12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

**12D2-4**

# Influence of carrier traveling length on transient properties of fast-response organic light sources

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**Abstract**

Organic light sources are required for optical interconnect applications because of its flexibility and low fabrication cost. We have investigated transient properties of organic light sources with different thicknesses of organic layers. The cutoff frequency of 12 MHz has been achieved.

## 1 Introduction

Organic light-emitting diodes (OLEDs) and organic photo-diodes (OPDs) have several advantages over inorganic devices, such as flexibility and low fabrication cost. So, organic devices have been attracted for optical interconnect applications, of which a schematic configuration is shown in Fig. 1 [1, 2].

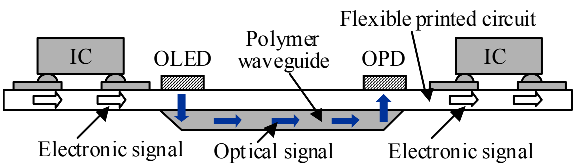



Fig1. A schematic configuration of an example of an optical interconnects with an OLED and an OPD.

Several factors to affect a response time of an OLED have been already investigated, particularly capacitance [3], a fluorescence lifetime (FL) of a light emitting-material [4], and carrier mobility of electron/hole transport materials [5]. To date, the –3 dB cutoff frequency of more than 10 MHz has been achieved [4]. The reported cutoff frequency was less sufficient to apply these OLEDs for optical interconnects. It has been recognized that several hundreds of MHz or over GHz transmission speed is desirable to correspond to expand an application field. Furthermore, other factors to limit the transmission speed are important to examine possibilities of organic light sources.

In this paper, we have investigated that the relationship between the transient property of OLEDs and the carrier traveling length, which is determined as thicknesses of organic layers.

## 2 Experimental

We fabricated OLEDs using a vacuum evaporation machine. The OLEDs consists of X nm of 4,4’-bis[N-(1-napthyl)-N-phenyl-amino]-biphenyl as a hole transport layer (HTL), 20 nm of 0.5 mol% 1,4-bis[2-[4-[*N,N*-di(*p*-tolyl) amino]phenyl]vinyl]benzene doped 4,4'-bis(9-carbazolyl) biphenyl as a light-emitting layer, 10 nm of bathocuproine as a hole block layer, Y nm of tris(8-hydroxyquinoline)aluminum as an electron transport layer (ETL), 0.4 nm of LiF, and MgAg (9:1 mol ratio) as a metal cathode, upon an indium tin oxide coated glass substrate. Active sizes of all the devices were 1.0 $mm^2$ by using a metal shadow mask. Here, we fabricated three devices with different thicknesses in the HTL and the ETL, of which thicknesses are shown in Table 1.

Table1. Thicknesses of the HTL (X) and the ETL (Y)

| | X (nm) | Y (nm) |
|---|---|---|
| Device A | 50 | 30 |
| Device B | 40 | 25 |
| Device C | 30 | 20 |

A transmission speed was estimated from a frequency dependence of an output power when a sine wave voltage was applied using the programmable FM/AM standard signal generator (SG-7200, KENWOOD). The output power was recorded using an avalanche photo diode. The amplitude of the sine wave voltage and the bias voltage were 5 V.

We also measured rise and decay times when a pulse voltage with the duration of 1 μs was applied. Rise and decay times were defined as times required for optical responses to change from 10 % to 90 % of the maximum output power and the inverse, respectively.

## 3 Results and discussion

Figure 2 shows the frequency dependence of the output power of OLEDs with different thicknesses of organic layers. The transmission speed increases with the decrease in thicknesses of organic layers, and the fastest –3 dB cutoff frequency of 12 MHz has been achieved for the thinnest device with thicknesses of X = 30 nm (α-NPD) and Y = 20 nm ($Alq_3$).

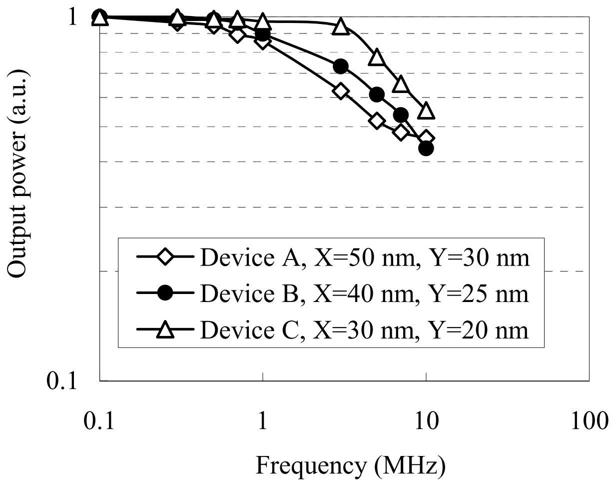
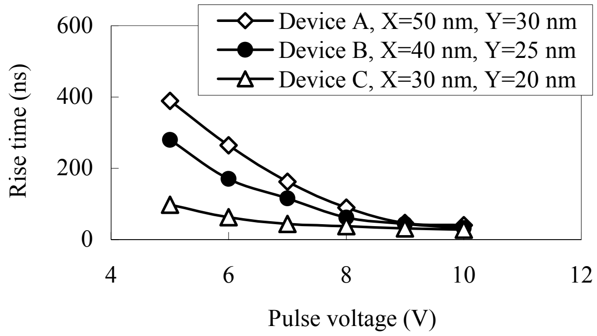


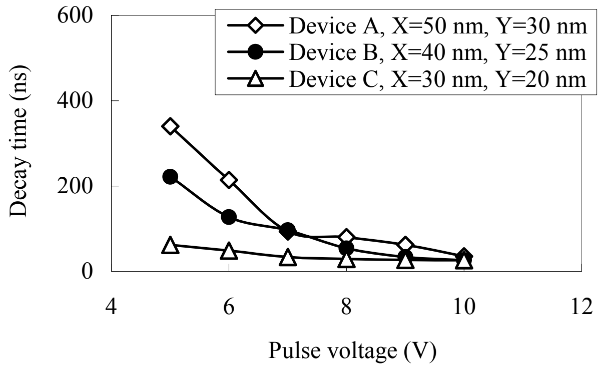

Fig.2 The frequency dependence of the output power of OLEDs with different thickness of organic layers.

Figures 3 (a) and (b) show rise and decay times as a function of a pulse voltage at a bias voltage of 5 V. Both rise and decay times decreases with increasing the pulse voltage. Carrier mobility of organic materials tends to increase with increasing an applied voltage. Therefore, transient properties are considered to improve with increasing a pulse voltage.

Although the decrease in thicknesses of organic layers causes the increase of the device capacitance, we observed that both rise and decay times shortened with the decrease in thicknesses of the HTL and the ETL. This is mainly contributed to the effect of electric-dependent carrier mobility. However, at high pulse voltage of 10 V, response times of all the devices reach almost the same, indicating that carrier mobility does not limit the transmission speed by applying a high pulse voltage.




(a)




(b)

Fig.3 The influence of a pulse voltage on (a) rise and (b) decay times at the bias voltage of 5 V.

## 4 Conclusion

We have investigated the relationship between thicknesses of organic layers and transient properties of OLEDs. A transmission speed can increase with the decrease in thicknesses of organic layers, and the maximum cutoff frequency 0f 12 MHz has been achieved.

## 5 References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