Improvement of output coupling efficiency of organic light emitting device by using porous anodic alumina

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Abstract

Porous anodic alumina(PAA) which has arrays of nano size holes, was incorporated into organic light emitting devices. Porous anodic alumina on glass scattered the light generated from emitting layer and was decreased the waveguiding modes within the glass. An increase in the device coupling-out factor for the scattering structure is demonstrated.

1. Introduction

Organic light emitting devices (OLEDs) have attracted a great deal of attention, but a low external efficiency was obstructed to be commercialized. The external efficiency of OLED is significantly lower than the internal efficiency. External and internal efficiencies are connected by device couple-out factor. Ultimately, the photons have to travel from the emissive layer through the ITO contact and substrate and finally into air. Thus, because of total internal reflection, which occurs when going from high to low index media, light is trapped inside the device. The fraction of surface emission can be simply estimated using Snell's law. [1-2]

$$\eta_{forward} = 0.5/n^2$$

Here, n is the highest refractive index within the structure, typically the organic layer or the ITO. Only 17.5% of total EL emission is coupled into air at OLEDs. Recently, many structures such as silica aerogels[3], mesa structure[4], micro lens[5] were studied to improve output coupling efficiency.

In this paper, PAA film on the backside of ITO glass was prepared by electrochemical oxidation. Because PAA film has arrays of nano size pores, light was scattered in PAA surfaces and output coupling efficiency can be increased significantly. Theoretically, because 31.5% of emitting light waveguided by the glass and outer layer, it is possible that external efficiency can be increased up to 200%.[1] We prepared simple device of ITO/TPD/Alq_3/Al:Li and compared devices with and without PAA.

2. Experimental

PAA films were prepared from thermally deposited aluminum in various acidic solutions by electrochemical oxidation method.[6]

The transmittance of the PAA films on glass was increased by ion drift method.[7]

ITO films were patterned 3mm

line by wet etch. Simple OLEDs were prepared to use the ITO glass with and without PAA. The ITO-coated glass was treated with O_2 plasma before being loaded into the deposition chamber. The organic films were deposited onto ITO-coated glass. We used TPD as a hole transport material, Alq_3 as a electron transport and emitting material. The rate of deposition was typically 1-2Å/s. The cathode, consisting of a 1,500Å thick, 99.5:0.5 Al:Li alloy, was deposited and the rate of deposition was 5-10Å/s. The luminance of OLEDs was measured with spectrocolorimeter (Photoresearch PR-650) and I-V characteristics were measured by source measurement unit(Keithley 236).

3. Results

PAA films on glass have a different transmittance and hole size depend on acid solutions.

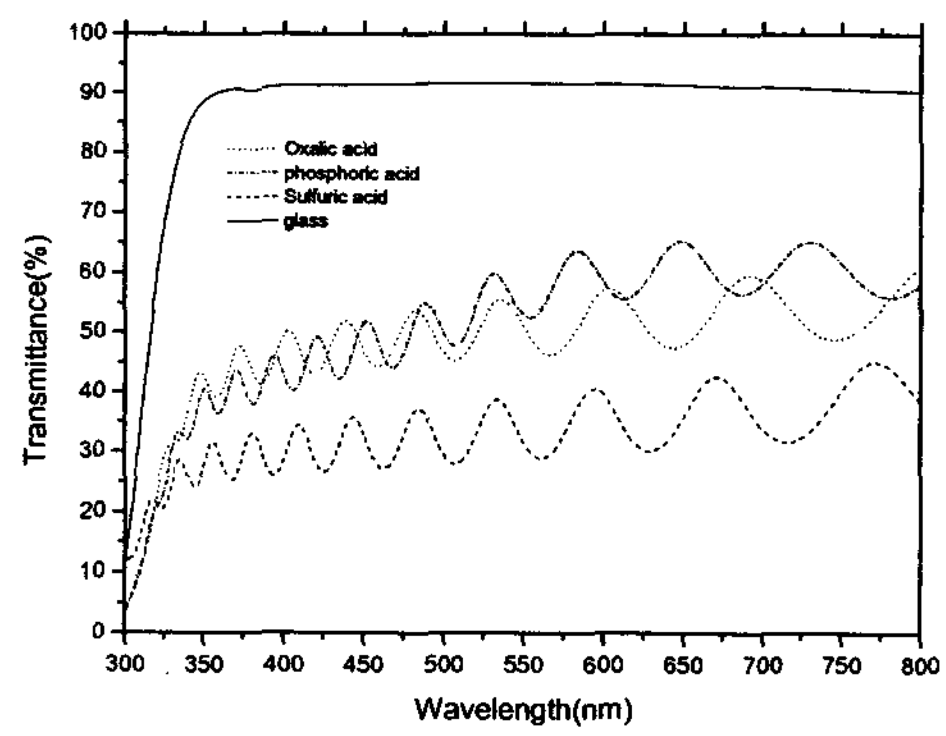


Figure 1. Transmittance spectra of PAA films on glass and glass

The surface of PAA films was observed by SEM. Hole size of PAA films was about from 20nm to 120nm depends on electrolyte and forming voltage.

Fig 1. shows the transmittance spectra of PAA films on glass and their optical transmittance were below 70%. Type 1 devices ware prepared by using low transmittance. Type 1 devices with and without PAA film have very similar I-V curves.

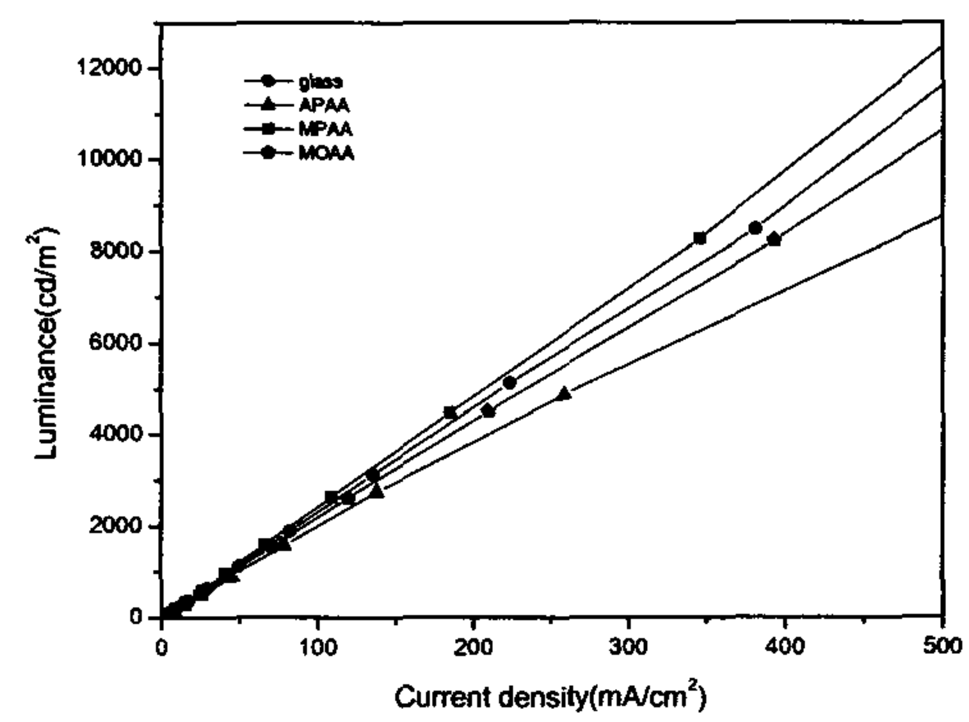


Figure 2. I-L curves of type 1 devices

Table 2. Luminance of type 1 devices

Acid	Luminance (cd/m²)[a]	Correct luminance[b]	External efficiency rate[c]
Oxalic acid(OD)	4295	5856	1.29
Phosphoric acid(PD)	4861	6730	1.57
Without PAA	4597	-	1

a : Current density at 200 mA/cm^2

b : $L = L_0 \times (T_0/T)$, L : luminance, T : transmittance

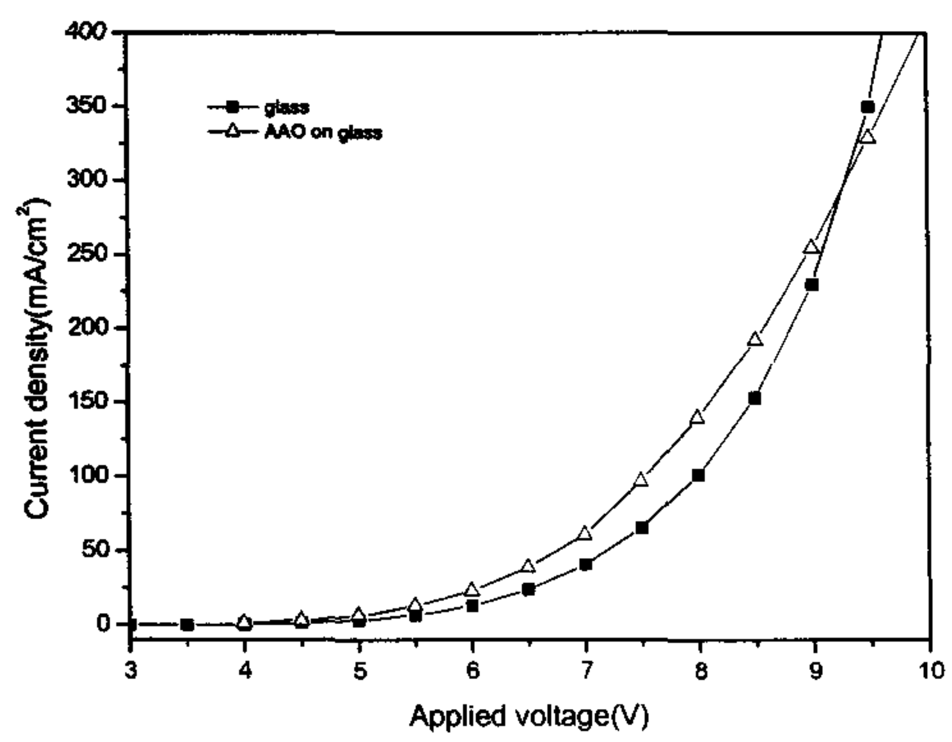
c: external efficiency of without PAA = 1

Figure 2 shows the I-L characteristics of type 1 devices. Only

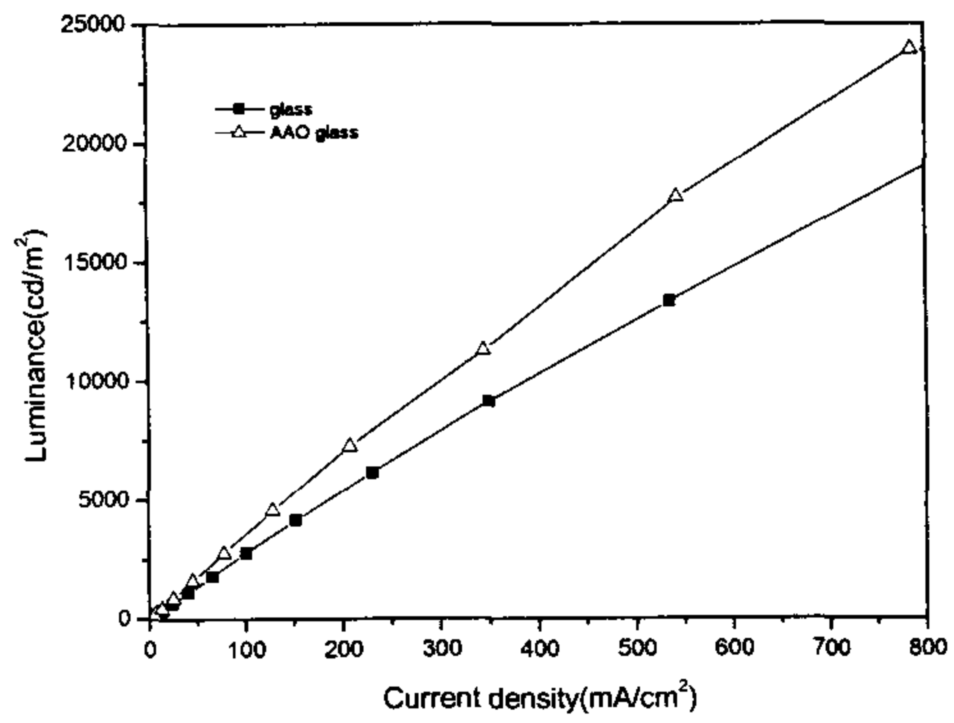
PAA film prepared in phosphoric acid showed higher luminance than that of device without PAA film. If the transmittance of the PAA films was considered, external efficiency is increased by more than 50%.(table 2) In addition, we scarcely observed the edge light that desired from light waveguiding substrate.

Since PAA films prepared by electrochemical oxidation was not transparent due to the residual nano sized aluminum particles. By using the ion drift method, nano sized aluminum islands were oxidized to alumina and the transparency and the adhesion between PAA and glass substrate were significantly improved.[7]

A highly transparent PAA film on glass with transmittance of 90% was prepared. ITO film was deposited on glass after ion drift treatment. OLED was prepared on this substrate with such structure; ITO/TPD(50nm)/Alq_3(50nm)/ Al:Li.(type 2).



(a) I-V curves of type 2



(b) I-L curves of type 2

Figure 4. I-V-L characteristics of type 2 devices

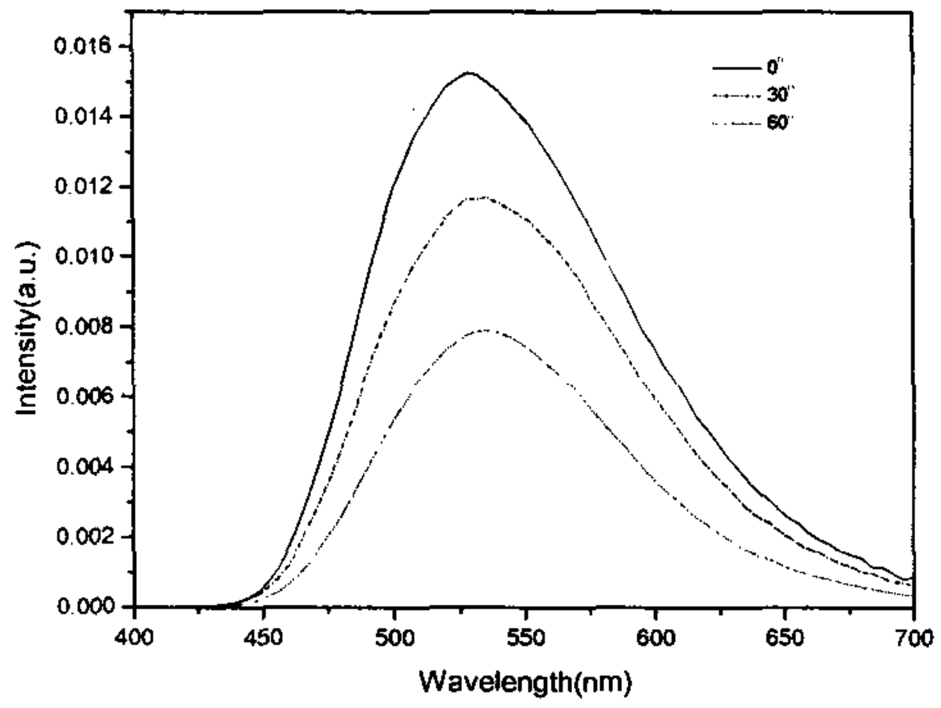
Figure 4 is shown I-V curves of type 2 devices and their layers electrical properties were very similar.

Table 2. Luminance and external efficiency of type 2 devices

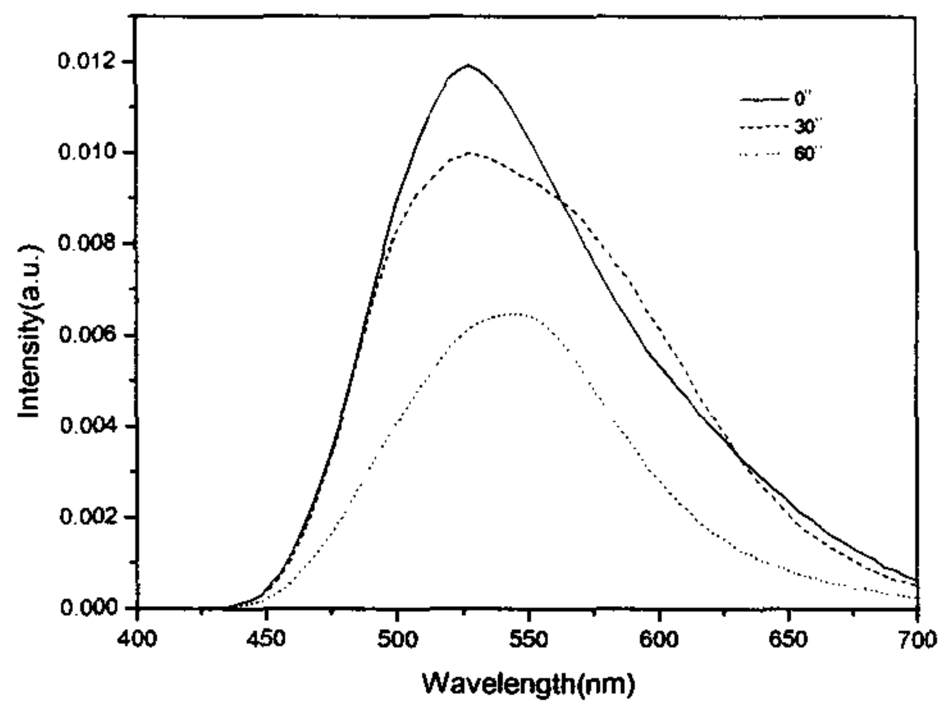
Acid	Luminance(cd/m²)[a] at 200mA/cm²	External efficiency rate
Oxalic acid	7051	1.27
Without PAA	5383	1

The device with PAA film has a higher luminance than the device without PAA film at same current density. External efficiency was found to increase about 30%.

Fig. 3 shows the electroluminescence spectra of different view angles up to 60o from the substrate normal.



(a) PAA prepared in oxalic acid



(b) PAA prepared in phosphoric acid

Figure 3. Electroluminescence spectra through view angle

Since PAA prepared from phosphoric acid has longer pore size(~120nm) than that prepared from oxalic acid(~40nm), emission wavelength shift is more pronounced in the device prepared from phosphoric acid(~16nm) while the device prepared from oxalic acid shows about 6nm shift.

4. Conclusion

External efficiency of OLEDs has much lower than internal efficiency. Device using PAA on glass expected to increase the out-coupling factor due to the scattering of a rough PAA surface and reduced waveguiding mode.

Transparent PAA were prepared by ion drift method. The device showed an increase of external efficiency by a factor of 1.3. It is possible to overcome an external efficiency limit of common OLEDs.

The emission wavelength does not vary with viewing angles. In addition, no image blurring was observed since the structure of PAA film is in nanometer dimension.

5. Acknowledgements

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