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Organic Electroluminescent Diode Fabricated on ITO-Coated Polyimide Substrate as an Electro-Optical Conversion Device for Polymeric Waveguides

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1. Introduction

Recently, organic light-emitting diodes (OLEDs) utilizing fluorescent dye[1] or conducting polymer[2] have been realized which have a long lifetime and excellent durability for flat panel display applications. There are some requirements of the OLEDs not only for display application but also for various light sources.

On the other hands, there are two types of LEDs and laser devices for transmitting optical energy. LEDs have lower power but are much less expensive, and are used for short distances and multimode paths. An additional advantage is that OLEDs are simple to fabricate on various kinds of substrates, including polymer[3] and glass substrates. That is, the mechanical flexibility is one of the key advantages of OLEDs. In addition, the nanosecond transient electroluminescence of blue OLED has also been reported[4]. OLEDs can also be expected to be applied to electro-optical conversion devices for generating the high-speed optical pulses. For example, the combination[5,6] of OLED and polymer waveguide[7] will provide huge advantages as regards fabricating optical integrated circuits in data communication systems. Therefore, it is important to develop the visible OLEDs for high-speed switching applications in the field of local-area network (LAN) such as FTTH (Fiber TO THE HOME) and car-LAN.

In this study, we examined the properties of OLEDs fabricated on the indium-tin-oxide (ITO) -coated polyimide substrate utilizing rubrene doped in 8-hydroxyquinoline aluminum (Alq_3) as an emissive layer for generating the high-speed optical pulses at lower voltages.

2. Experimental

Polyimide film with the high thermal stability, high optical transparency and control of refractive index is one of the promising candidates for the substrate of the polymer waveguide device. Therefore, we selected a polyimide film as the substrate. For reducing the capacitance of the OLED, the devices with the active area of 0.01 mm^2 were fabricated by organic molecular beam deposition on an ITO-coated polyimide substrates at a background pressure of about 10^{-5} Pa. In this paper, the typical device consists of an ITO - coated polyimide substrate, 50nm-thick N,N'-di(naphtalen-1-yl)-N,N'-diphenylbenzidine (NPB) as a hole transporting layer, 30nm-thick rubrene doped in Alq_3 as an emissive layer, and 10nm-thick Alq_3 as an electron transporting layer, terminated with a silver containing magnesium (Mg:Ag) cathode.

Luminance was measured with an optical multi power meter Q8221 (Advantest). The transient EL measurements were performed by applying the voltages pulses generated by HP8110A source (Agilent Technology). The optical pulse was observed using a photomultiplier tube detector (Hamamatsu Photonics). The EL response and voltage were simultaneously digitized by a Sony Tektronix TDS3054 oscilloscope.

3. Results and Discussion

The dependence of the injection current and luminance on an applied voltage for the OLED with an active area of 0.01 mm^2 under the forward bias condition are presented in Fig. 1. The luminance increases significantly in the forward bias direction above a threshold voltage of about 2.4 V. It finally reaches about 45 mW /cm^2.

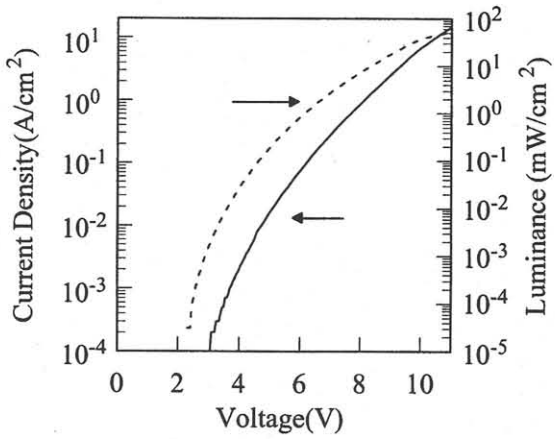

Figure 1. Voltage-injection current and voltage-emission intensity characteristics of ITO/ NPB (50nm) / Rubrene doped in Alq_3 (30nm)/Alq_3(10nm)/Mg:Ag with an active area of 0.01 mm^2.

It is important to focus on the transient properties of OLEDs for transmitting the high modulation signals in

data communication systems. The applied voltage and optical output characteristics of the OLED based on the Alq_3 doped with rubrene driven at 10 ns period and duty ratio of 0.5 pulses are presented in Fig. 2. We created clear light pulses by direct modulation of the OLED with rubrene doped in Alq_3 driven at the applied voltage pulses of 100MHz. This organic diode can be expected to be utilized as one of the flexible electro-optical conversion devices for transmitting the digital pulses driven at about 100 MHz.

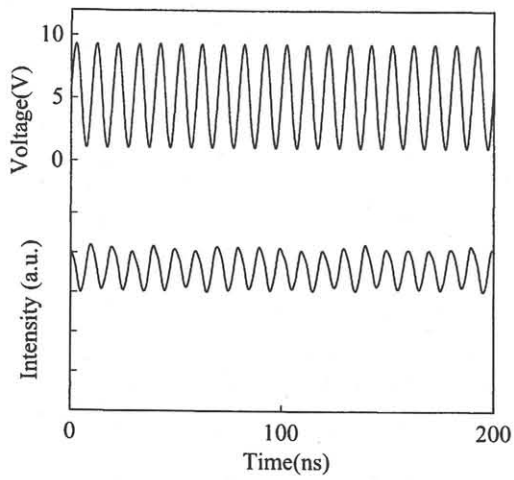

Fig. 2. The applied voltage and optical output characteristic of the 0.01 mm^2 OLED with rubrene doped in Alq_3 driven at 10ns period and duty ratio of 0.5 pulses.

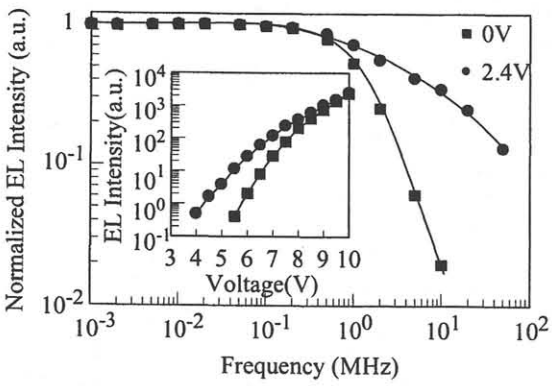

Fig. 3. The frequency dependence of EL intensity of the 0.01mm^2 OLED performed with the voltage pulses of peak value of 5 V for different offset dc biases of 0 and 2.4 V. The inset shows the dependence of EL intensity on the applied voltage pulses of 20 MHz for different offset dc biases of 0 and 2.4 V.

Figure 3 indicates frequency dependence of EL intensity of the 0.01 mm^2 OLED performed with the voltage pulses of peak value of 5V for different offset dc biases of 0 and 2.4 V. It should be noted that frequency dependence of device was significantly improved by applying the offset bias of 2.4V. Under the applied voltage pulses of 20 MHz for different offset dc biases of 0 and 2.4 V, the ratio of EL intensities between the offset biases of 0 and 2.4 V decreases with increasing the applied voltage as shown in the inset of Fig. 3. That is, the performance of modulation speed in OLED was improved significantly by applying the positive offset voltage, especially at low voltages.

4. Conclusions

Organic light emitting diodes (OLEDs) were fabricated on the ITO-coated polyimide substrates for application on the electro-optical conversion devices for polymer waveguides. Optical pulses of 100 MHz have been obtained from an OLED based on the rubrene doped in Alq_3 emissive layer with the active area of 0.01 mm^2 fabricated on the ITO-coated polyimide substrate. The performance of modulation speed of OLED was improved significantly by applying the positive offset voltage in the range of lower voltages.

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