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Fabrication and Characteristics of Increased Efficiency of Layered Polymeric Electroluminescent Diodes

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1. Introduction

Organic light emitting diodes (OLEDs)[1-3] utilizing fluorescent dye or conducting polymer have attracted great interest because they have advantages for thin film flat-panel display application. An additional advantage for OLED utilizing polymeric materials is that they are simple for fabrication by wet-process, including spin coating and ink-jet printing method on various kinds of substrates. Emissive materials of low molecular such as iridium derivatives[4-6], which are known for their high efficiency phosphorescence from their triplet states, are doped in polymeric materials for fabrication of highly efficient OLED[7-10]. Combination of polymeric and low molecular materials will realize highly efficient OLED. On the other hand, fabrication of OLED with layered structure which consist of an emissive layer and carrier transport layers will realize increased emission efficiency for polymeric OLED.

In this paper, we discuss fabrication and characteristics of layered polymeric OLED using water-soluble molecular and polymer with wet process.

2. Experimental

Figure 1 shows the molecular structures of organic materials using in this study and schematic description of EL device. Organic layers were fabricated by spin coating onto a glass substrate coated with an indium tin oxide (ITO) layer. The substrate was degreased with solvents and cleaned in a UV ozone chamber. First, poly(ethylenedioxythiophene): poly(styrene sulfonic acid) (PEDOT:PSS) hole injection layer was spun over the ITO-coated glass substrate. Poly(9-vinylcarbazole) (PVCz) was used as a hole-transporting host. The conducting host polymer, PVCz and dopants, *fac*-tris(2-phneylpyridyl)Ir(III) ($Ir(ppy)_3$) and 2-(4-biphenylyl)-5-(4-*tert*-butyl-phenyl)-1,3,4,-oxadizol e (PBD) were dissolved in chloroform. Next, a mixture of the PVCz and dopants, $Ir(ppy)_3$ was spin-coated at room temperature under ambient conditions. Furthermore, the device with three layered structure was fabricated using water-soluble organic materials such as bathocuproinedisulfonic acid (BCPac) and sodium poly[2-(3-thienyl)ethoxy-4-butylsulfonate] (TP). The cathode consisting of Mg:Ag layer was vapor-deposited at a background pressure of 10^{-4} Pa. Finally, the device was covered with a glass plate and encapsulated by epoxy resin in an argon gas atmosphere to prevent oxidation of the magnesium cathode. The active device area with 4 mm^2 was obtained by shadow mask. Forward bias condition is positively biased against the Mg:Ag cathode, vice-versa for negative bias. All measurements were carried out at room temperature.

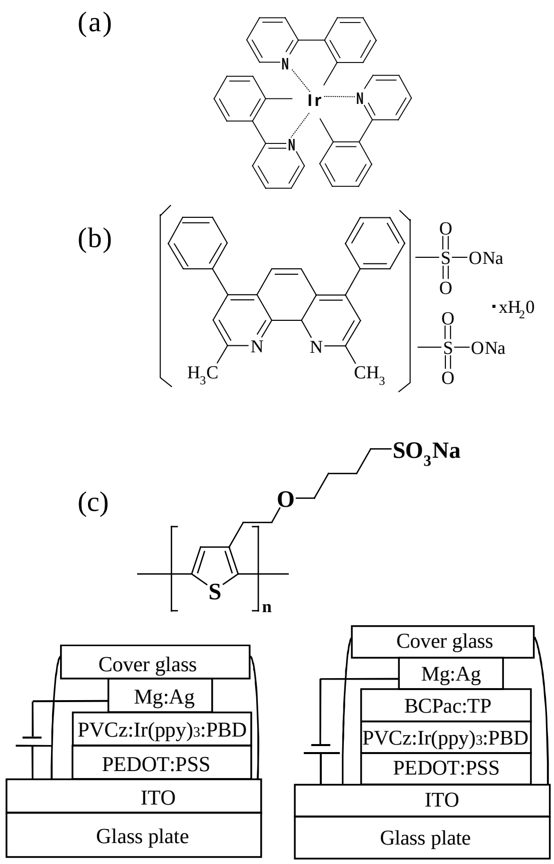

Fig.1 Molecular structures of organic materials using in this study and schematic description of EL device. (a)$Ir(ppy)_3$ (b)BCPac (c) sodium poly[2-(3-thienyl)ethoxy-4-butylsulfonate]

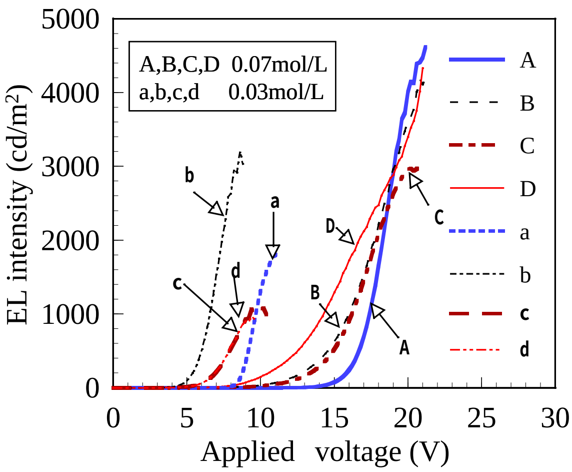

Fig.2 Emission characteristics of two and three layered devices.
(A,a)ITO/PEDOT:PSS/PVCz(Ir(ppy)$_3$,PBD)/Mg:Ag,
(B,b)ITO/PEDOT:PSS/PVCz(Ir(ppy)$_3$,PBD)/BCPac/Mg:Ag,
(C,c)/ITO/PEDOT:PSS/PVCz(Ir(ppy)$_3$,PBD)/TP(BCPac)/Mg:Ag,
(D,d)ITO/PEDOT:PSS/PVCz(Ir(ppy)$_3$,PBD)/TP/Mg:Ag.

3. Results and Discussions

Figure2 indicates the dependence of EL intensity on the applied voltage for two and three layered structure devices with an active area of 4 mm^2. The device structure is (A,a) ITO/PEDOT:PSS/PVCz(Ir(ppy)$_3$, PBD)/Mg:Ag, (B,b) ITO/PEDOT:PSS/PVCz(Ir(ppy)$_3$, PBD)/BCPac/Mg:Ag, (C,c)/ITO/PEDOT:PSS/PVCz (Ir(ppy)$_3$,PBD)/TP(BCPac)/Mg:Ag, (D,d)ITO/PEDOT: PSS/PVCz(Ir(ppy)$_3$,PBD)/TP/Mg:Ag. A molecular weight ratio for PVCz:PBD:Ir(ppy)$_3$ is 26:10:1(A～D), respectively. EL intensity for the two layered structure device of an ITO/PEDOT:PSS/ PVCz(Ir(ppy)$_3$, PBD)/Mg:Ag is as same as that of three layered structure using water-soluble thiophene derivative and BCPac. Comparing a threshold voltage of two and three layered device, the former device is about 15V and latter devices are less than 11V. The reason of decreasing voltage for three layered structure can be explained considering properties of BCPac and TP. These materials have hole-blocking and transport ability, so the recombination of injected holes from ITO anode and electrons are carried out efficiency. As a result, excitons are confined in the emissive layer and threshold voltage decreased. In the case of the same structure devices which is a molecular weight ratio 16:6:1(a～d), threshold voltage also decreased and the device structure (b) is the lowest threshold voltage of all devices.

We fabricated two and three structure OLEDs using spin coating method. This method can be expected to be utilized as simply and low cost process for fabricating OLEDs. The result in this study suggested that the recombination efficiency of the OLEDs with three layered structure using water-soluble organic materials can be improved.

4. Conclusions

We demonstrated the emission properties of OLEDs with the three layered structure using water-soluble organic materials. The threshold voltage of an OLED with three layered structure using water-soluble organic materials is lower than that with two layered structure. The result in this study suggested that the energy efficiency of the OLEDs with three layered structure using water-soluble organic materials can be improved.

Acknowledgements

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