Effects of Passivation and Desiccant on Organic Light-Emitting Diodes

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The lifetime of organic light-emitting diodes (OLEDs) strongly depends on removing H2O from the passivation atmosphere. Therefore, practical OLEDs require excellent passivation to block invading moisture and desiccant to remove moisture in a metal can or a glass cap. We observed the emitting area in OLEDs passivated by a glass cap. Dark spots in OLEDs passivated without a desiccant and grew more rapidly than those in OLEDs passivated with a desiccant. We speculated that the difference between both samples is caused not only by the imperfection of our passivation, but also occurrence of H2O from the OLED device.

Keywords : OLED, Moisture, Desiccant, Passivation, Dark spot

1. Introduction
Organic light-emitting diodes (OLEDs), which are reported by Tang & VanSlyke [1,2], are noted as one component for flat panel displays. A flat display using OLEDs has many advantages: it is thinner and lighter (vs. cathode-ray tubes (CRT) and plasma display (PDP)), higher brightness (vs. liquid-crystal display (LCD)), higher image-quality (vs. LCD), higher scanning speed (vs. LCD), easier fabrication process (light-emitting diodes (LED)), and low operating voltage (~ LED).

These OLEDs can be applied to both small and large displays. The OLEDs are vulnerable to moisture. Therefore, incursion of moisture during OLED fabrication must be avoided. In general, OLED fabrication is carried out in a vacuum or with a dry inert atmosphere (i.e. N2) of ~10ppm-moisture.

This paper addresses the emitting area of glass cap-passivated OLEDs with and without a desiccant.

2. Experimental
The authors used Phthalocyanine Copper (CuPc) as a hole injection layer, N,N’-di(1-naphthyl)-N,N’-diphenyl-1,1’-diphenyl-1,4’-iawhile) NPD) as a hole transport layer, and 8-hydroxyquinoline aluminum (Alq3) as an emitting material. Sublimated organic materials were obtained from Nippon Steel Chemical Co., Ltd. A NPD thin film was prepared on a glass substrate with an indium-tin-oxide (ITO) transparent electrode (anode). Then, a thin Alq3 film was formed on it. Organic thin films were prepared using vacuum deposition at a pressure of 0.8 ~1x10⁻³ Pa at room temperature. Typical deposition rates of NPD and Alq3 were about 0.2 ~0.3nm/s. Then, for the upper metal electrode (cathode), LiF/Al was evaporated without breaking vacuum.

The effective electrode area of the specimens was 2x2mm². Size of glass substrate was 29x14mm. The size of glass cap, which is cut in 0.5mm-depth, is 25x12mm. Desiccant size is sheet-type and 10x10mm. Maximum absorbed moisture is 300mg. Glass cap passivating is carried out in highly pure N2 gas of 40ppm (H2O). An epoxy resin is used for contact between the sample and glass cap.

Current-voltage characteristics of organic LEDs were measured with a programmable electrometer having current and voltage sources.
3. Experimental results and Discussion

Figures 1a and 1b show current density – voltage and brightness – voltage characteristics, respectively. The threshold voltage at 0.1 cm²/m² is 3.2 V. Different symbols describe reproducibility of different samples.

Figure 2 shows that EL/current efficiency (cd/A) is about 4 cd/A. We believe that our device performance is good. Of course, it is apparently not difficult to increase EL/current efficiency. For example, if Alq3 layer thickness is changed from 50 nm to 70 nm, EL/current efficiency increases. However, increased thickness leads to the emission peak redshift from ~520 nm to ~540 nm because luminance depends on luminous achieving maximum at 555 nm. Therefore, we do not improved device performance.

Figure 3 shows the photographs of an OLED emitting area without desiccant. The 0th photograph is not oriented in the same direction as the others. Dark spots grow with increased operating time. Our OLEDs have many dark spots because the ITO substrate may be made wash in a usual room, although usual fabrication of organic thin films and a cathode is carried out in a clean room of class 10,000. Recently, however, when we fabricated OLED on another ITO substrate prepared for OLEDs using the same fabrication procedure and conditions, an emitting area with few dark spots was observed as shown in Figure 4. Formation of many dark spots in our OLEDs is caused by different ITO surface conditions.

On the other hand, figure 5 shows photographs of an OLED emitting area with desiccant. Many dark spots are observed in this OLED. However, small dark spots grow with increasing operating time.
Figs. 3 The emitting area of an OLED without desiccant.

Figs. 5 The emitting area of an OLED with desiccant.
The reason dark spots grew with increased operating time is thought to be due to the following: moisture invades the passivated device through passivation imperfections. Otherwise H2O may occur in the passivated device during operation.

Moisture permeability is estimated by the MOCON method. The measuring region of MOCON method is 0.01-600g/(mm•m²•day)[3]. Moisture permeability for the passivation film for flexible OLEDs must be <10^{-5}g/(mm•m²•day)[4, 5]. Moisture permeabilities of poly(ethylene telephthalate)(PET) and polyamide are 1.38 and 6.0 g/(mm•m²•day), respectively[3]. If an epoxy region is assumed to be 100μm-thick, the maximum cross section of the epoxy resin layer is 8.6x10^{-6}m² (2*(29mm+14mm)*100μm). In addition, if moisture permeability of the epoxy region is thought to be on the same order as 10g/(mm•m²•day), the total H2O content invading after 375h will be estimated to be the maximum, 1.34μg. This value is larger than ~3ng in the glass cap filled with 40ppm dry N2 gas.

In the case of total H2O content of 100mg, moisture permeability must be calculated to be 744 g/(mm•m²•day). This permeability is unreasonable for a passivation film. In fact, as overlap width between a base glass substrate and a top glass cap is 2mm wide, use of epoxy resin is not thought to cause the imperfection of passivation. We carried out the passivation test several times. All experimental results indicated identical behavior.

Finally, we infer that H2O occurs from an OLED when it is operating. Here the authors observed the emitting area of the OLEDs as a desiccant area (water absorption).

4. Conclusions

The authors observed OLED emitting area (ITO/CuPc/NPD/Alq3/LiF/Al) with and without a desiccant. Dark spots in the OLED without a desiccant grew rapidly, but those in the OLED with a desiccant grew little. The authors speculated its occurrence from the operating device.

References