Twofold enhancement in reliability of organic light emitting diodes with thermally-induced morphological change of organic layer

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The reliability enhancement because of annealing of organic light emitting diodes (OLEDs) fabricated under high vacuum condition (10^{-6}~10^{-7} Torr) can be as a result of the morphological change of organic layers and/or the removal of residual water from the deposited material after annealing.[1-2] Recently, we achieved the lower region of ultra-high vacuum (UHV) condition (10^{-10}~10^{-11} Torr) with extremely low concentration of residual water by utilizing non-evaporable getter pumps (NEGPs) and regular turbo molecular pumps (TMPs) in OLED deposition chamber.[3] In this report, we demonstrate twofold enhancement in reliability of OLED can be achieved by the thermally-induced morphological change of organic layers.

OLEDs with a structure of ITO/MoO_3(0.75nm)/α-NPD(90nm)/Alq_3(70nm)/LiF(1nm)/Al(100nm) were fabricated in UHV chamber pumped with TMPs and NEGPs. After fabrication, OLEDs were thermally annealed in air at 50 °C and 75 °C for 3 h, then decreased to 25 °C and left for 30 min before characterization. The reliability of OLED was measured at a constant current density of 50 mA/cm^2.

The operation time to reach to 90% of initial luminance (LT_{90}) of the OLED after annealing at 75 °C is 236 h, which is about two times compared to that (LT_{90}=136 h) of the as-deposited OLED (Fig. 1). The decrease in thickness of film (α-NPD/Alq_3) suggests that thermal annealing may increase the density of organic layers.

The p-polarized multiple-angle incidence resolution spectrometry (pMAIRS) reveal that the orientation angle (ϕ) with respect to surface normal is about 61 degree and slightly increase after annealing. This result suggests that α-NPD molecules horizontally oriented after deposition and slightly more lie down after annealing (Fig. 2). Such molecular change is evident with the increase of density resulting from the more packed α-NPD molecules (Fig. 3). As shown in Fig. 2, the increase in photoluminescence intensity from α-NPD molecules after annealing indicates the decrease of nonradiative deactivation centers followed by photochemical reactions of excited states in highly packed α-NPD.[4] This could be the reason for the enhancement in short-term reliability of OLEDs.

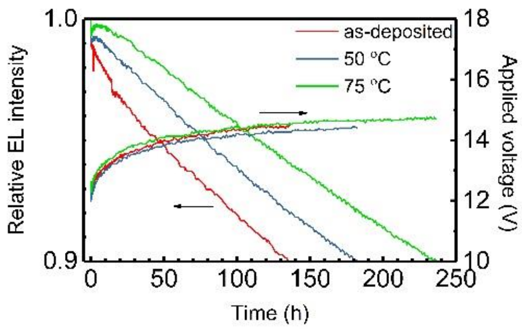

Fig. 1. Luminance/initial luminance-time characteristics of OLEDs.

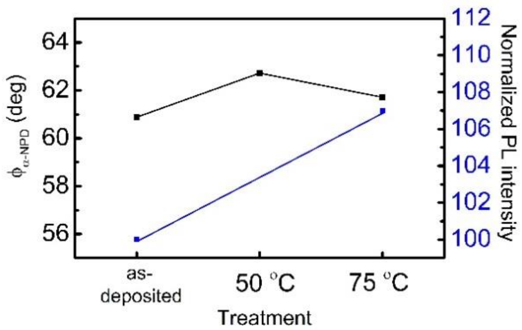

Fig. 2. Orientation angle of α-NPD, $\phi_{\alpha\text{-NPD}}$, and normalized PL intensity.

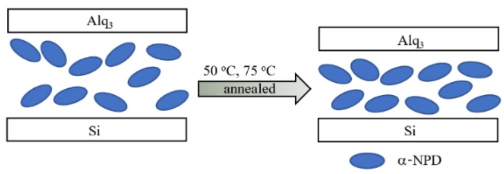

Fig. 3. Morphological change of α-NPD film.

References

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Key words: reliability, annealing, molecular orientation.