BLUE ELECTROLUMINESCENCE IN ORGANIC MULTILAYER THIN FILM DEVICES

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ABSTRACT

Organic thin-film electroluminescent devices with multilayer structures which exhibited bright blue emission were reported. Three typical multilayer cell structures were proposed, and the importance of the proper selection of cell structures according to the electronic properties of emitter dyes was emphasized. Blue EL devices with three types of multilayer cell structures, which gave the luminance exceeding 100 cd/m^2 at the drive current of 100 mA/cm^2, were shown.

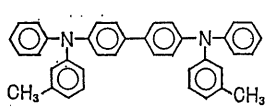
1. INTRODUCTION

The success in the fabrication of high performance organic electroluminescent (EL) devices has attracted much interest (1-6). Organic thin-film EL devices which exhibit high luminance at low dc drive voltages less than 10 V are promising for full color flat panel displays. One of the most fascinating advantages of organic EL devices is the possibility of molecular design of fluorescent dyes which are used for emitter layers. Thus we expect that we can control emission colors as well as emission efficiencies, through the design of molecular structures of dyes. In this report, we will show that blue EL devices can be fabricated based on the detailed examination of fluorescent and electronic properties of dyes.

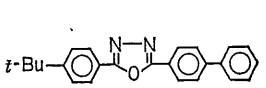
The key to success in obtaining high performance EL devices has been known to be the use of multilayer cell structures (1,2). Thus we, at first, discuss on proper selection of multilayer cell structures. In other words, we have to properly understand semiconducting properties of emitter materials. Then, we will demonstrate three types of blue EL devices using variety of emitter dyes.

2. EXPERIMENTAL

Fifteen dyes which showed intense blue photoluminescence (PL) were used for emitter dyes. A triphenylamine derivative (TAD) and an oxadiazole derivative (PBD) were used for hole and electron transporting layers, respectively. All

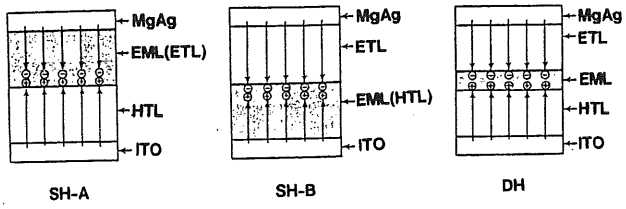


TAD



PBD

the dyes used were purified by use of a train sublimation method (7). On precleaned indium-tin-oxide (ITO) glass substrates, two or three organic layers were deposited by vacuum deposition successively. A typical thickness of organic layers was 50 nm. On organic multilayers, a MgAg alloy top electrode was deposited. The emitting area of the devices was 2x2 mm^2.



HTL : Hole Transport Layer
ETL : Electron Transport Layer
EML : Emission Layer
ITO : Anode
MgAg : Cathode

Fig. 1 Three typical EL cell structures.

3. SELECTION OF CELL STRUCTURES

We proposed three typical cell structures shown in Fig. 1 (8,9). When emitter materials possess the electron transporting tendency (electrons are easily injected from an electrode to an emitter layer and move rapidly), the cell structure SH-A which has a hole transporting layer is used. In contrast, when emitter materials have the hole transporting tendency, the cell structure SH-B should be used. If an emitter material has the bipolar carrier transporting tendency, the cell structure DH in which a thin bipolar emitter layer is sandwiched between the hole and electron transporting layers is preferable.

Figure 2 shows the current density-luminance relations of two type of cells in which a phthaloperinone derivative was used as an emitter. The efficiency of the SH-A type cell was more than 4 orders higher than that of the SH-B type cell, indicating that the emitter dye had an electron transporting tendency. In contrast, the SH-B type cell showed about two orders higher efficiency than the SH-A type cell did, when another emitter dye with the hole

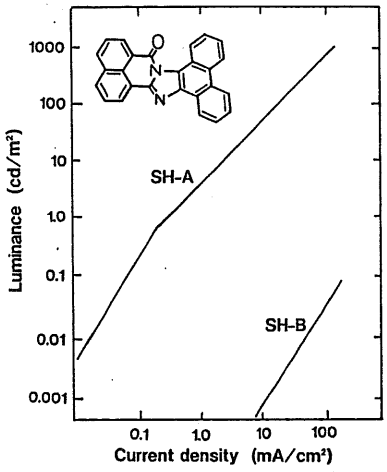


Fig. 2 Current density-luminance relations in two types of cells.

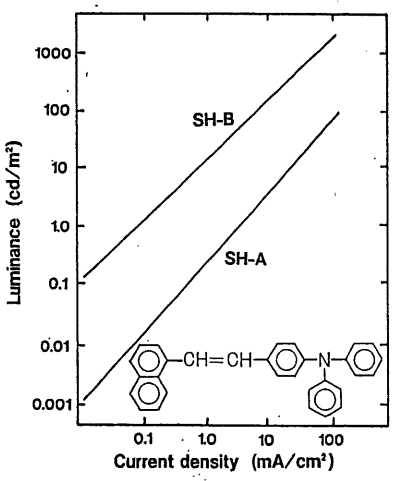


Fig. 3 Current density-luminance relations in two types of cells.

transporting tendency was used, as shown in Fig. 3. These results clearly demonstrates the importance of the proper selection of cell structures.

4. BLUE ELECTROLUMINESCENCE

Firstly, we tried to fabricate SH-A type cells using variety of aromatic hydrocarbons and heterocyclic compounds, which were assumed to possess the electron transporting tendency (10). Figure 4 lists 11 dyes with intense PL in their solid states. We fabricated SH-A type EL cells and observed their EL properties. Table 1 summarizes the film quality of emitter layers, PL peak wavelength, EL peak wavelength, and the luminance at the current density of 100 mA/cm^2. The film forming capabilities of dyes E1 to E6 were not enough to give high EL performances. Other 5 dyes gave rather homogeneous emitter layers, and EL efficiencies were good. The emission colors in the dyes, E7 to E9, however, were not blue but green. This turned out to be originated from the formation of exciplex at the boundary between an emitter layer and a hole transporting layer. Two phenyl-substituted cyclopentadienes gave excellent EL efficiencies, and emission color was really blue. Very good correspondence between EL and PL spectra was observed.

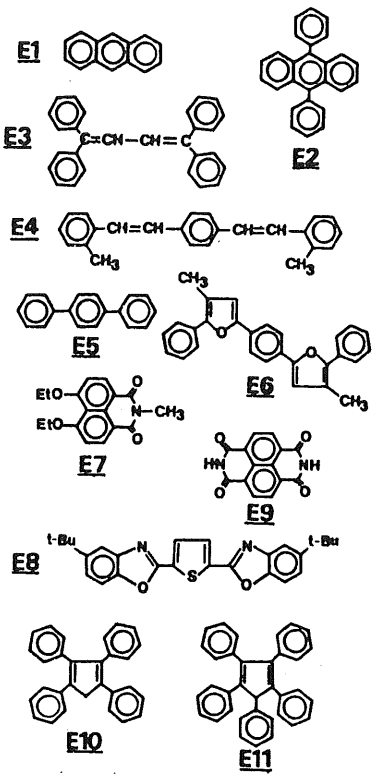


Fig. 4 Structures of dyes with blue fluorescence.

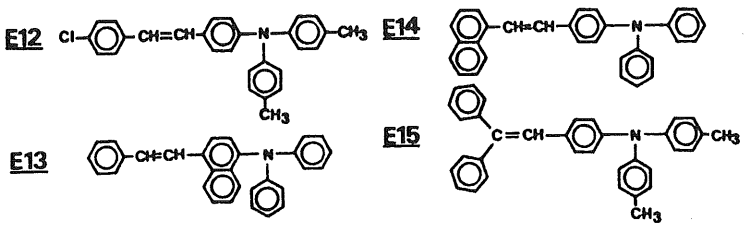
Secondly, we succeeded in fabricating the SH-B type cells using dyes E12 to E15 as an emitter. Table 2 summarizes the performance of those cells.

Finally, blue EL was also realized in the DH type cell, when we used E3 as an emitter. Figure 5 shows EL and PL spectra of this cell. Blue EL centered at 432 nm with the luminance of

Table 1 Film quality, PL and EL spectra, and luminance at 100 mA/cm^2 in SH-A type cells.

Emitter	Quality of film	PL peak (nm)	EL peak (nm)	Luminance (cd/m^2)
E1	fair	420	425	0.02
E2	fair	472	475	0.09
E3	fair	432	430	6
E4	fair	452	460	1
E5	fair	370	···	0.004
E6	fair	478	590	0.09
E7	good	460	520	35
E8	good	435	530	12
E9	good	440	560	0.08
E10	good	460	460	70
E11	good	467	465	120

700 cd/m^2 at the drive current density of 100 mA/cm^2 was observed.



5. CONCLUSIONS

We reported that variety of blue organic dyes were available for EL emitters if we paid proper attention for the selection of cell structures. Thus we expect that EL devices with any emission colors can be fabricated through the molecular design of organic dyes. At the present stage, however, it should be noted that durability of multilayer organic EL cells are not enough for practical applications. Undoubtedly, further extended efforts to develop not only new organic dyes but also cell structures are necessary.

The success in blue EL devices opens fascinating possibility of applying organic thin film EL devices for full-color displays.

Table 2 Film quality, PL and EL spectra, and luminance at 100 mA/cm^2 in SH-B type cells.

Emitter	Quality of film	PL peak (nm)	EL peak (nm)	Luminance (cd/m^2)
E12	good	478	470	360
E13	good	450	460	220
E14	good	469	480	180
E15	good	459	460	400

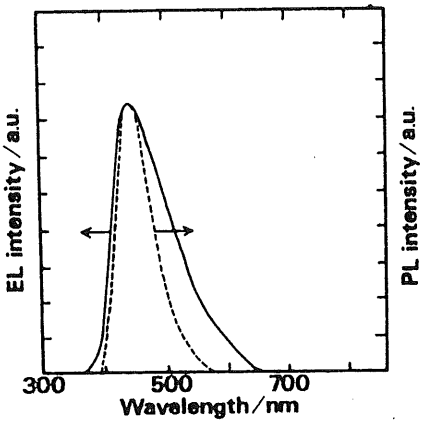


Fig. 5 EL spectrum of DH type cell with E3 as an emitter.

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