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Organic Multi-Function Diodes Operable for Emission and Photo detection Modes

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1. Introduction

Recently, organic devices, such as, high-efficiency organic light-emitting diodes (OLEDs) and organic photodiodes (OPD) are actively studied. Moreover, stacked organic device structures are also reported. In the last year's conference, we have presented a stacked layer of OLED and OPD matrix arrays, named Bi-Matrix.[1)] This panel configuration is suitable for light emitting display with a function of scanner. In this panel, however, fabrication process is difficult and operation of the interference between OLED and OPD may exist. It is considered that these problems can be solved by applying single-layered device exhibit multi-functions, such as poly[2-methoxy-5-(2'-ethylhexyloxy)]-1,4-phenylenevinylene (MEH-PPV).[2,3)] In this paper, we find out that a special low-molecular-weight organic material of pyrazoline derivative exhibit both functions of luminescence and light detection. And we have also investigated optimization of device structure and operation of 4x4 Matrix panel.

2. Experiment

Figure 1 show basic concept of the multi-function diode (MFD). Device structure is identical to that of the OLED. One side of the electrode is transparent, and the other side is reflective. Necessary point is that spectrum overlapping between emission and absorption has to be small because of its independent operation.

In this study, we have been searching many organic materials and we encounter the pyrazoline derivative 4-[2-[5-[4-(Diethylamino)phenyl]-4,5-dihydro-1-phenyl-1H-pyrazol-3-yl]-ethenyl]-N,N-diethylaniline (PPR) known as a hole transport material.

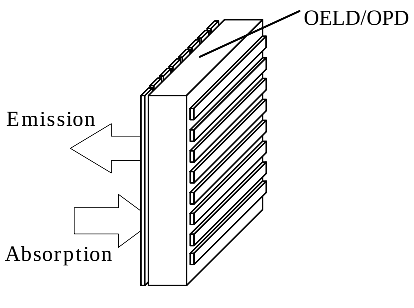


Fig.1 Basic concept of the Multi-Function diode.

Figure 2 shows organic materials under study. Fabrication process is as follows: First, indium zinc oxide (IZO, Idemitsu Kosan Co. Ltd.) coated glass substrate was patterned and cleaned. Second, device structure of copper phthalocyanine (CuPc) (30 nm)/ PPR (50 nm)/ 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP) (20 nm)/ lithium fluoride (LiF) (1 nm)/Al (70 nm) (Device 1) was subsequently evaporated. Here, the PPR can be solved into organic solvents, such as, chloroform or tetralin, so another device structure of spin-coated N,N'-bis(3-methylphenyl)-(1,1'-biphenyl)4, 4'-diamine (TPD): PPR = 20: 80 (1 wt %, chloroform) was formed. Device structure obtained was IZO/ TPD+PPR (110 nm)/ BCP (20 nm)/ LiF (1 nm)/ Al (70 nm) (Device 2).

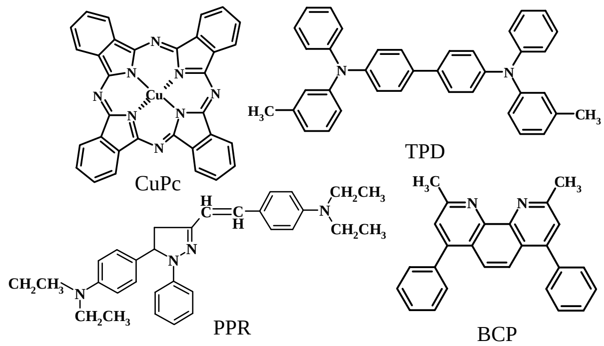


Fig.2 Organic materials under study.

The OLED/OPD characteristics were measured using a semiconductor parameter analyzer (HP4155B). Emission intensity was also measure using a luminance meter (Topcon BM-3). The light source for measuring OPD characteristics was xenon (Xe) lamp at an intensity of 33 mW/cm^2, for DC and matrix-driven characteristics. External drive circuit for prototype 4x4 Matrix used was field programmable gate array (FPGA) (Altera, university program design laboratory kits).

3. Experimental Results

Figure 3 shows photoluminescence (PL) and the absorption spectra of PPR. The solution of chloroform, 0.1 wt% was used for PL measurement. Concentration of the chloroform for measuring absorption spectrum was 10^{-4} wt%. In order to evaluate a quantum yield as a comparison, typical emission material of tris (8-hydroxy-quinoline) aluminum (Alq_3) was used. It is estimated that the fluorescence quantum yield of the PPR is almost equal to the Alq_3 from comparison of PL intensity. In addition, absorption coefficient of the PPR was much larger than that of the Alq_3. Therefore, it is considered that the PPR is suitable for ability of the luminescence and light absorption. Figure 4 shows current density (J) versus voltage (V) characteristics and luminance (L) versus voltage (V) characteristics of the Device 1 and 2. In the Device 1, a maximum luminance of 9,270 cd/m^2 (J =693 mA/cm^2) was obtained. The EL efficiency and external quantum efficiency were 2.58 lm/W (J =1.8 mA/cm^2) and 1.11% (J =2.99 mA/cm^2), respectively.

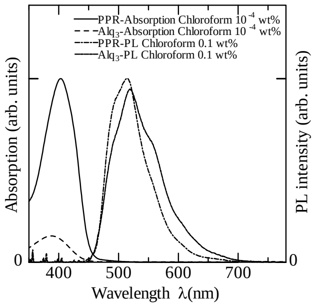


Fig.3 Photoluminescence/absorption spectrum.

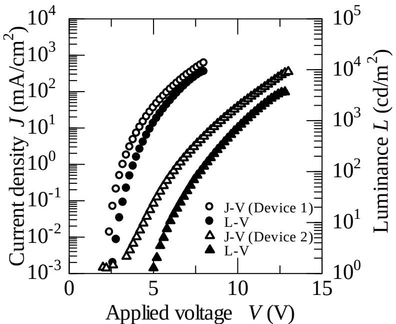


Fig.4 Luminance/current density versus voltage characteristics of OELD.

Figure 5 show current density (J) versus voltage (V) of the OPD. Open circles, triangles and filled circles, triangles show J-V characteristics under illumination and dark conditions, respectively. In the Device 1, ratio of photoconductivity to dark conductivity σ_R obtained was 2×10^3 at voltage of -4 V. Moreover, there is no difference between evaporation-processed Device 1 and solution-processed Device 2. Compared to another kind of device structure,[4] the photocurrent is one magnitude order smaller. Searching of another organic material is issue of this type of device.

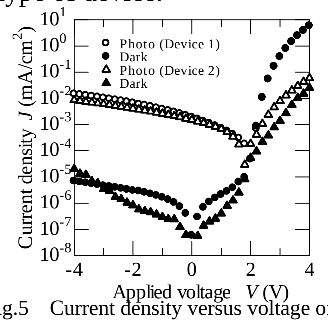
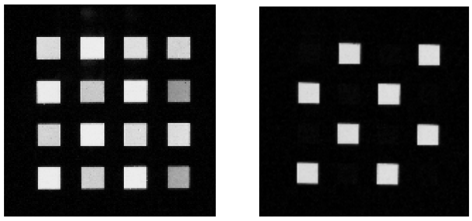


Fig.5 Current density versus voltage of OPD.

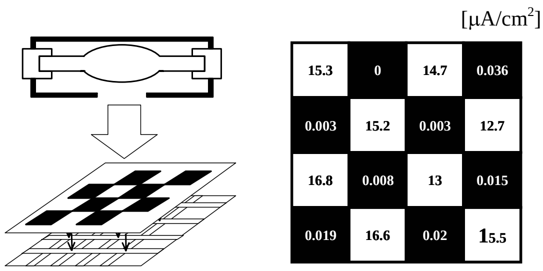
In order to demonstrate the device operation, prototype device of 4x4 Matrix with the structure of device 1 was fabricated. Figures 6 (a) and (b) show full dot and checked emission pattern of the OLEDs. It is obvious that clear emission can be obtained. Next, matrix operation of the OPD was tested as in a similar manner to previous report.[1] For the figure of merit of the higher performance of OPD operation, larger maximum number of capable driving columns N_{max} defined as a condition of I_P/I_D = 1 is necessary. From Fig.5, the estimated N_{max} was as large as 267. This large value of N_{max} was possibly due to easiness of carrier transport of this device structure because hysteresis was smaller that compared to the previous report.[1]



(a) (b)

Fig. 6 Emission patterns of Matrix OELD.

Figure 7(a) and (b) shows measurement system of the matrix operation and observed current values, respectively. In Fig. 7(b), numeric values indicate the observed current at the selected point. A clear checked pattern with clear on and off currents was observed.



(a) (b)

Fig. 7 Demonstration of Matrix OPD operation.

4. Conclusions

We have studied multi-function diode operable for OLED and OPD. The pyrazoline derivative is useful for both of emission and light detection in single device structure. In addition, prototype 4x4 Matrix was demonstrated and independent operation of OLED and OPD were confirmed.

1) Y. Matsushita, H. Shimada, T. Miyashita, M. Shibata, S. Naka, H. Okada and H. Onnagawa: Jpn. J. Appl. Phys. **44** (2005) 2826.
2) T. Echigo, S. Naka, H. Okada and H. Onnagawa: Extended Abstracts (The 49th Spring Meeting) of the Japan Society of Applied Physics and Related Societies, 27p-YL-16 (2002).
3) H. Shimada, S. Naka, H. Okada and H. Onnagawa: Extended Abstracts (The 51st Spring Meeting) of the Japan Society of Applied Physics and Related Societies, 31a-ZN-13 (2004).
4) H. Shimada, S. Naka, H. Okada and H. Onnagawa: Jpn. J. Appl. Phys. **44** (2005) 2830.