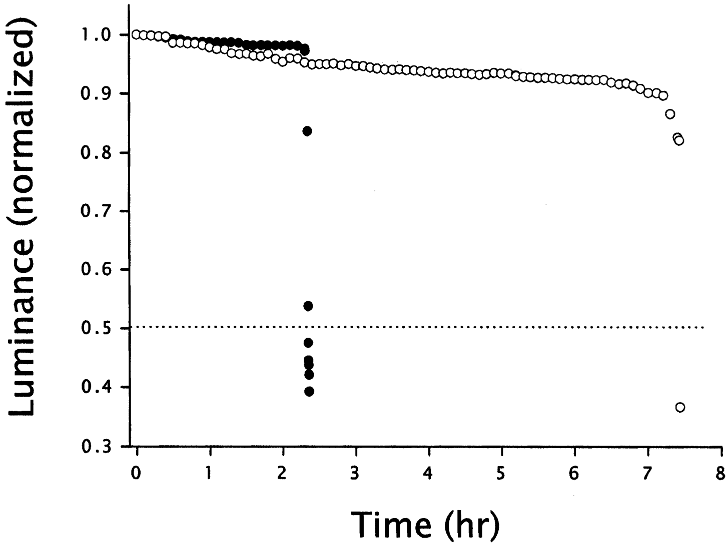

FIGURE 4 Lifetime of organic light-emitting device with the dc electric field of 0.039 mA/mm^2. These measurements were carried at 40°C and 60% RH. ●, without the passivation layer; ○, with the polyacrylate passivation layer (thickness, 14.5 μm).

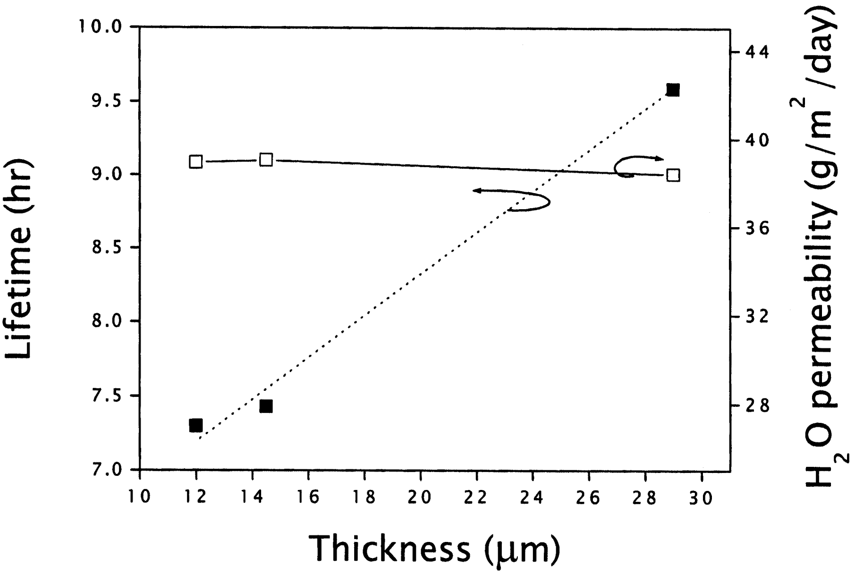

FIGURE 5 Dependence of the polyacrylate film thickness on lifetime of organic light-emitting device and water vapor transmission rate. The lifetime of the devices were examined at 40°C and 60% RH with the dc electric field of 0.039 mA/mm^2.

the polyacrylate films hardly changed within the range of the film thickness examined. It is well known that oxygen and moisture are primary factors leading to the degradation process of OLEDs. However, this result indicates that the degradation is not entirely due to moisture. The degradation mechanism of the encapsulated device is unclear at present. Further works are necessary fully this phenomenon.

CONCLUSIONS

We found a novel encapsulation method of OLED displays based on wet process. For encapsulation of OLEDs, the photopolymerizable blends of acrylate monomer and initiator were spin-coated onto the devices and then cured with UV light. Its fabrication process, which was very simple and convenient to perform, did not influence the EL characteristics of the devices. The longevity of the device encapsulated with the polyacrylate passivation layer was longer than that of the non-encapsulated device and its behavior was affected by the polyacrylate film thickness. This method might be applied to plastic-based OLED displays and to pre-encapsulation for thin film encapsulation of OLEDs.

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