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# Organic Bi-Function Matrix Array

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## 1. Introduction

Recently, multi-layered organic devices with higher performances have been reported, such as, multiphoton emission devices[1] and tandem-type organic solar cell.[2] Research reports combined with organic electroluminescent device (OELD) and organic photo detector have been also reported. Xue et al. have reported the organic optical bi-stable switch by integrating OELD, photo detector and two transistors.[3] Chikamatsu *et al.* also reported stacked two-terminal device with OELD and organic photodiode (OPD)[4] However, there are no report on the matrix array combined with OELD and OPD. In this paper, we have proposed and demonstrated on the "bi-function matrix array (Bi-Matrix)" with stacking layer of OELD and OPD matrix array, which can be operated independently.

## 2. Experimental Results

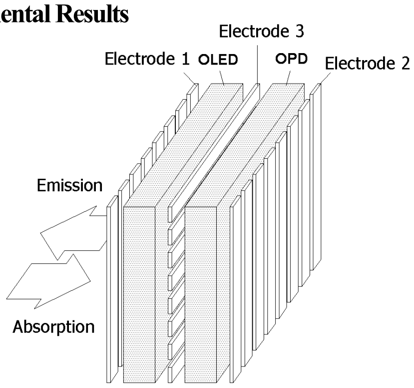



Fig. 1 Basic concept of Bi-Matrix.

Figure 1 shows basic concept of the Bi-Matrix. For the OELD operation, emission was able to seen through glass substrate. And image sensing operation, light absorption is carried out through the OELD, *i.e.*, transparent organic light-emitting diode (TOLED)[5] have to be necessary. From a standpoint of application, ultra-light-weight and hand-held emission panel with function of scanner will be realized.

Figure 2 shows organic materials under study. In order to demonstrate the operation of the Bi-Matrix, following device structure is fabricated on the glass substrate. The device structure is indium tin oxide (ITO)/copper phthalocyanine (CuPc) (5nm)/ 4,4'-bis [N-(1- naphtyl)-N-phenyl-amino]biphenyl ($\alpha$-NPD) (50nm)/ tris-(8-hydroxyquinoline) aluminum ($Alq_3$) (50nm)/CuPc (5nm) / sputtered indium zinc oxide (IZO, Idemitsu Kosan Co.

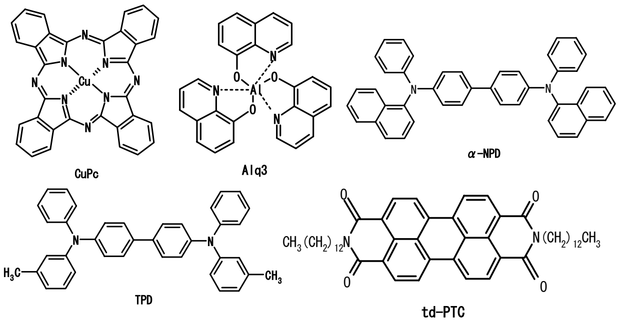



Fig.2 Organic materials under study.

Ltd.)/ N,N'- bis(3-methylphenyl)-(1,1'-biphenyl)4,4'-diamine (TPD) (50nm)/ N,N'-ditridecyl-3,4, 9,10-perylene-tetracarboxylic diimide (td-PTC) (50nm)/Al. To reduce sputtering damage at OELD, we inserted thin CuPc layer in OELD structure and transparent material of IZO was selected. This CuPc layer also acts an electron injection layer. For light absorption material, perylene derivative of td-PTC was used. The OELD characteristics were measured using a semiconductor parameter analyzer (HP4155B) and a luminance meter (Topcon BM-3). Light source of the measurement of the OPD characteristics was Xenon lamp at typical intensity of 33 and 23 mW/cm$^2$, for DC and matrix characteristics, respectively. External drive circuit for prototype 4x4 Bi-Matrix used was FPGA (Altera, university program design laboratory kits).

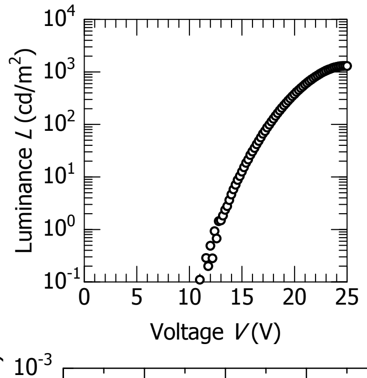



Fig.3 Luminance versus voltage characteristics of OELD.

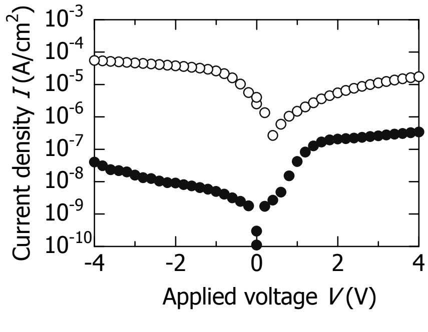
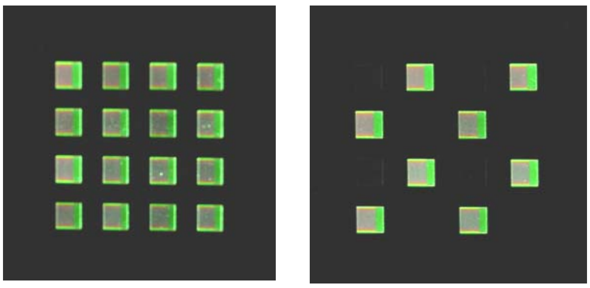



Fig.4 Current density versus voltage characteristics of OPD.

Figure 3 shows luminance ($L$) versus voltage ($V$) characteristics of the stacked OELD. Maximum luminance of 1,290 cd/m$^2$ (current density $J$ of 234 mA/cm$^2$) was obtained. These luminance value was one third compared to the TOLED reported to date,[5] however, this will be improved by changing the combination of the organic materials and device structures.[6] Figure 4 shows experimental result of current density ($J$) versus voltage ($V$) characteristics of the stacked OPD. Open circles and filled circles show $J$-$V$ characteristics under illumination and dark conditions, respectively. Ratio of photoconductivity to dark conductivity obtained was $10^3$ at voltage of –2 V. For the device with thickness of TPD of 100 nm, similar characteristics were obtained. This trial will be effective because higher electric strength is necessary for combination of OELD operation.



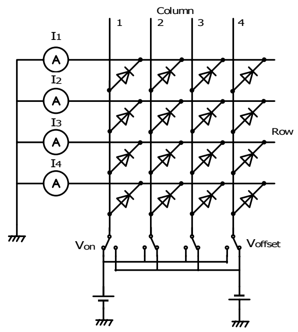
(a) (b)

Fig. 5 Emission patterns of Bi-Matrix OELD.

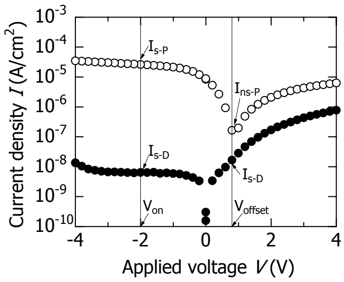
In order to demonstrate the device operation, prototype device of 4x4 Bi-Matrix was fabricated. Figure 5 shows photograph of the operation of Bi-Matrix OLED. Figures 5 (a) and (b) show full dot and checked emission pattern of the OELDs. It was obvious that clear emission was obtained. Figure 6 shows driving scheme (Fi. 6(a)) and typical operation point (Fig. 6(b)) of the Bi-Matrix OPD. Basic operation is similar to that of Yu and Cao.[7] When, column 1 is selected and columns 2-4 are non-selected, the selecting voltage $V_{on}$ and the non-selecting voltage $V_{offset}$ is applied, respectively, as shown in Fig. 6. On these occasions, total current flow was the sum of different columns. Minimum photocurrent $I_P$ and maximum dark-current $I_D$ are described as

$$I_D = I_{s-D} + 3 \times I_{ns-P}$$
$$I_P = I_{s-P} + 3 \times I_{ns-D}$$

Where, symbols are written in Fig. 6. Therefore, minimum number of capable driving column $N_{min}$ was $I_P / I_D$ and was estimated to 19. Figure 7 shows demonstration of the Bi-Matrix operation. Upper and lower figures show measurement system and observed current values, respectively. In the experiment, checked pattern was used. Obviously, clear on- and off-current was detected.

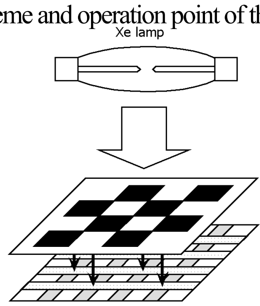



(a) Diving scheme




(b) Operation point

Fig.6 Driving scheme and operation point of the Bi-Matrix OPD.




[$\mu$ A/cm$^2$]

| | | | |
|---|---|---|---|
| 17 | 1 | 20 | 2 |
| 0.3 | 22 | 0.3 | 17 |
| 18 | 2 | 21 | 0.3 |
| 0.7 | 19 | 0.3 | 21 |

Fig. 7 Demonstration of Bi-Matrix operation.

## 3. Conclusions

Basic operation of the Bi-Matrix combined with OELD display and OPD array had demonstrated. Herewith, independent operations of emission and photo detection can be achieved for the multi-layered array. From the application, ultra-light-weight and hand-held emission panel with scanner will be realized.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