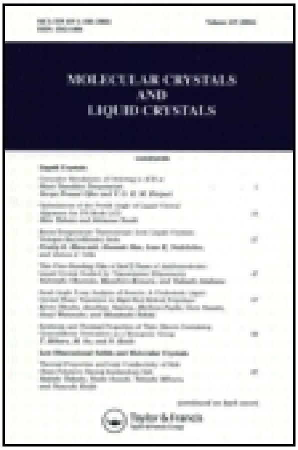

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Dielectric Phenomena of An Organic Light Emitting Diode

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The dielectric properties of an organic light emitting diode have been studied. Dielectric constant showed the frequency independence in the low frequency range below 100kHz, while the frequency dependent property was observed at above 100kHz. Dielectric loss factor showed the peak at about 300kHz, which might be attributed to the dipolar polarization. The dielectric relaxation time is calculated to be about 0.531μs from the complex dielectric constant plot. We obtained the frequency dependent properties of OLED by measuring its capacitance and quality factors.

Keywords: organic light emitting diode, complex dielectric constant, capacitance, frequency dependence

INTRODUCTION

The organic light emitting diodes based on small molecules or conjugated polymers have been greater interest due to their possible applications for flat panel displays. They are attractive because of the capability of multicolor emission, low operating voltage, and competitive cost. A lot of investigations for the commercial application have been studied, but the important questions remain about the electrical characteristics. The dielectric or impedance spectroscopy is a powerful tool to study relaxation and loss processes in solids. In this study, we have investigated the dielectric properties of organic light emitting diodes of indium tin oxide/N,N'-diphenyl-N,N'-(3-methyl-phenyl)-1,1'-biphenyl-4,4'-diamine (TPD)/tris(8-hydroxyquinolino)aluminum (Alq_3)/

aluminum structure. Their dielectric properties will be discussed.

EXPERIMENTAL DETAILS

The devices were fabricated on patterned indium tin oxide(ITO) on slide glass substrates with 100nm thickness and less than 20Ω/square sheet resistance. The TPD and Alq_3 were thermal evaporated on ITO substrate without breaking vacuum, under 2×10^{-6}Torr. The TPD used as a hole transport layer, Alq_3 as an emitting layer and electron transport layer. The aluminum cathode was evaporated at less than 5×10^{-6}Torr. The emission area was about 0.09cm^2. During the evaporation, the substrates were held at room temperature. The thickness of organic layers and cathode was about 50nm and 100nm, respectively. The dielectric properties were measured for HP 4192A LF impedance analyzer, in the frequency ranges from 100Hz to 1MHz. The OSC level was set 10mV.

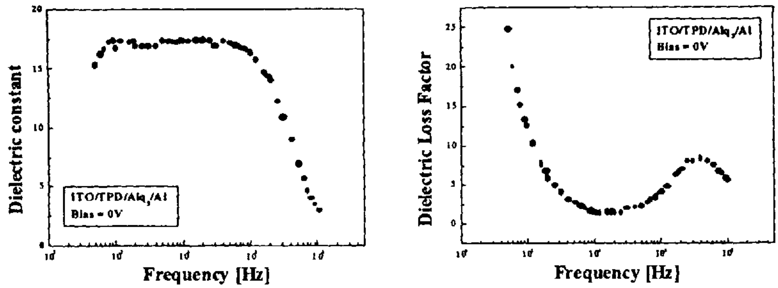
RESULTS AND DISCUSSION

Figure 1(a) and (b) showed the dielectric constant, ε' and dielectric loss factor, ε''(complex dielectric constant $\varepsilon^* = \varepsilon' - i\varepsilon''$) at zero bias, respectively. By measuring the admittance (conductance, G and susceptance, B) of the device at each frequency, the complex dielectric constant were calculated by

$$\varepsilon' = 1 + \frac{1}{\omega\varepsilon_0}\left(\frac{d}{A}\right)B \qquad \varepsilon'' = \frac{1}{\omega\varepsilon_0}\left(\frac{d}{A}\right)G$$

where ω is the angular frequency, ε_0 the dielectric constant of free space, d the separation between the electrodes, and A the effective cell area, respectively. The real part of complex dielectric constant, ε' in a range of low frequency was at around 17 and had the frequency independent property (figure 1(a)). As the frequency increases, it decreases abruptly from about 100kHz. The imaginary part of complex dielectric constant, ε'' showed the peak at around 300kHz as can be seen in figure 2(b). That was related to the dipolar polarization and the corresponding dielectric relaxation time is calculated to be about 0.531μs, which determines the mean time for the dipole to lose its alignment.

The Cole-Cole plot was shown figure 2. It represents the one semi-circle shape. This indicates that the device is modeled the equivalent parallel circuit with a resistor and capacitor. The abrupt increase of dielectric loss factor in a low frequency regime is supposed to be associated with the double layers structure. Further studies should be pursued.



(a) (b)

FIGURE 1. The complex dielectric constant at zero bias.
(a) Dielectric constant, (b) Dielectric loss factor.

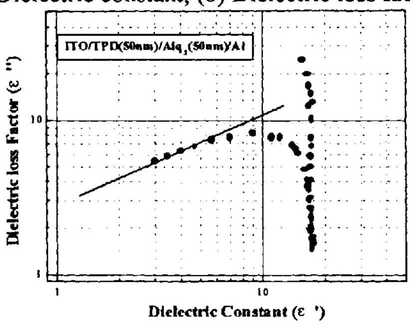


FIGURE 2. Cole-Cole plot on the complex plane.

Figure 3 showed the capacitance as a function of the frequency at 0V. The capacitance was dependent on the frequency at low frequency region. In a range of low frequency, the capacitance decreases steeply and showed the independent properties at high frequency region. This is related to the trapping and detrapping process of the charge carriers. At low frequency, the states have the sufficient time to trap the carrier. Therefore, the states can be charged. However, The trapping processes are too sluggish to trap the carrier at high frequency region.

The quality factor is the ratio of the reactance to the resistance of a device or system. The quality factor of the capacitor is the equivalent parallel resistance that represents the dielectric loss. The quality factor of the resonant circuit measures the circuit's peak response at the resonant frequency. Figure 4 showed the quality factor as a function of the frequency with the applied DC bias. The peak was at about 20kHz at 0V, which means the resonant frequency.

As the applied bias increases, the intensity decreases and the peak shifts to the high frequency. This indicates that when the high voltage applied, the time of the trapping and detrapping is faster than that with low applied voltages. Therefore, the frequency dependent peak shift is observed.

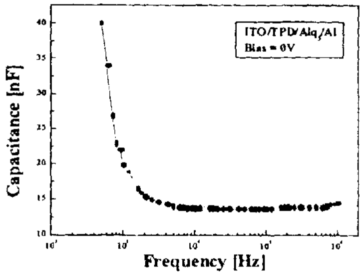


FIGURE 3. Capacitance as a function of frequency.

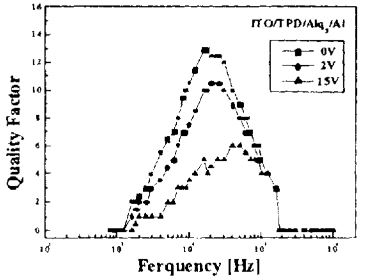


FIGURE 4. The quality factor versus frequency.

CONCLUSIONS

We have studied the dielectric properties of organic light emitting diodes. In a low frequency range, the dielectric constant is at about 17 and it decreases from about 100kHz. The dielectric loss factor has a peak at 300kHz and the corresponding relaxation time is calculated to be 0.531μs. By the Cole-Cole plot, we presumed that the device is modeled the parallel circuit with a resistance and capacitor. We obtained the frequency dependent properties of capacitance and quality factors. We guess that they are related to the trapping and detrapping process of the charge carriers.

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