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# Corelation between Organic Electroluminescent Characteristics and Surface Composition of Oxygen-Plasma treated Indium-Tin-Oxide

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**Synopsis**

Organic electroluminescent(EL) device was fabricated on the oxygen($O_2$)-plasma treated indium-tin-oxide(ITO) surface. The corelation between the device performance and the chemical composition of the $O_2$-plasma treated ITO surface was investigated. The operating voltage of the devices were decreased by $O_2$-plasma exposure. This reduction is due to the change of surface composition with exposure time.

KEYWORD: $O_2$-plasma treatment, Organic EL device, ITO, Operating voltage, XPS spectra

## 1. Introduction

Organic EL devices are typically fabricated on ITO coated glasses which have the advantages of high work function and transparency. It has been reported that surface treatment of $O_2$-plasma is effective in improving organic EL performance.[1]

In this paper, ITO surface was treated by $O_2$-plasma and the corelation between organic EL performance and the change of the surface composition with different exposure time was investigated.

## 2. Experimental

Fig. 1 shows the molecular structure of poly(*N*-vinylcarbazole)(PVK)(Souwa Kagaku Products Co., $M_w$=135,600/$M_n$=56,400) and tris(8-hydroxyquinoline)aluminum($Alq_3$) (Tokyo Kasei Kogyo Co., Ltd.)used in this study.

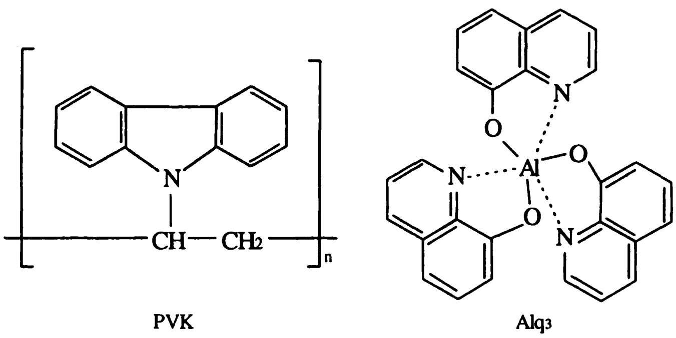


Fig. 1: Molecular structures.

Indium-tin-oxide(ITO)(Kinoene Kogaku Kogyo Co., $SiO_2$(SP)+ITO(SP) 25 × 25 × 0.7 [mm]) surface was treated by $O_2$(Neriki Gass Co., 6N)-plasma with different exposure time using the direct glow discharge system. ITO coated substrate was set on the cathode electrode. Electrical discharge voltage and current were 500 V and 15 mA, respectively.

The PVK powder was dissolved in chloroform(Wako Pure Chemical Industries, Ltd., special grade chemical). The concentration of PVK in chloroform was 5 mg/ml. PVK thin films were prepared on the ITO surface by spin-coating method. $Alq_3$ and Al-Li (Kojundo Chemical Laboratory Co., Ltd.)

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upper electrode were formed by vacuum vapor deposition at $10^{-6}$ torr. Fig. 2 shows a schematic structure(ITO/PVK/$Alq_3$/Al-Li) of EL device used in this study.

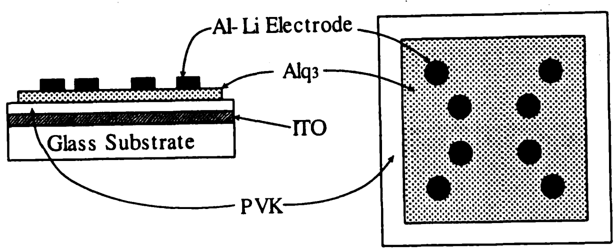



Fig. 2: Structure of organic EL device.

We investigated EL characteristics using this device. Fig. 3 shows the schematic diagram of the measurement system for the characteristics.[2] Moreover, photoluminance spectrum was measured by measurement system shown in Fig. 4.

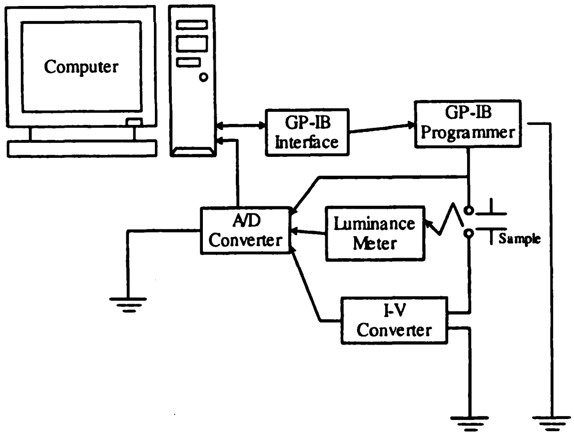



Fig. 3: Schematic diagram of current and luminance measurement system.

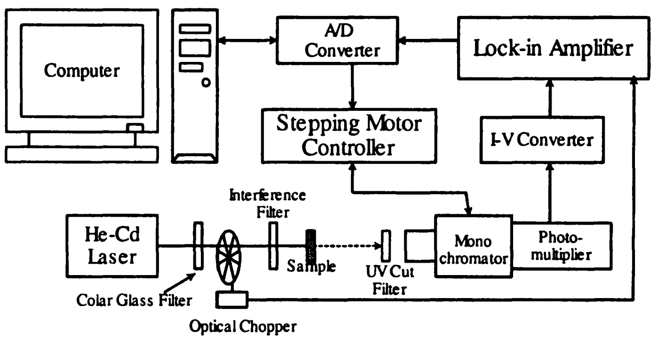



Fig. 4: Schematic diagram of photoluminance spectrum measurement system.

The surface chemical composition of ITO was analyzed by X-ray photoelectron spectroscopy(XPS). XPS spectra were recorded with a Shimadzu electron spectrometer ESCA-750 employing MgK$\alpha$-exciting radiation(1253.6eV) at 8 kV in $5\times10^{-6}$ Pa.

## 3. Experimental results and discussions

### 3.1 Organic EL characteristics

The luminance-voltage characteristics and the luminance-current density characteristics are shown in Fig. 5 and Fig. 6, respectively.

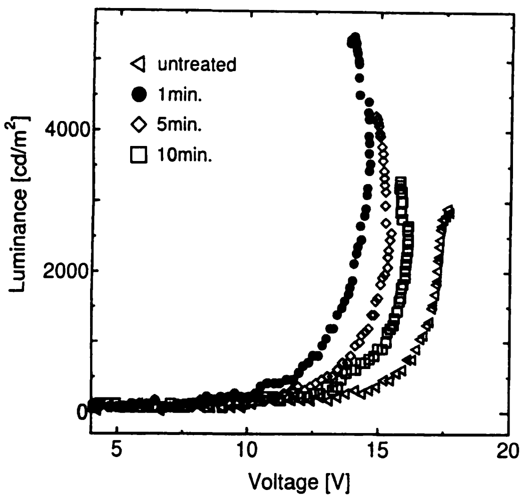



Fig. 5: Luminance versus voltage characteristics.

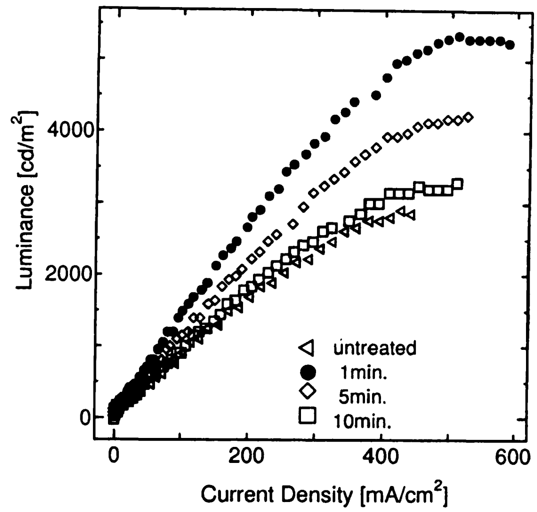


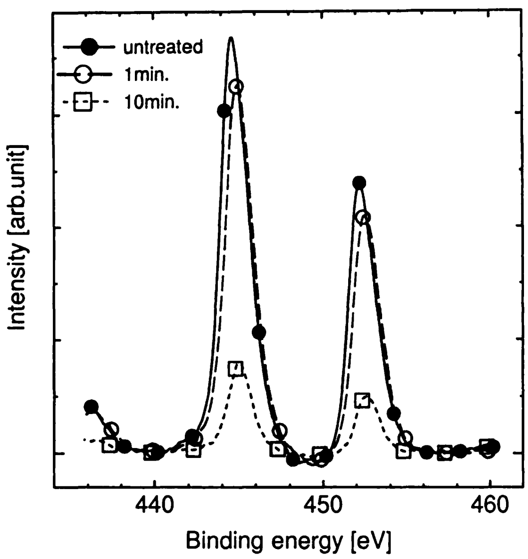

Fig. 6: Luminance versus current density characteristics.

Compared with the untreated device, the operating voltage of the treated devices were decreasing and luminescence of the treated devices were high. Fig. 5 shows that exposure time for 1 minute is the most effective, and operating voltage is increasing as exposure time is increasing. The device treated for 1minute is the highest luminescent efficiency as shown in Fig. 6.

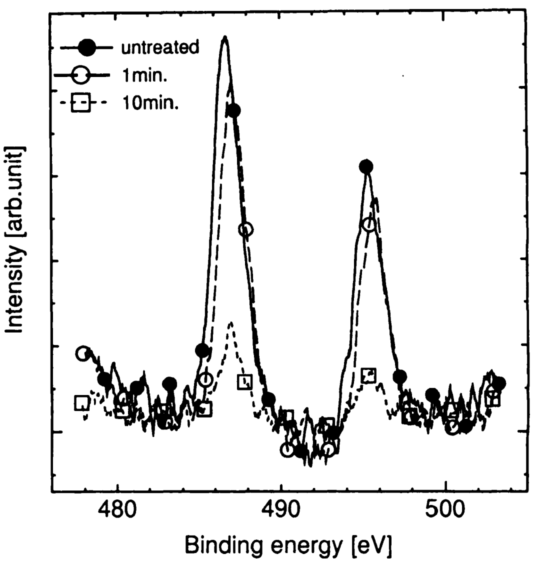
### 3.2 Surface chemical composition of ITO

Fig. 7 shows $In_{3d}$, $Sn_{3d}$, $O_{1s}$ and $C_{1s}$ XPS spectra of untreated and plasma-treated ITO surface. Both the peaks of $In_{3d}$ and $Sn_{3d}$ are decreasing by plasma treatment as shown in Fig. 7(a) and (b). On the contrary, the peak of $O_{1s}$ is increasing as shown in Fig. 7(c). From these results, it is thought that by carrying out plasma treatment, a certain oxidization layer is formed on the ITO surface, and the peaks of $In_{3d}$ and $Sn_{3d}$ are decreasing.

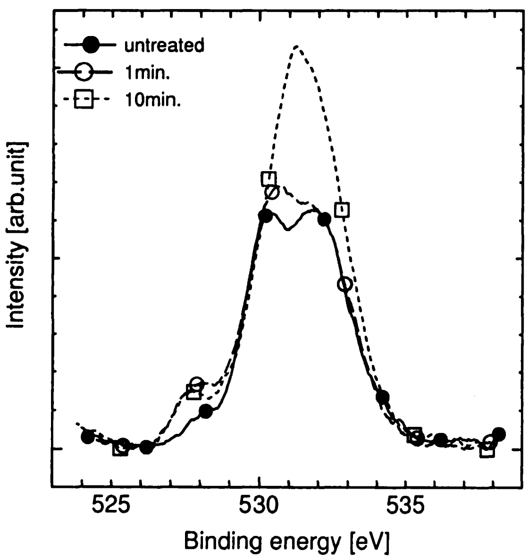
An untreated device has a high peak in 285eV as shown in Fig. 7(d). This peak expressed carbon contaminants and it was removed from ITO surface by carrying out plasma processing. And a new peak was appeared by plasma treatment.



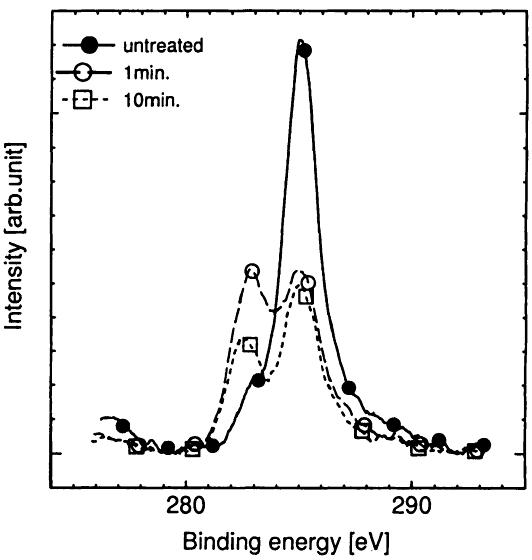

(a) $In_{3d}$ spectra.




(b) $Sn_{3d}$ spectra.




(c) $O_{1s}$ spectra.




(d) $C_{1s}$ spectra.

Fig. 7: Changes of surface composition with exposure time ; (a)$In_{3d}$, (b)$Sn_{3d}$, (c)$O_{1s}$ and (d)$C_{1s}$ XPS spectra.

### 3.3 EL and PL spectra

We measured EL and PL spectra, and compared untreated device with plasma treated one. Fig. 8 and Fig. 9 show EL and PL spectra. It was found that the plasma treatment doesn't make EL spectra changed in Fig. 8. And in Fig. 9, PL spectrum of treated device is not different from that of untreated one.Therefore, even if plasma processing was carried out, any influence cannot be found in a luminescence color.

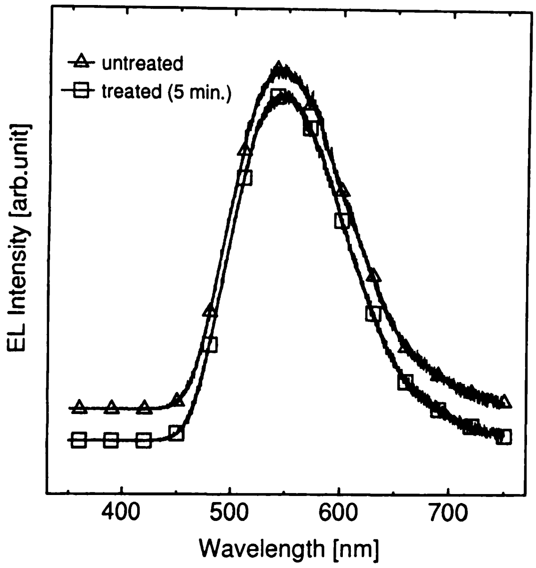



Fig. 8: EL spectra.

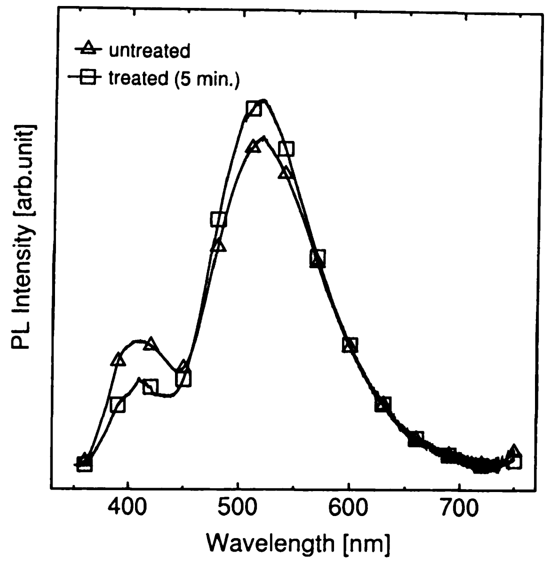



Fig. 9: PL spectra.

## 4. Conclusions

The conclusions can be summarized as follows :

1. By $O_2$-plasma treatment of ITO surface, operating voltage of organic EL devices were decreasing and luminescent efficiency were improved. The EL device with the ITO treated for 1 minute showed the lowest operating voltage and the highest luminescent efficiency
2. By $O_2$-plasama treatment, both the peaks of $In_{3d}$ and $Sn_{3d}$ are decreasing and the peak of $O_{1s}$ is increasing. And carbon contaminants are removed from ITO surface by treatment.
3. Even if $O_2$-plasma treatment was performed, a luminescence color was almost same.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## References


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