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Fabrication of vertical organic light emitting transistor using thin-film ZnO

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1. Introduction

Organic light emitting diodes (OLED) have much attention for flexible, low cost, and ease of processing and OLED are adopted as the display components of mobile phone in recent years. However, it is required to improve lifetime and high-efficiency using for practical electronic devices. Although the active matrix display is a suitable system but it is necessary to make driving transistor, switching transistor, and OLED, with large light emitting area.

Zinc oxide (ZnO) is a transparent material of which electrical property varies from conductive to insulating depending on the growth conditions, and it is able to deposited on flexible substrate. [1-3] In this work, we have fabricated the FET (field-effect transistor) combined with an OLED on thin-film ZnO which works as transparent semiconductor layer, electron injection layer and electrodes, moreover it could be fabricated without the damage to organic layer from electrode sputtering .

2. Device structure and fabrication process

Fig.1 shows the device structure of OLET(Organic Light Emitting Transistor). The ZnO films were deposited by radio frequency (RF) and direct current (DC) magnetron sputtering using a ZnO target or Zn target. RF sputtering equipment was used to deposit ZnO films and Al_2O_3 films. Organic layers and electrodes are formed by a standard vacuum evaporation technique. We have optimized these growth conditions of ZnO and Al_2O_3 thin-films for FETs. The deposition parameters are shown in Table I.

A transparent FET could be fabricated with an indium tin oxide(ITO) gate and an Al_2O_3 gate insulator and these materials are expected to be promising components of high-efficiency light-emitting transistors. On the other hand, the OLED has a electron injection layer and hole blocking layer of ZnO thin-film as shown in Fig.1[4-5]. These layers have high transparency, therefore the OLED have high external quantum efficiency.

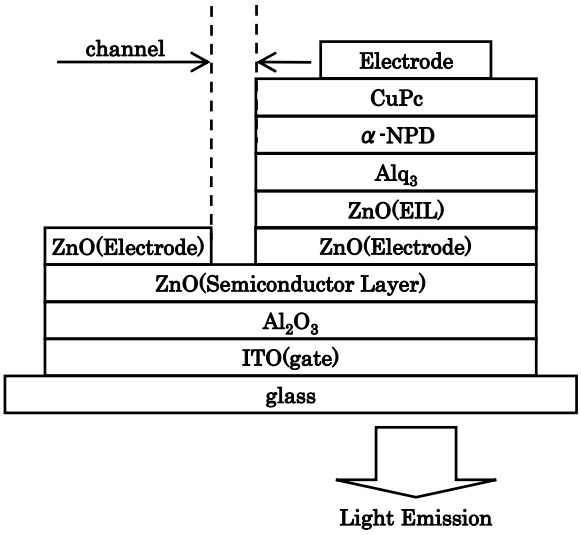

Fig.1 The structure of OLET using thin-film ZnO films.

Table I Deposition parameters and properties.

		Materials Deposition method	Deposition condition
FET	Gate insulator	Al_2O_3 RF Sputter (Target : Al)	Ar/O_2 Thickness 400nm
	Semiconductor layer	ZnO RF Sputter (Target : ZnO)	Ar Thickness 200nm
	Electrode	ZnO RF Sputter (High doping)	Ar Thickness 100nm
OLED	Electron injection layer	ZnO DC Sputter (Target : Zn)	Ar/O_2 Thickness 50nm

3. ZnO film for semiconductor layer

The ZnO active channel layer was deposited on the Al_2O_3 film formed glass substrate. The carrier concentration decreases by deposit pressure increase. However, the mobility does not depend on the deposition pressure. The excellent device maximum saturation drain current of ZnO FET was 6.0×10^{-2}A/m, it is enough to drive the OLED, and obtained on-off ratio of the output current was 6.1×10^{4}.

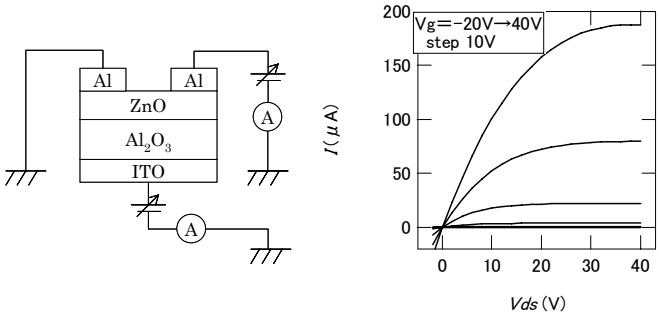

Fig.2 The electrical measurement circuits and I_D-V_{DS} characteristic for a ZnO-channel FET.

4. Al_2O_3 film for gate insulator layer

Al_2O_3 film as the gate insulator was deposited by RF reactive sputtering. As the sputtering conditions of Al_2O_3 thin-films, the Ar/O_2 gas flow ratio and gas pressure was varied under the constant RF power of 4.9 W/cm^2. The leakage current increases as the deposition pressure increases. The results suggest that the decrease of the pressure, decreases the deposition rate, and these films have good stoichiometry. The low leakage current less than 40pA between Vg=-40V and 40V, enough to drive the ZnO FET.

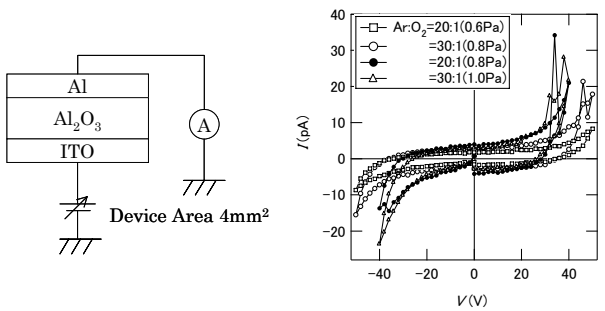

Fig.3 The electrical measurement circuits and *I-V* characteristic of insulator(Al_2O_3).

5. ZnO film for electron injection layer

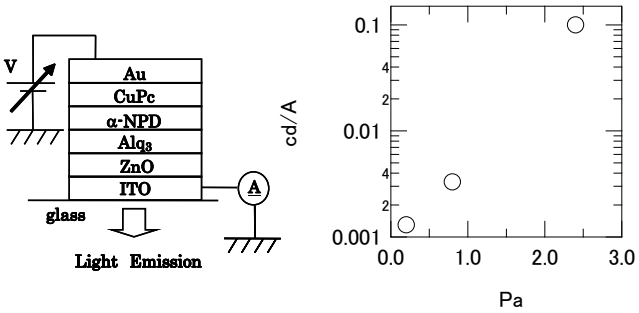

Fig.4 The electrical measurement circuits and deposition pressure vs light-output.

Fig.4 shows the luminance vs. deposition pressure. The ZnO film was deposited by DC magnetron sputtering, and the result shows by increase deposition pressure, the luminance increase. The OLED without ZnO film could not emitting, and show that the ZnO film function as electron injection layer.

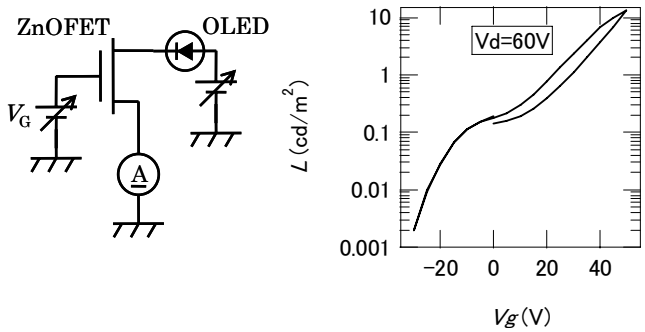

Fig.5 The electrical measurement circuits and *L-Vg* characteristic of OLED wired ZnO FET.

Fig(5) shows the *L-Vg* characteristic of OLED driven by ZnO FET. The results show that it is possible to drive the OLED, and to fabricate the OLET we proposed.

6. Conclusions

This paper reports on the electrical properties of ZnO and Al_2O_3 films prepared by DC and RF magnetron sputtering, and the FET characteristics of the driving transistor for OLED. The results demonstrate that the excellent properties of ZnO FET and Al_2O_3 insulating layer were obtained by optimizing the conditions, such as the total and oxigen partical pressure, type of plasma power intensity, doping, could be obtained. The results also show that it is possible to fabricate the OLET using thin-film ZnO.

References

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