Dual - Drive & - Emission Panel

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Abstract

We have proposed on dual-drive & -emission (DDE) panel based on organic light-emitting diodes (OLEDs). The device is composed on independent operation of two OLED structures with two transparent electrodes for data signals and an intermediate reflective electrode for common scan signal. Typical device structure is ITO / organic electroluminescent layer (1) /intermediate reflective electrode / organic electroluminescent layer (2) /transparent electrode. Symmetric bright emission could be obtained by applying AlNd as the intermediate reflective electrode and MoO_3 *as a hole injection layer for upper device structure. The proposed panel is useful for emissive face-to-face panel exhibited for different images.*

1. Introduction

Organic light-emitting diodes (OLEDs) have excellent properties of low driving voltage and bright emission. One of interesting topics is transparent OLED (TOLED) that emitted double sided.[1,2] This types of matrix panels have been demonstrated by Samsung SDI in IDW'02 (Hiroshima, Japan) and by Semiconductor Energy Laboratory in 13th FPD Manufacturing Technology Expo & Conference (Tokyo, Japan). However, image of this display showed flip horizontal and is limited for few applications. For example, for a flip-type cellular phone, it is necessary to switch the display image so that there may be no inconsistency in the observed direction. Moreover, emission of one direction is into useless luminescence.

In this paper, we have demonstrated newly proposed device structure of dual-drive & -emission (DDE) panel and preliminary optimization results of the device structure.

2. Concept

Figure 1 shows typical device concept of the dual-drive & -emission (DDE) panel under study. In this device, two OLED structures are stacked on the both sides of intermediate electrode with reflective characteristics. This intermediate electrode acts as common scan line of the double-sided matrix panel. Independent image can be displayed by applying in dependent data signal to each transparent electrode.

Figure 2 shows typical driving waveform of the DDE. Scan scheme is identical to time-multiplexed passive-type OLEDs. The scan signal is applied to the intermediate electrode. When first row line is selected, the scan signal is changed from +V to 0 V. If a pixel is selected to emit, the data signal is selected to +V. If the pixel is non-selected, the data signal is set at 0 V. Both of the transparent electrodes can be driven independently.

We will express feature of the DDE. Obviously, these types of operation can be also realized by adhering two panels. However, this two panels system require cost over-run and bulky. Therefore, the DDE configuration is suitable for low-cost, lightweight and simple connection for its common scan signal.

3. Results and discussion

3.1 Optimization of device performance

In order to realize the DDE panel, device performance of upper OLED, *i.e.*, top-emission device, have to be improved as follows:

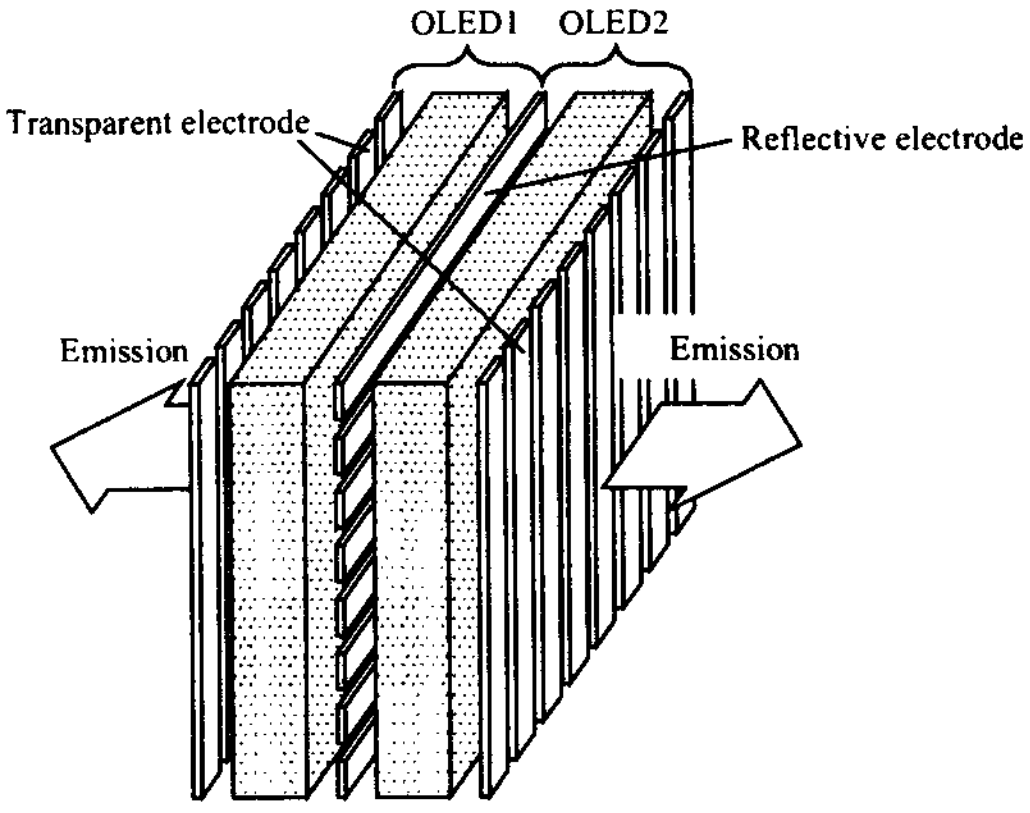

Fig. 1 Device concept of the DDE panel.

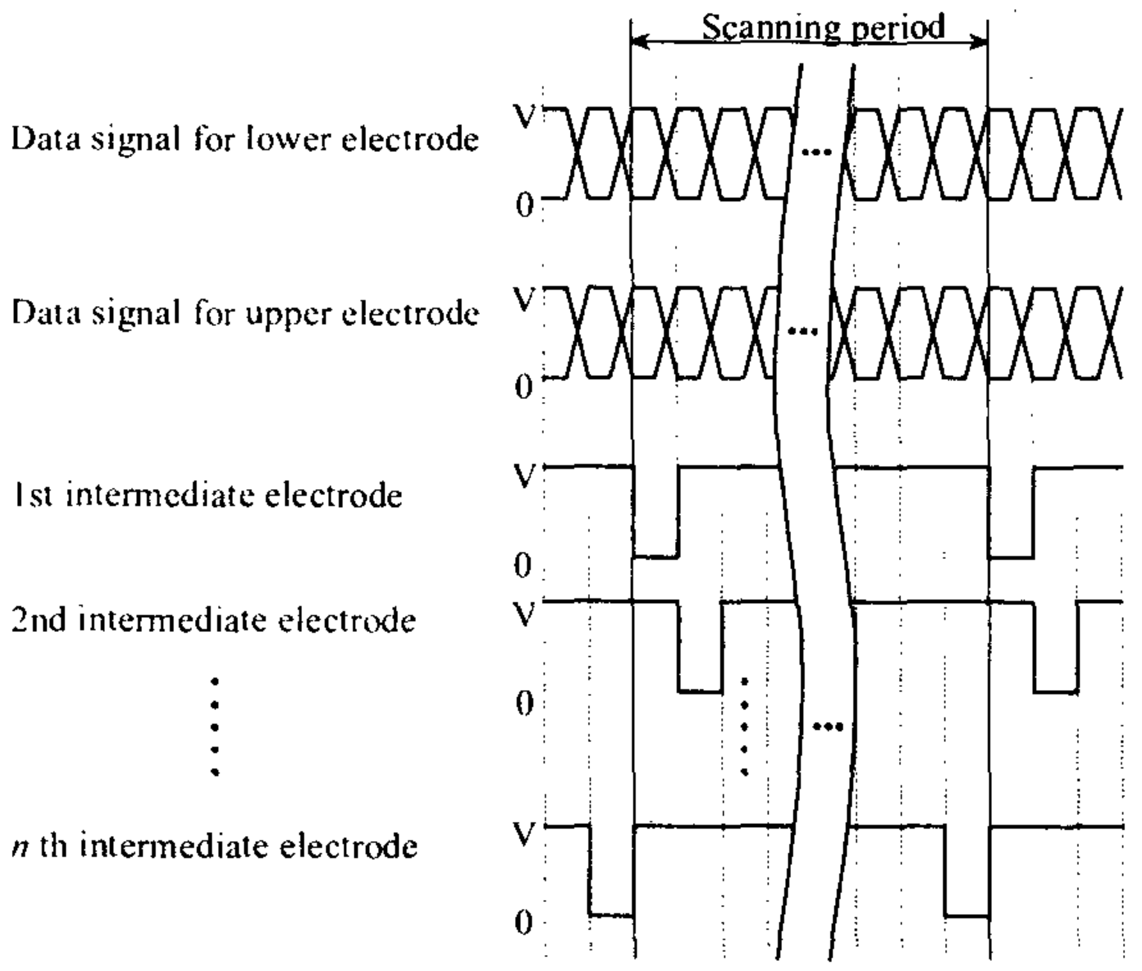

Fig. 2 Driving waveform of the DDE panel.

(*a*) Improvement of surface morphology for intermediate electrode

In an initial stage of experiment, we used aluminum (Al) as intermediate electrode and short-circuiting sometimes occurred. One of the reasons for the short-circuiting might be due to surface roughness of Al film. In order to obtain smoother electrode surface, we employed AlNd (Kobelco Research Institute) as intermediate cathode, where AlNd was used for fabricating a semiconductor device to prevent hillock.[3] Figure 3 shows atomic force microscope (AFM) images of Al and AlNd films. The mean roughnesses of 2.09 and 1.24 nm were obtained for Al and AlNd films, respectively. Therefore, AlNd was effective for obtaining a smoother surface morphology and resulted smaller leakage current in comparison with Al electrode.

(*b*) Consideration for side of driving scheme

For driving the DDE configuration, as shown in Fig. 2, electrons and holes have to be injected from lower intermediate electrode and upper transparent electrode, respectively, into OLED2 (upper organic electroluminescent layer). Therefore, inverted structure of top-emission OLED have to be selected.

(*c*) Selection of the transparent electrode

Requirements for the transparent electrode are (1) low resistivity, (2) smaller damage for organic film during deposition, (3) highly transparency, and (4) longer durability. For satisfying these requirements, we selected sputtered indium-zinc-oxide (IZO, Idemitsu Kosan), where weight fraction of In_2O_3:ZnO was 9:1. The IZO film was deposited at room temperature using a radio-frequency (RF) magnetron sputtering system with a power density of 0.13 W/cm^2. For our typical condition, a sheet resistance of the sputtered indium-tin-oxide (ITO) was 1kΩ/□, while the optimal sheet resistance of the IZO was 100 Ω/□. Hardness of the IZO was softer than that of the ITO. Therefore, sputtering damage of under layer might be small compared to the case of the ITO. Transmittance of the practical IZO film was more than 90 % at all visible range. For the respect of durability, the IZO film is inherently stable for moisture and oxygen that compared to conventional low-work-function and transparent electrode, such as, thin Ca/Ag stack.[4] Therefore, stable operation will be expected.

(*d*) Improvement of electron injection

For improving an electron injection characteristics, an additional organic layer of 2,5-bis(6'-(2'-2''-bipyridyl))-1,1-dimethyl-3,4-diphenylsilole (PyPySPyPy[5], Chisso) was evaporated on the intermediate electrode. Figures 4 (*a*) and (*b*) show current density versus voltage (*J-V*) and luminance versus current density (*L-J*) characteristics of the device structure AlNd (70 nm)/ PyPySPyPy (20 or 0

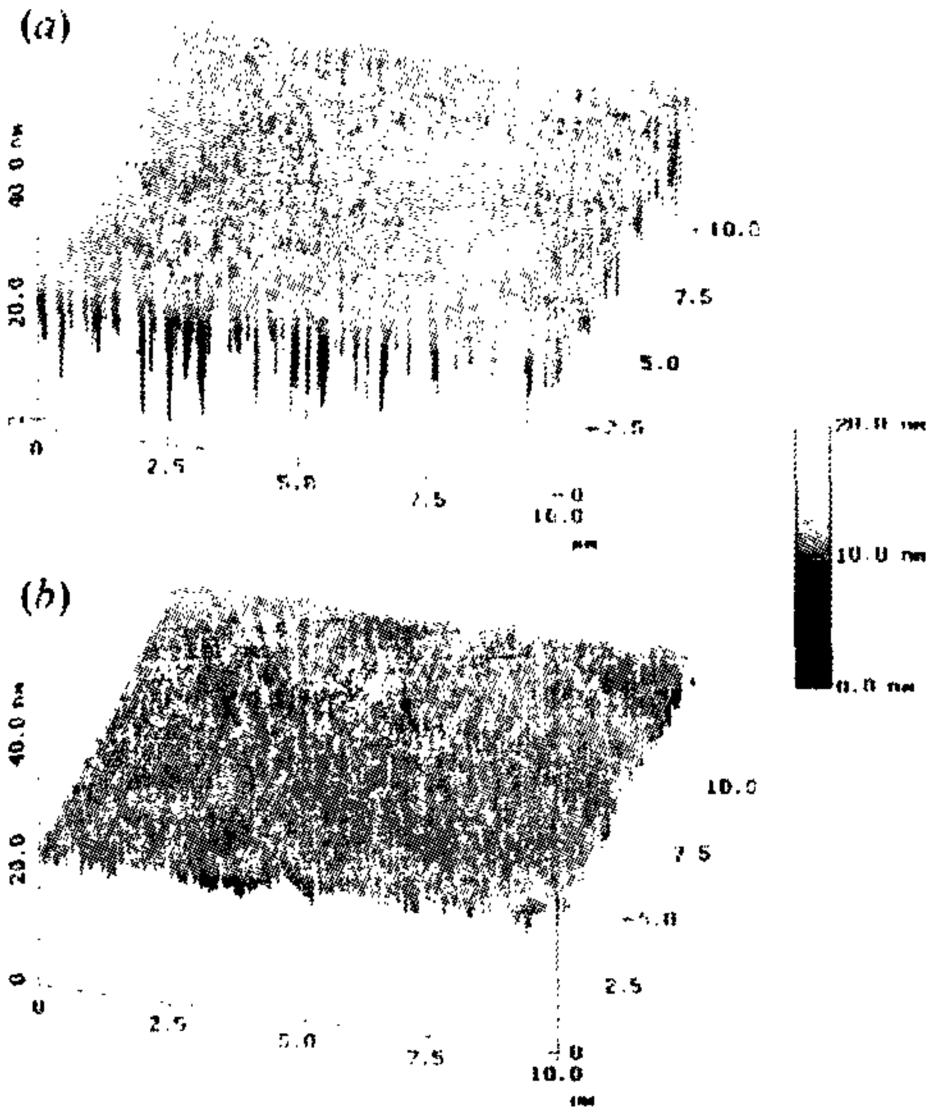

Fig. 3 Surface morphology of (*a*) Al and (*b*) AlNd.

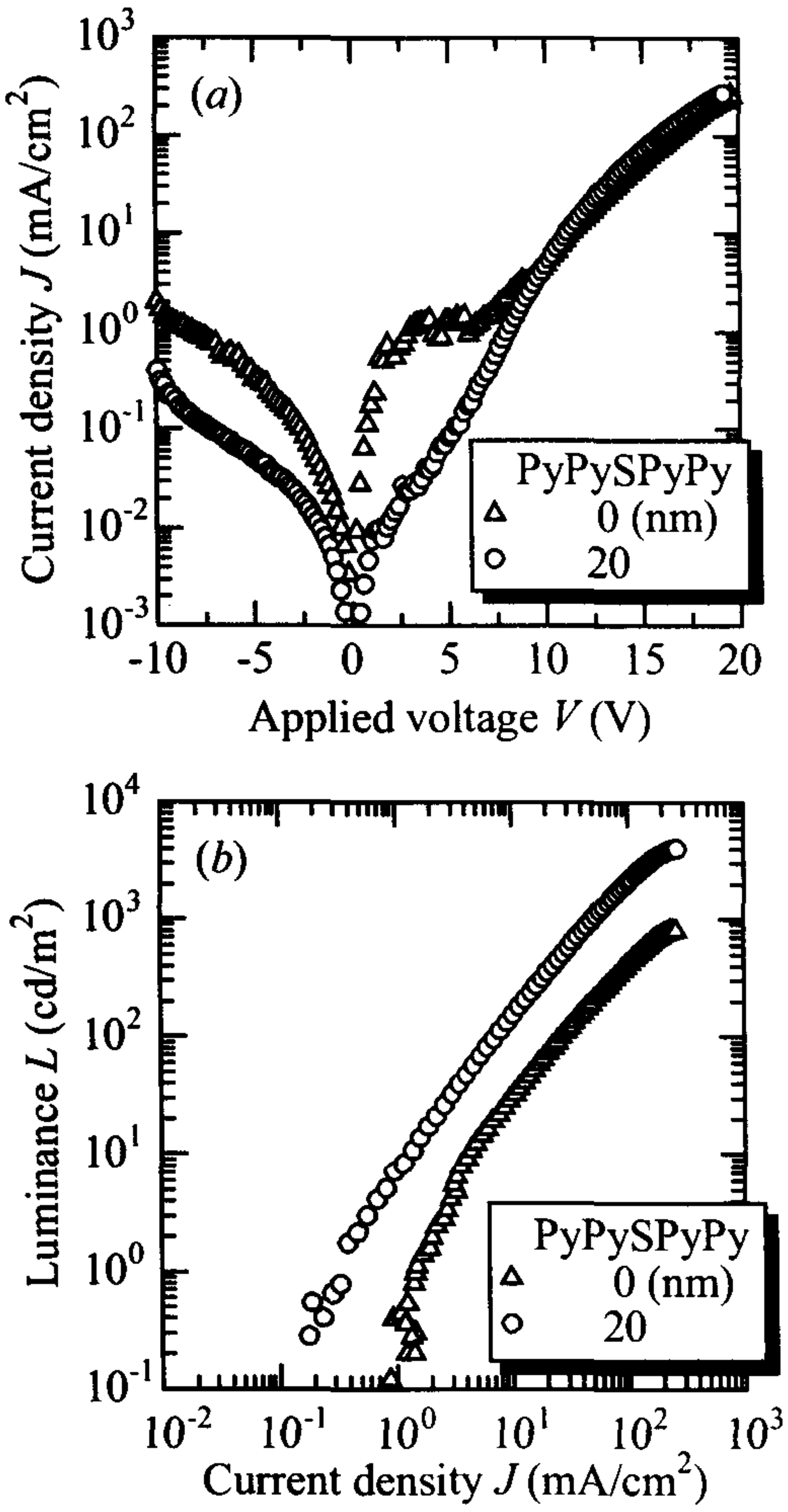

Fig. 4 Comparison of the J-V and L-J characteristics by adding electron transport layer of PyPySPyPy.

nm)/ tris(8-hydroxyquinolinato) aluminum (III) (Alq_3) (30 nm)/ bis-[N-(1-naphthyl)-N-phenyl] benzidine (α-NPD) (50 nm)/ MoO_3 (50 nm)/ IZO, where role of molybdenum oxide (MoO_3) layer is explained in (*e*).

By adding the PyPySPyPy, the leakage current was suppressed, as shown in Fig. 4 (a). And luminance characteristics were dramatically improved because the electron injection was increased.

(*e*) Employment of hole injection/buffer layer

As shown in (*c*), basic properties of the IZO is excellent. However, there may still exist the sputtering damage. Therefore, we added a buffer layer that also acts as a hole injection layer. By considering the hole injection/buffer layer, hard material will be suitable for stopping the sputtering energy of the incoming IZO. As a result of investigation, we arrive reach at last on oxide semiconductors. Above all, the MoO_3 was found to show excellent hole injection ability.[6,7] Figures 5 (*a*) and (*b*) show *J*-*V* and *L*-*J* characteristics of the device structure AlNd (70 nm)/ PyPySPyPy (20 nm)/ Alq_3 (30 nm)/ α-NPD (50 nm)/ MoO_3 (69 nm)/ IZO. Without MoO_3, the current density was quite fluctuated and the emission was not observed even in lower current density. On the other hand, clear *J*-*V* and *L*-*J* characteristics could be obtained by adding MoO_3.

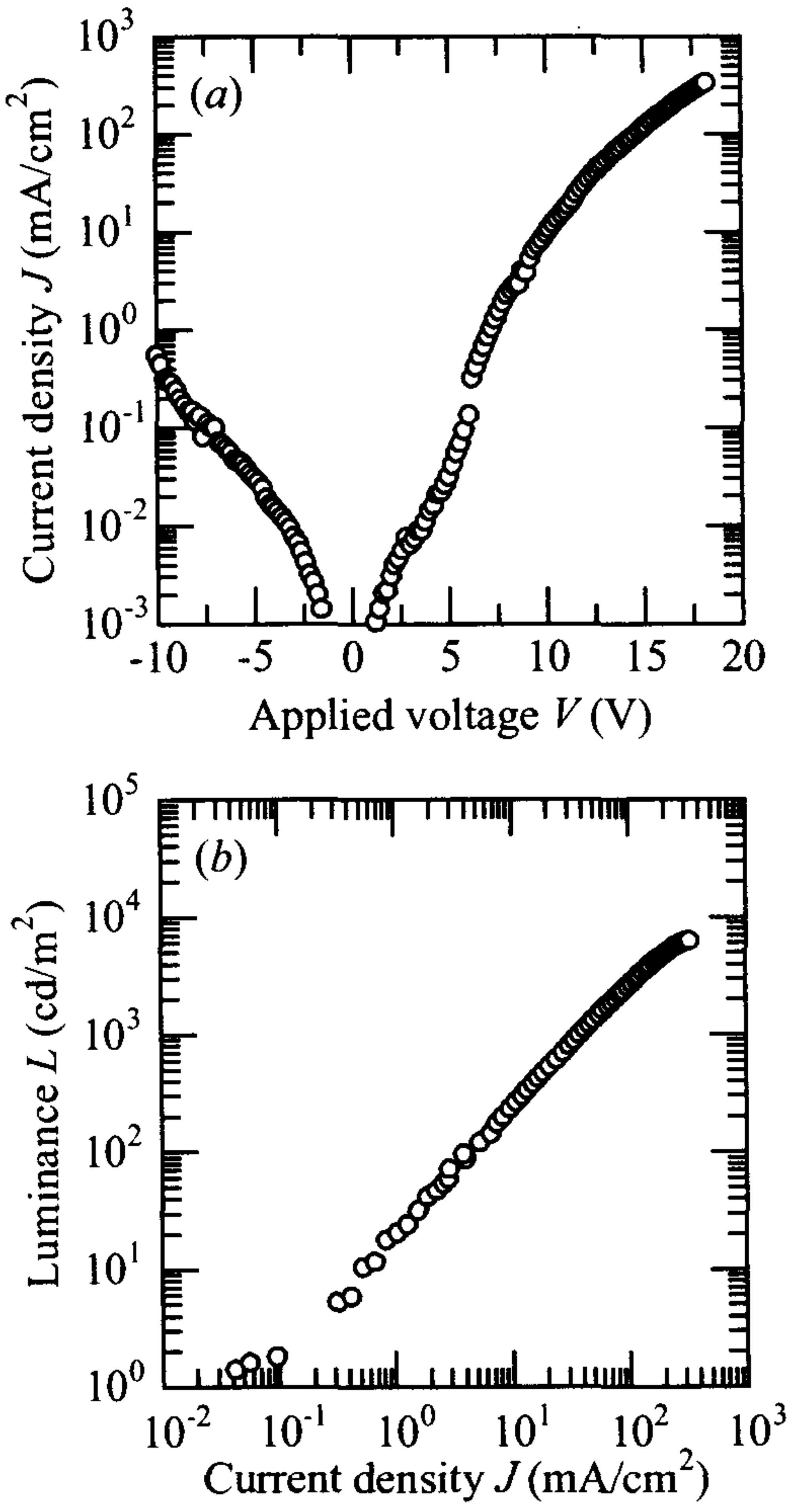

Fig. 5 J-V and L-J characteristics with MoO_3 as hole injection/buffer layer.

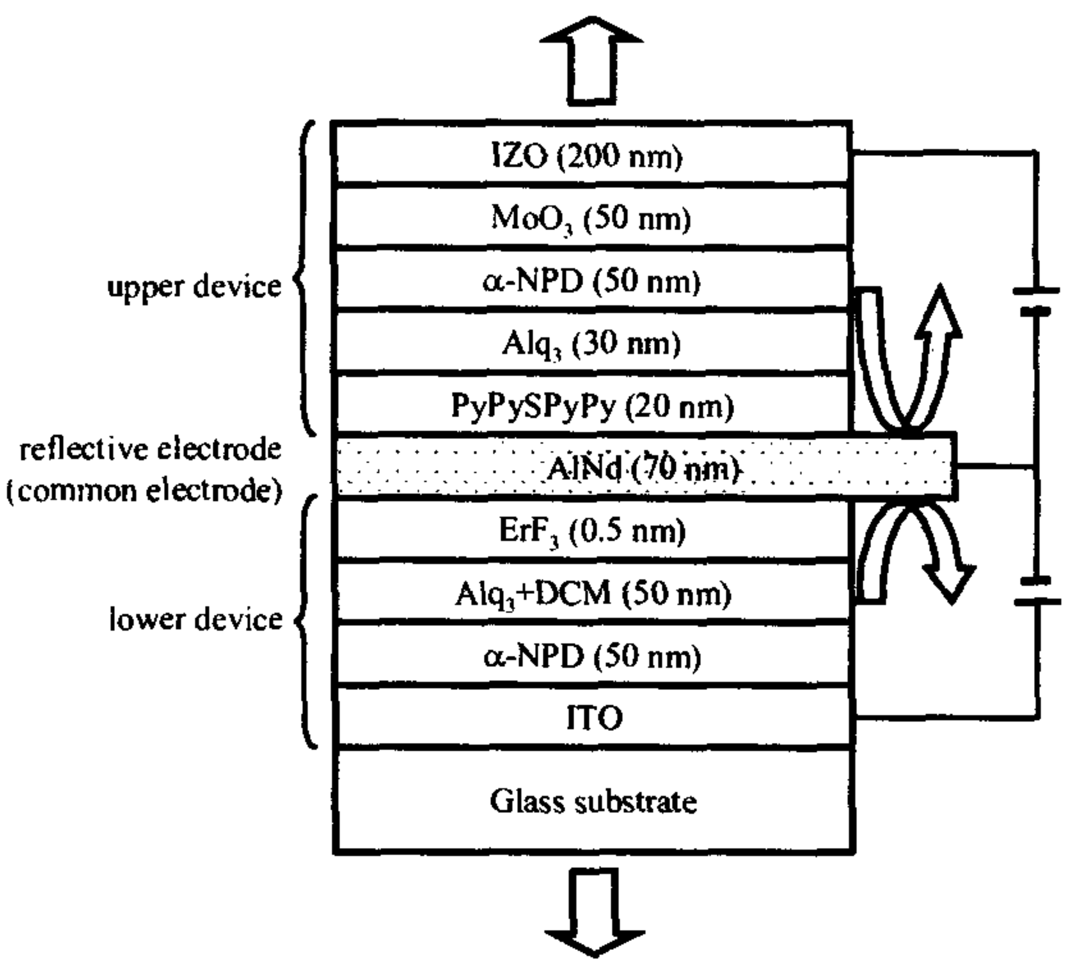

Fig. 6 Device structure under study.

3.2 Device performance of the DDE structure

Figure 6 shows device structure of the optimized DDE panel. Lower device structure was ITO/ α-NPD (50 nm)/ Alq_3 (50 nm)/ ErF_3 (0.5 nm)/ AlNd. Upper device structure was AlNd/ PyPySPyPy (20 nm)/ Alq_3+DCM (100:1) (30 nm)/ α-NPD (50 nm)/ MoO_3 (50 nm)/ IZO (200 nm). Figure 7 shows the J-V and L-J characteristics of the devices. Where, inverted structure was made for upper device. In both devices, the symmetric characteristics were obtained and the luminances exceeded over 4,000 cd/m^2 could be obtained.

4. Conclusion

We have proposed new device concept of the dual-drive & -emission panel without flip horizontal. And we demonstrated the improvement of device performance by applying AlNd as the reflective electrode, sputtered IZO as the transparent electrode, PyPySPyPy as the electron injection layer, and MoO_3 as the hole injection layer. The proposed panel is suitable for emissive face-to-face panel exhibit for different images.

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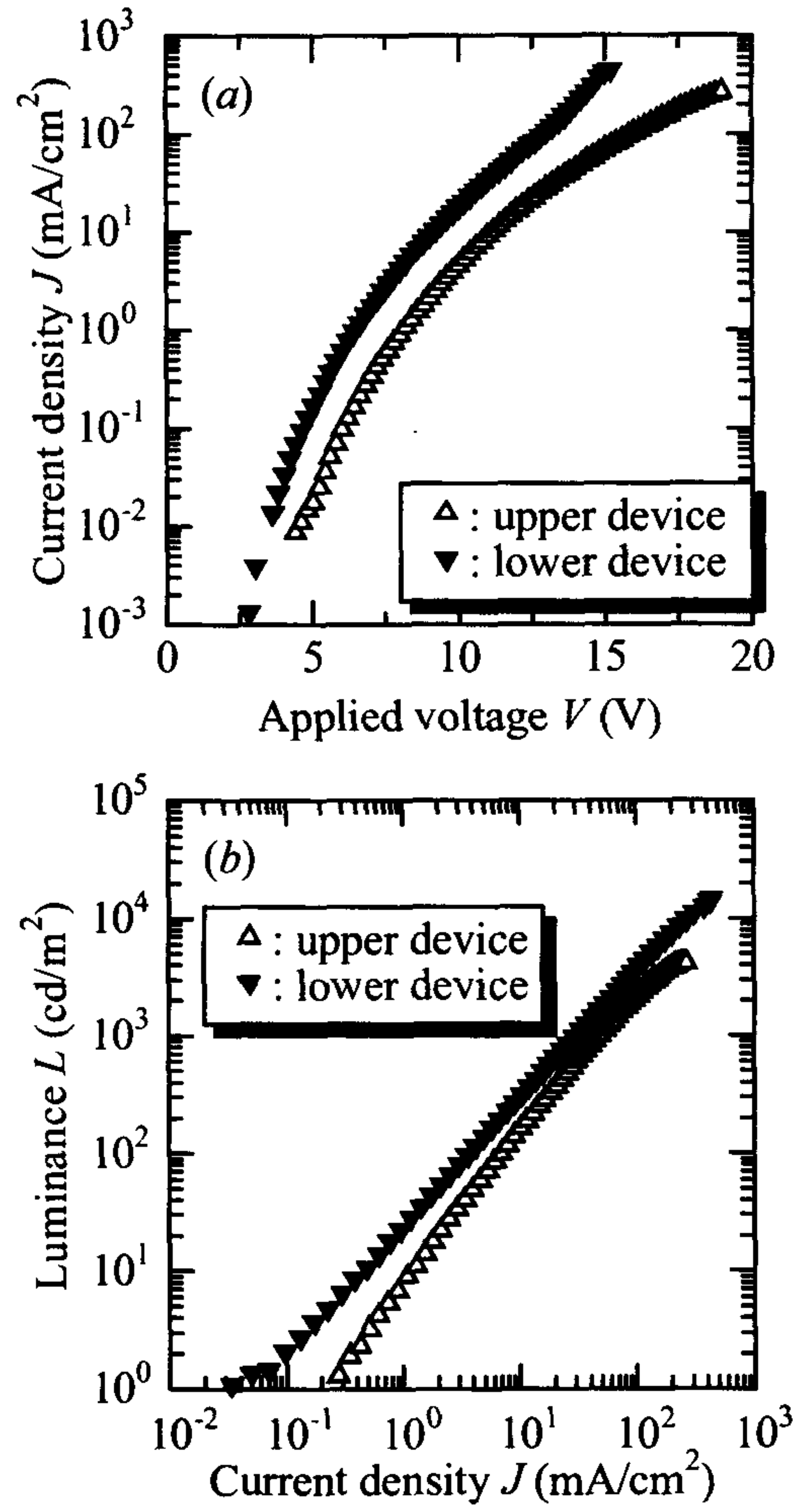

Fig. 7 J-V and L-J characteristics of the DDE panel.

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