# Change of Internal Resistance of OLED Devices during Operation

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## Abstract

*The luminance and operating voltage were measured during OLED operation for the purpose of analyzing the efficiency and change of internal resistance. The half lifetime of OLED was affected by degradation of OLED due to heat generated by ambient temperature and self heating. The operating voltage constantly increased due to the increase of internal resistance. The half lifetime of OLED driven by constant current source was found to be longer than that of the OELD driven by constant voltage and the reasons were clearly explained in this paper.*

## 1. Introduction

The half lifetime of the first reported multilayer organic light emitting diode(OLED) was about 100 hours. The half lifetime is affected by various factors, such as thermal instability of OLED materials, instabilities of interfaces, and local breakdown. Many researches have been performed to improve these factors and recently the half lifetime of over 10,000 hours has been achieved by the accumulation of research result. But detail mechanisms of degradation leading to luminance decay could not be fully understood. Table 1 shows the current status of half lifetime of OLED devices. Many researchers prospect that the OLED may be used most widely to display pixel, if half lifetime exceeds over hundred thousand hours for red, green, and blue colors. So the half lifetime improvement of blue OLED devices was developed for commercial product of OLED display.

In this paper, we measured the luminance and operating voltage of OLED devices driven at DC constant current during operation to find the causes leading to the degradation of the half lifetime, efficiency, operating voltage, and change of internal resistance.

Table 1 Current status of half lifetime of OLED devices.

| | Fluorescent EL | | | Phosphorescent EL | | |
|---|---|---|---|---|---|---|
| | X | y | Lifetime | x | y | Lifetime |
| R | 0.67 | 0.33 | >100,000h @1000cd/m$^2$ | 0.67 | 0.33 | 300,000h @500cd/m$^2$ |
| G | 0.30 | 0.63 | >100,000h @1000cd/m$^2$ | 0.28 | 0.63 | 40,000h @1000cd/m$^2$ |
| B | 0.15 | 0.15 | 12,000h @1000cd/m$^2$ | 0.16 | 0.29 | 17,000h @200cd/m$^2$ |

## 2. Results and Discussions

The OLED devices of blue emission with a multilayer structure of ITO/NVHIL(600 Å)/NPB(200 Å)/NVBH-1:NVBD-32(300 Å) $Alq_3$(300 Å)/LiF(300 Å)/Al(1000 Å) were fabricated by thermal evaporation system at the rate of 1 Å/sec under $10^{-6}$ torr. The NVHIL,

NVBH, and NVBD developed by NeoView KOLON were used as a hole injection material, blue host material and dopant material, respectively. The active area of fabricated OLED devices was 2 x 2 $mm^2$. Figure 1 shows the cross sectional view of OLED device.

Figure 2 shows the luminance and power efficiency of the fabricated OLED devices as a function of the applied DC voltage. The luminance sharply increased at low voltage and then slowly increased over 5 V. The power efficiency also sharply increased in the range of low voltage but decreased after reaching maximum efficiency. The luminance and efficiency were 68 $cd/m^2$ and 4.81 lm/W at 4.5V and 15.03 $cd/m^2$ and 2.97 lm/W at 9.5V. The blue emission was observed and the CIE color coordinate was (0.1491, 0.2209).

Figure 3 show the power efficiency decay and the current efficiency decay during operation. The efficiency changed in two regions. It was shown that the current efficiency stayed constant up to 60 hrs of operation and decreased after 60 hrs of operation. The current efficiency and the power efficiency were 8.6 cd/A, 3.5 lm/W at start and 4.35 cd/A, 1.1 lm/W at half lifetime. The decrease of efficiency is believed to be due to the degradation of OLED devices.

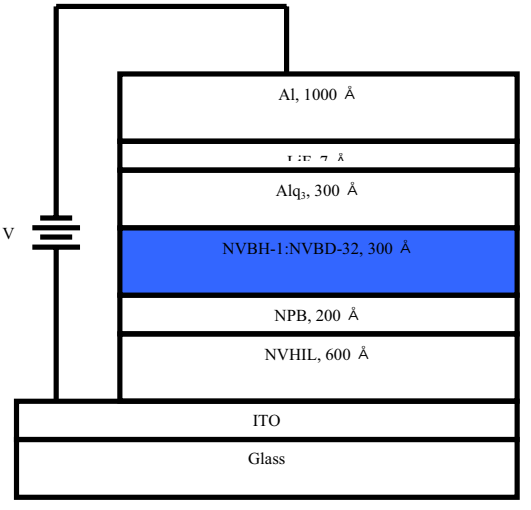



**Figure 1 Cross section of OLED**

Figure 4 shows the relative luminance decay during operation at 23 °C, 53 °C, and 83 °C. The luminance was nearly constant during the initial operation and then slowly rose after 10 to 40 hrs of operation, and followed by decrease after over 100 hrs of operation at 23 °C. But in case of 53 °C, 83 °C, the luminance was almost constant for about 60 hrs and then decreased. Figure 4 shows that the half lifetime may be affected by degradation OLED devices due to ambient temperature and self heating.

Figure 5 shows the change of operating voltage and internal resistance of an OLED device driven by DC constant current density of 57.5 $mA/cm^2$ during operation.

The internal resistance value was obtained by dividing the operating voltage by constant current flowing through an OLED device. The internal resistance continuously increased from 3.4 k Ω at start to 5.5 k Ω at half lifetime. The internal resistance value increase more than 62% from the initial resistance value.

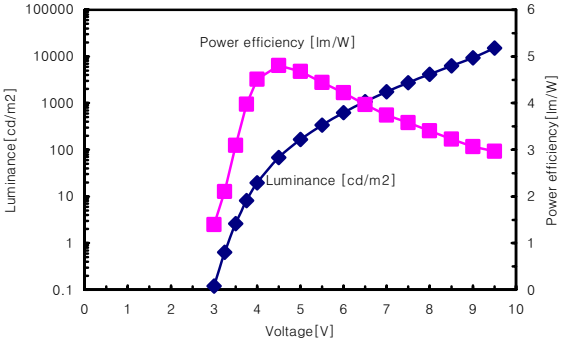
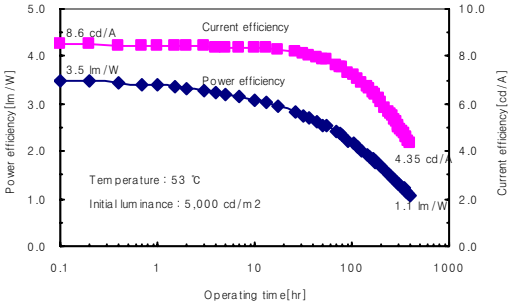



**Figure 2 Luminance and efficiency**




**FiFigure 3 Efficiency decay curve**

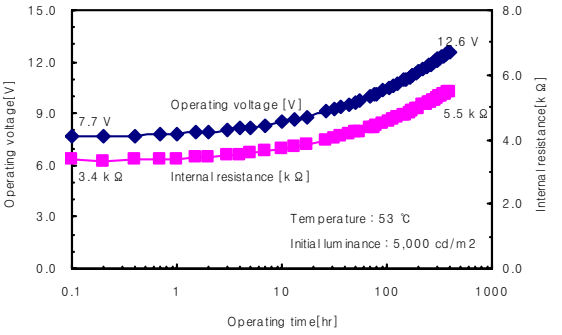



**Figure 5 The change of resistance**

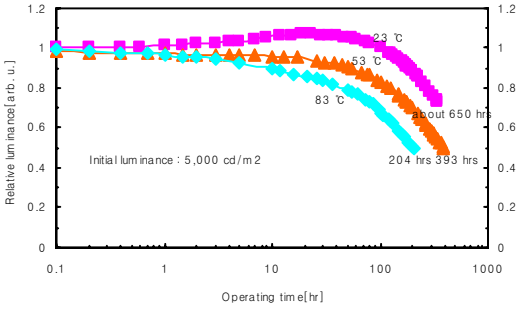



**Figure 4 Luminance decay curve**

The increase of internal resistance during operation is believed to be due to the degradation of OLED device and so the operating voltage increased as internal resistance increased. Figure 4 shows the change of internal resistance and explains the reason for the longer half lifetime of OLED driven by constant current than that driven by constant voltage. The luminance decreased by only self heating degradation under constant current driving, but there is another degradation factor in constant voltage driving mode. The decrease of current flowing through OLED device due to increase of internal resistance resulted in the luminance decrease.

## 3. Conclusions

The OLED devices with a multilayer structure were fabricated to analyze the causes of the decrease of half lifetime, efficiency, operating voltage, and change of internal resistance during operating time.

The luminance decay curve shows that the luminance was nearly constant in the range of initial operation and then decreased. And also it was found that the efficiency decay curve was very similar to luminance decay curve. The degradation of OLED half lifetime was affected by ambient temperature in addition to self heating. The operating voltage continuously increased due to the increase of internal resistance during operation. It was explained that the half lifetime of OLED driven by constant current is longer than that of OLED driven by constant voltage.

## 4. Acknowledgements

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