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Research and Development of Organic Electroluminescent Devices and Application for Plastic Information Devices

Yutaka Ohmori and Hirotake Kajii

Osaka University, Center for Advanced Science and Innovation (CASI)
2-1 Yamada-Oka, Suita, Osaka 565-0871, Japan
Phone: +81-6-6879-4212 E-mail: ohmori@casi.osaka-u.ac.jp

1. Introduction

Organic light emitting diodes (OLEDs) utilizing fluorescent dye or conducting polymer have attracted great interest because they have advantages for thin film flat-panel display. An additional advantage is that they are simple for fabrication on various kinds of substrates, including polymeric substrates. On the other hands, polymeric waveguide devices have attracted great attentions with regard to their use for flexible optical circuits and optical interconnection. The combination of polymer waveguide and optical devices (OLED and OPD) will realize a flexible optical integrated circuits [1]. In this presentation, we discuss the characteristics of OLEDs fabricated on the glass and polymeric substrates for application of flat-panel display and optical inter-connection. OLED with polymeric materials fabricated by wet process is also discussed.

2. Organic Electroluminescent Devices and Applications for Information Devices

2.1 Polymeric optical integrated device

Schematic of polymeric optical integrated device fabricated on a polymeric waveguide is shown in Fig. 1. Here, organic electroluminescent (EL) device is used as an electro-optic conversion device and organic photo-detector used as an opto-electric conversion device.

Polymeric waveguide is connected with an optical fiber through an optical connector. Electrical video or audio signals are converted with organic EL device to optical signals, and are transmitted to optical fiber through polymeric waveguide. And then, the optical signals are received to organic photo-detectors (OPD) through the polymeric waveguide. The converted output signals of photo-detectors are displayed on terminal devices such as displays, facsimiles or phones.

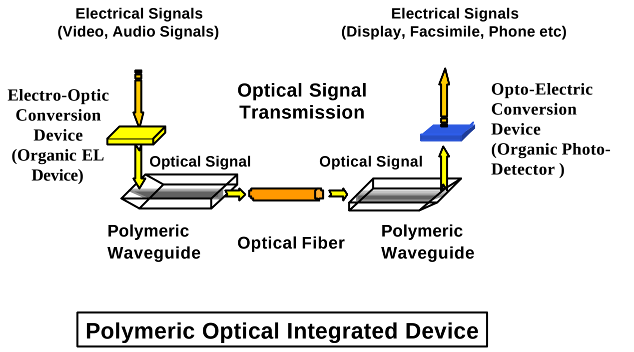

Figure 1. Schematic of polymeric optical integrated device.

2.2 Organic electroluminescent devices with low molecular materials

OLEDs with various low molecular materials including red, yellow, green and blue light emissions have been investigated. The organic layers for OLEDs were vacuum deposited by organic molecular beam deposition (OMBD) system at a background pressure of 10^{-5} Pa. For substrates used for the experiments, polymeric substrates as well as glass substrates were used for comparison.

A typical OLED consists of indium-tin-oxide (ITO) coated polymeric substrate with buffer layers with thin layers of silicone oxide and silicone nitride multilayer, 4,4'–bis[N-(1-napthyl)-N-phenylamino]-biphenyl (α-NPD) as a hole transporting layer, doped emissive layer, 8-hydroxquinoline aluminum (Alq_3) as an electron transporting layer, terminated with silver-containing magnesium (Mg:Ag) cathode. As a dopant of the emissive layer, 5,6,11,12-tetraphenyl-naphthacene (rubrene) or 5,10,15,20-tetraphenyl-21H,23H-porphine (TPP) molecules were doped in Alq_3, respectively. In order to reduce the straight capacitance of the diode, the active size of the device was employed as small as 0.01 mm^2 and so on.

The emission characteristics of OLEDs with low molecular materials are summarized in Table 1. In case of a device in which α-NPD as an emissive layer, the device consists an ITO-coated glass substrate, 60 nm-thick α-NPD as a hole transporting emissive layer, 5 nm-thick 4,4'-bis (carbazol-9-yl)-biphenyl (CBP) and 10 nm-thick 2',9-dimethy-4,7-diphenyl-1,10-phenanthroline (BCP) as hole-blocking layers, and 15 nm-thick 8-hydroxquinoline aluminum (Alq_3) as an electron transporting layer, terminated with a silver containing magnesium (Mg:Ag) cathode. The device has a turn-on voltage of about 3V.

The OLED made with Alq_3 as an emissive material emits clear green emission centered at about 520 nm. However, the modulation characteristics are rather poor compared with α-NPD device, and its high frequency modulation limited to 60 MHz. It will be due the fluorescence lifetime of Alq_3, which is more than 10 ns. The device which consists of 9.1vol% of 5,6,11,12-tetraphenyl-naphthacene (rubrene) doped in Alq_3 layer as an emissive layer [2], emits clear yellow emission centered at about 560nm. The emission reaches 30mW/cm^2, at an applied voltage of 9V and the current density of 10 A/cm^2. The device also emits more than 100MHz modulated light. The red light emitting device, which consists of 5,10,15,20 tetraphenyl-21H,23H-porphine (TPP) doped in 30 nm-thick

30 nm-thick Alq_3 as an emissive layer, has two peaks centered at 650 nm and 720 nm, and the mole fraction of 1% TPP is enough to emit red light. The modulation frequency reaches at 100MHz, however, the emission intensity is rather poor compared with other materials, and the maximum emission intensity is 4 mW/cm^2 at a current density of 2 A/cm^2.

Table 1. Summary of emission characteristics of various kind organic light emitting diodes.

Emissive Materials	α-NPD	Alq_3	Rubrene	TPP
Central Wavelength	430nm	520nm	560nm	655nm 720nm
Emission Intensities	More than 40mW/cm^2	More than 30mW/cm^2	More than 30mW/cm^2	More than 4mW/cm^2
Frequency Limitation	More than 100MHz	~60MHz	More than 100MHz	More than 100MHz

In Fig. 2, emission characteristics are compared as a function of injection current for the OLED with 30-nm thick Alq_3 and 50-nm thick α-NPD fabricated on a glass and a polyimide substrate. The emission characteristics of both the OLED fabricated on a glass substrate and a polymer substrate are the same, however, the emission efficiency is rather high in the device with polyimide substrate compared with that with glass substrate. The difference will come from the difference of the thickness and the refractive index of the substrate.

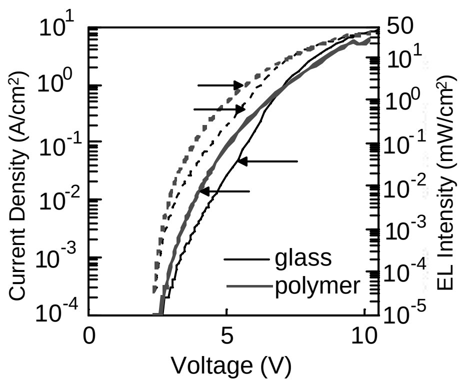

Figure 2. Emission characteristics of OLED fabricated on a glass and a polymeric substrate.

2.3 Organic electroluminescent devices with polymeric materials

Highly emissive OLED with polymeric materials fabricated by wet process is discussed. Two kinds of OLED are fabricated by spin coating method. The device consists of poly (ethylene dioxythiophene) : poly(styrene sulfonic acid (PEDOT:PSS) as hole transporting layer, emissive layer of mixed materials and terminated with cesium and silver. Two kinds of emissive layer were prepared by spin coating. Methoxy-substituted 1,3,5-tris[4-(diphenylamino) phenyl]benzene (TDAPB), and poly(*n*-vinylcarbazole) (PVCz) were employed as host materials, and 2-(4-biphenylyl)-5-(4-*tert*-butylphenyl)-1,3,4,-oxadiazole (*t*-Bu-PBD) and rubrene were mixed as electron transporting and emissive materials, respectively. The molar ratio for the emissive layer is as follows; TDAPB: t-Bu-PBD: rubrene = (100:72:1.65), PVCz: t-Bu-PBD: rubrene = (100:72:1.65).

As is shown in Fig. 3, the OLED with TDAPB emit higher than that of PVCz in EL intensity. This will be due to the energy transfer between host materials and emissive materials. The device can be also used as a light source for the polymeric integrated device.

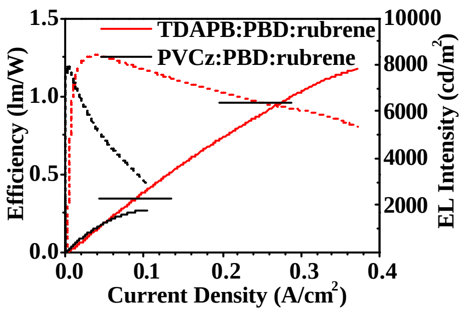

Figure 3. Emission characteristics of OLED fabricated by wet process.

3. Summaries

In summary, OLEDs with low molecular and polymeric materials are discussed as a light source for the polymeric integrated device.. Both the OLEDs with low molecular and polymeric materials can be used as a light source for transmitting moving picture signals.

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