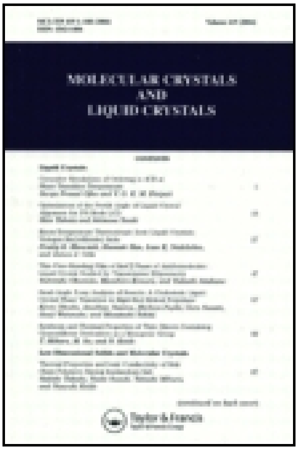

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Electric Conduction of Electroluminescent Metal Chelate Thin Films

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Electric conduction in vacuum-deposited films of electroluminescent metal-chelates, tris-(8-hydroxyquinoline) aluminum (Alq3) and zinc bis-(2-(o-hydroxypheyl)-benzoxazolate)) (ZnPBO), were studied by current (I)-voltage (V) measurement. The I-V characteristics demonstrated that the films exhibited trap-controlled conduction. For the Alq3 film, conductivity σ was estimated to be 3.0×10^{-15} Scm^{-1} from the characteristic in ohmic current region. From the I-V characteristic in space charge limited current region, further, carrier mobility μ of the Alq3 film was estimated to be 5.0×10^{-7} $cm^2V^{-1}s^{-1}$; this value is in good agreement with electron mobility evaluated by the time-of-fight technique. For ZnPBO, the values of σ and μ were estimated to be 2.0×10^{-14} Scm^{-1} and 7.0×10^{-6} $cm^2V^{-1}s^{-1}$, respectively.

Keywords: mobility; conductivity; metal chelate; electroluminescence

INTRODUCTION

Metal-chelate systems such as metal quinolates and metal benzoxalates are promising emissive materials for organic electroluminescent (EL) device because they exhibit relatively efficient photoluminescence and long term stability in film morphology.[1-3] For developing of the metal chelates for the EL application, it is important to understand not only their emissive properties but their electric conduction, in particular, carrier mobility μ. In high electric field region where EL occurs, electric conduction is assumed to be dominated by space charge limited current (SCLC) which express the current (I_{SCLC})-voltage (V) characteristic by the equation $I_{SCLC} = (9/8)\varepsilon\varepsilon_0\mu V^2/L^3$, where $\varepsilon\varepsilon_0$ is permittivity of EL material.[4] The SCLC equation tell us that enhancement of carrier mobility provides diminution of the drive voltage of EL device which is expected to improve performance of EL devices (power efficiency and long term stability). However, few studies have been made on the electric conduction of the electroluminescent metal chelates. In this study, we evaluated electric conduction properties (conductivity, carrier mobility and so on) in thin films of the metal chelates, tris-(8-hydroxyquinoline) aluminum (Alq3) and zinc bis-(2-(o-hydroxypheyl)-benzoxazolate)) (ZnPBO), by measuring the temperature dependence of current-voltage (I-V) characteristic.

EXPERIMENTAL

Molecular structures of Alq3 and ZnPBO are shown in Fig.1. Previous EL studies on the metal chelates demonstrate that the metal chelates possess electron transporting nature. Accordingly, we selected magnesium with a low ionization potential (3.7eV) as electrode and prepared a sandwich type device Mg/metal chelate/Mg for evaluating electric conduction properties due to electron transport. The sandwich type devices were prepared by successive vacuum-deposition of Mg and the metal chelates at about 10^{-5}torr without exposure to the air.

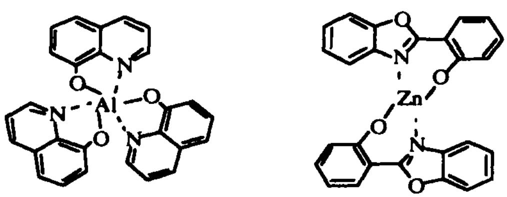

FIGURE 1 Molecular structures of metal chelates Alq3 and ZnPBO

RESULTS AND DISCUSSION

Figure 2 a) shows I-V characteristics of an Alq3 thin film (thickness L =310 nm) which was sandwiched with Mg electrodes. The characteristics demonstrates that the Alq3 thin film exhibits the typical trap-controlled electric conduction; the Ohmic current is observed in the low electric field region (< 10^4 Vcm^{-1}), and space charge limited current (SCLC), which is quadratic field-dependent, is observed in high electric field region (>3x10^5 Vcm^{-1}) after rapid rise of current. From the Ohmic current, the conductivity σ of the Alq3 thin film was estimated to be 3.0 x 10^{-15} Scm^{-15} at room temperature. We confirmed that the conductivity is independent on film thickness, where thickness was ranged between 100 nm and 400 nm. In

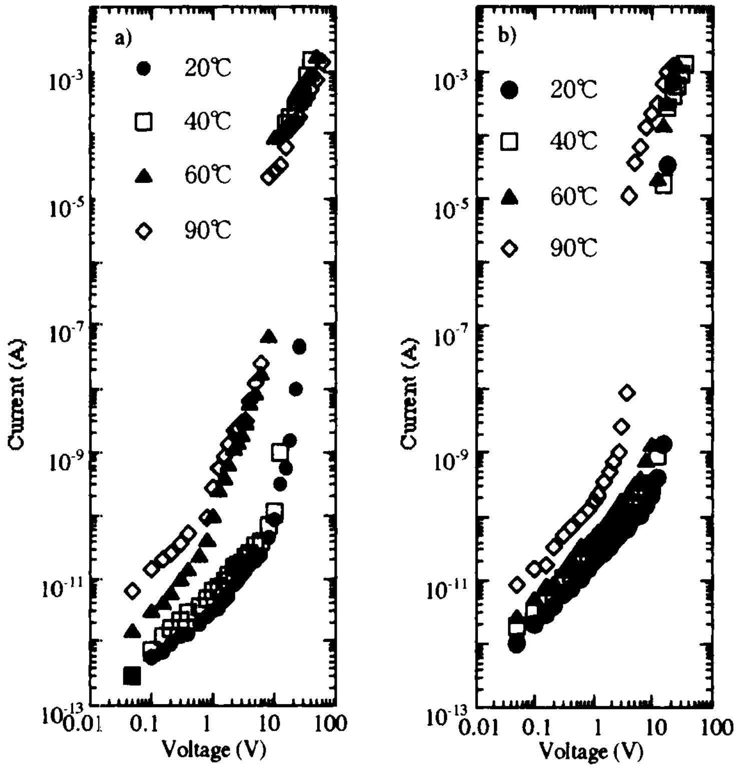

FIGURE 2 Current-voltaage characteristics of metal chelate thin films: a) Alq3 and b)ZnPBO

this measurement, therefore, the bulk conductivity without contact resistance effect was surely evaluated.

From the SCLC, carrier mobility μ was estimated to be 5.0 x 10^{-7} $cm^2V^{-1}s^{-1}$, where the mobility was calculated according to the equation $I_{SCLC} = (9/8)\varepsilon\varepsilon_0\mu V^2/L^3$. The permittivity ε of Alq3 requisite for the calculation was evaluated to be 3.13 by the capacitance measurement using a impedance analyzer (YHP 4192AFL). The carrier mobility is assumed to be due to electron-transport because we employed Mg electrode with low ionization potential for electron injection in this measurement. In fact, the value is in good agreement with the electron mobility of Alq3 which was determined by the time-of-flight measurement.[5]

The temperature dependence of the I-V characteristics demonstrated that the conductivity was temperature-dependent with the activation energy **Ea** of 0.54 eV while the carrier mobility was almost independent on temperature. Then, the activation energy is gathered to be mainly due to carrier generation. However, the **Ea** value is very small compared with the HOMO-LOMO band gap (2.65 eV) of Alq3 obtained from optical absorption spectrum. Therefore, the carrier is understood to be extrinsic; the origin of the carrier is not clear at this stage. Assuming that majority carrier is electron in the Alq3 thin film, carrier density **n** was estimated to be 3.3×10^{10} cm^{-3}.

Figure 2 b) show I-V characteristics in a ZnPBO thin film (L=380 nm). The ZnPBO film also exhibits the trap-controlled conduction. By using the same procedure with that in the case of Alq3, the values of σ, μ and **n** were estimated to be 2.0×10^{-14} Scm^{-1}, 7.0×10^{-6} $cm^2V^{-1}s^{-1}$ and 2.3×10^{10} cm^{-3}, respectively, where ε value of 3.27 was used. The high carrier mobililty of ZnPBO which is one order of magnitude larger than that of Alq3 suggests that employing ZnPBO as emissive layer in EL device would provide drastic decrease in drive voltage.

SUMMARY

We successfully evaluated the electric conduction properties of electroluminescent metal chelates, tris-(8-hydroxyquinoline) aluminum (Alq3) and zinc bis-(2-(o-hydroxypheyl)-benzoxazolate)) (ZnPBO), by measuring their current-voltage characteristics. The conductivity and carrier mobility of the metal chelates were evaluated to be 3.0×10^{-15} Scm^{-1} and 5.0×10^{-7} $cm^2V^{-1}s^{-1}$ for Alq3, and 2.0×10^{-14} Scm^{-1} and 7.0×10^{-6} $cm^2V^{-1}s^{-1}$ for ZnPBO, respectively.

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