Dependence of Resistance and Capacitance of Organic light Emitting diode (OLED) on Applied Voltage

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Abstract

Organic light emitting diodes (OLEDs) with multiple organic layers were fabricated to obtain and to evaluate an equivalent resistance and an equivalent capacitance of OLED device. The staircase voltage with an increasing period and a constant period was designed and applied to the OLED. The resistance of OLED was found to decrease from 270 kΩ to 2 KΩ as applied voltage increased after turn on. The equivalent capacitance of OLED maintained unchanged at low voltage level and deceased after showing peak value as the applied voltage increased.

1. Introduction

Organic light emitting diode (OLED) display using an OLED device as a display element has many advantages compared to other displays, such as liquid crystal displays (LCDs) and plasma display panels (PDPs), from the viewpoint of wide color gamut, high luminous efficiency, low driving voltage, and large view angle.

Various researches have been performed and reported on an equivalent circuit and an impedance or admittance to improve a performance of OLED devices and to evaluate a physical phenomenon occurring in an OLED device during operation. However, the structure of OLED devices studied was consisted of only one organic layer, the impedance or admittance was obtained as a function of frequency instead of a resistance and a capacitance as a function of applied voltage, and also the amplitude of an applied voltage was less than 3V.

Optical characteristics of OLED devices are easily affected by a variation of an equivalent resistance and an equivalent capacitance during operation. So we fabricated OLED devices composed of multiple organic layers to obtain the value of an equivalent resistance and an equivalent capacitance as a function of amplitude of voltage varying from 0 V to about 11.2 V. The special waveform voltage with a gradually increasing period and a constant period was designed and applied to the OLED to obtain the device parameters.

2. Experimental and results

Figure 1 shows the structure of OLED devices studied in this research. Indium tin oxide (ITO)/4,4',4''-tris(2-naphthyl(phenyl)amino) triphenylamine(2-TNATA)/N,N'-bis(naphthalene-1-yl)-N,N'-bis(phenyl)-benzidine (NPB)/9,10-di(naphtha-2-yl)anthracene (ADN):4,4'-bis(4-9diphenylamino)biphenyl (BDAVBi)/Alq_3/LiF/Al layers were used as an anode/hole injection layer/hole transport layer/emission layer/electron transport layer/hole injection layer/cathode, respectively. The ADN and the BDAVBi were also used as host materials and dopant materials of the emission layer, respectively. The devices were fabricated at a deposition rate of 1 Å/sec under a pressure of 10^{-6} Torr by using a thermal evaporation system at room temperature. The active area of the fabricated OLED devices was 2 x 2 mm^2.

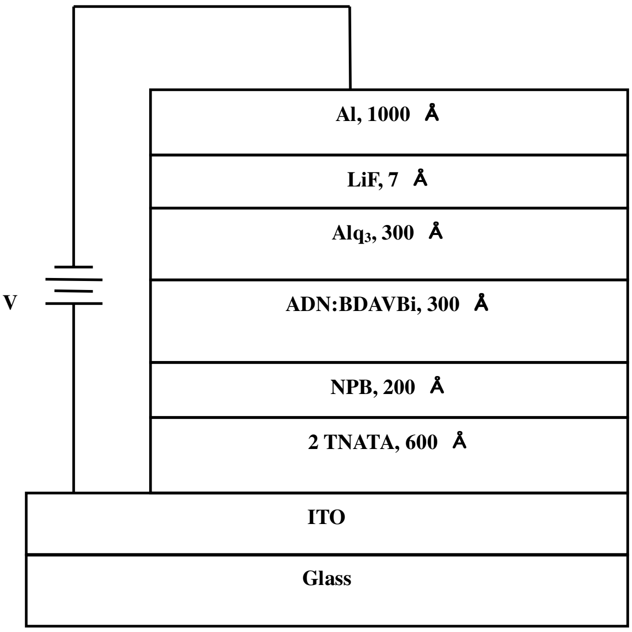
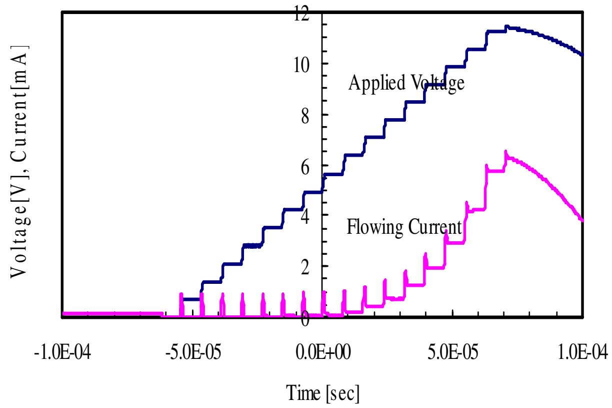


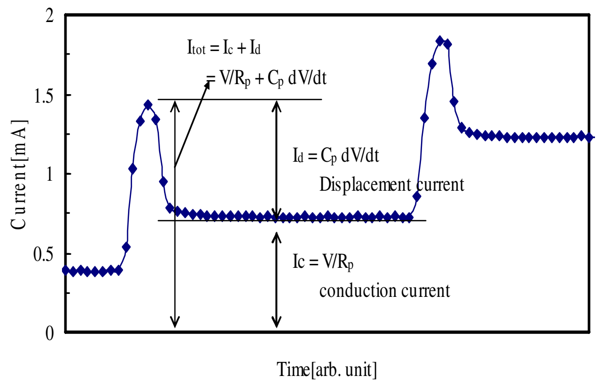
Fig. 1. Cross-sectional view of the fabricated OLED devices.

An arbitrary function generator (Tektronix, AFG 3021) was used to design and to provide the waveform voltage. This voltage drove the OLEDs which was connected in series with a sense resistor. The current flowing through the sense resistor is the same as the current flowing through the OLED, so various characteristics of the OLED can be obtained by using and calculating the current. A digital storage oscilloscope (Lecroy, WR64Xi) was used to acquire the voltage data.

An equivalent circuit for an OLED is known to consists of a parallel combination of a resistor and a capacitor. Figure 2 shows the applied voltage waveform and the current flowing through the device. The designed waveform of the voltage was consisted of a gradually increasing period and a constant period and is shown in Fig. 2(a). Figure 2(a) also shows the current flowing through the OLED as a function of time. Figure 2(b) shows a detail current which was amplified some part of flowing current of Fig. 2(a), and the displacement current and the conduction current were shown. A conduction current flows only during a constant period, and a displacement and a conduction current can together flow through during a gradually increasing period. Therefore we can easly seperate the conduction current and the displacement



(a) Applied voltage and measured current.



(b) Magnification for measured current.

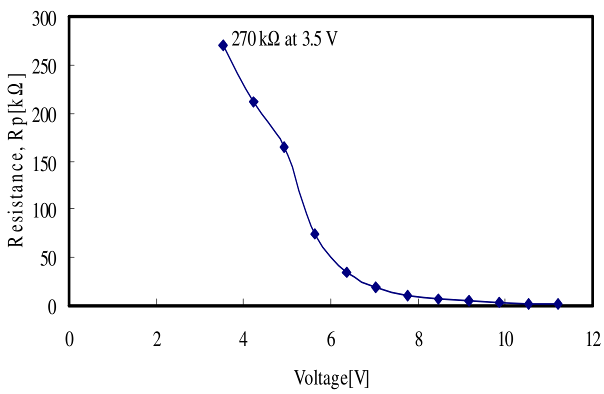
Fig. 2. Displacement current and conduction current during applied voltage.

current, which is the difference between a total current and an conduction current. The equivalent resistance could be obtained by dividing the flat voltage by the conduction current at each applied voltage. The capacitance of an OLED device could be easily obtained by times the value of displacement current and a time derivative of the applied voltage.

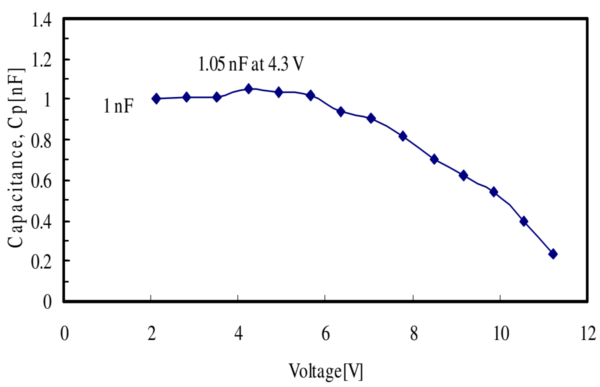
Figure 3 shows the equivalent resistance and the equivalent capacitance as a function of the voltage amplitude. The resistance could be obtained by dividing the voltage amplitude by the conduction current flowing at each constant period. Figure 3(a) shows that the resistance was several hundred kΩ at low voltage, but sharply decreased to several kΩ over 8 V. The decrease of the resistance was due to an increase of the injected electrons and holes, which are easily augmented by increasing the applied voltage.

The resistance was 270 KΩ at 3.5 V and 2 k Ω at 11.2 V.

Figure 3(b) shows the equivalent capacitance as a function of the amplitude of the applied voltage. The capacitance was about 1 nF at voltage below 3.5 V, and then became to increase to maximum of 1.05 nF at 4.3 V, and again slowly to decease at high voltage. Below 3.5 V, the organic layer can be thought as a dielectrics and the capacitance is the geometric capacitance due to the dielectric properties of the organic layer. The 3.5 V is the OLED's turn on voltage at which a majority charge injection into the organic layer starts, and the increase of the capacitance occurs due to an increase of the majority charge injection as the applied voltage is increased to 4.3 V. The 4.3 V corresponds to the OLED's light emission voltage, at which the minority charge starts to be injected into organic layer and marks a decline



(a) Resistance variation.



(b) Capacitance variation.

Fig. 3. Resistance and capacitance variation as a function applied voltage.

in the value of the measured capacitance. Above 4.3 V, the capacitance decreases due to a decrease of a polarization charge and the conduction current increases dramatically by the high external voltage. So we could obtain much physical phenomenon occurring in an OLED device by the equivalent capacitance.

3. Summary

Organic light emitting diodes (OLEDs) with multiple organic layers were fabricated to evaluate an equivalent resistance and an equivalent capacitance of OLED device as a function of operating voltage varying from 0 V to about 11.2 V. The special waveform voltage with an increasing period and a constant period was designed and applied to the OLEDs.

The equivalent resistance was found to decrease from 270 kΩ to 2 kΩ as the applied voltage was increased from 3.5 V to 11.2 V due to an increase of charges by injection. The equivalent capacitance could be varied by varying the amplitude of voltage. The capacitance maintained unchaged and was about 0.71 nF at low voltage level, and then deceased after showing a peak value of 1.05 nF at 4.3 V as the applied voltage was increased.

The equivalent resistance and the equivalent capacitance could be used to study the turn on voltage, carrier injection, formation of space charge, and light emission voltage.

4. Acknowledgements

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