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Highly Flexible Complementary Inverter with Pentacence/a-IGZO Hybrid Thin Film Transistors

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Abstract

Inverter is a fundamental building block for logic circuits. In flexible electronics, inverter is very important for data processing in memory, general logic circuit and peripheral circuit for display. In this work, we demonstrated an ultra-flexible, robust Pentacent/a-IGZO hybrid complementary inverter on commercial available PEN substrate. This inverter could be bent with radius around 4 mm (strain ~ 1.5 %) without performance degradation.

1. Introduction

Flexible optoelectronics that processing at low temperature on plastic substrate have attracted much attention for broad applications. The application covers sensors, flexible display, memory and integrated circuits. Among these applications, inverter is a basic element in a logic circuit for data processing. To have fast operation and low power consumption, the inverter generally in the complementary architecture. The logic symbol for a complementary inverter is shown in Fig. 1(a). Currently, the flexible complementary inverter was made by all organic materials exhibit excellent performance [1-3]. However, the relative small mobility and instability of n-type organic materials makes motivation to other materials. The inorganic n-type materials, such as amorphous indium-gallium-zinc oxide (a-IGZO) and MoS_2 are good alternatives to replace n-type organic material with p-type organic semiconductor compatible mobility. Recent works [4, 5] demonstrated good performance of organic/inorganic hybrid complementary inverter. However, the performance, especially the flexibility, is not as well as all-organic inverter. In this work, we demonstrated a Pentacene/a-IGZO hybrid complementary circuit on PEN substrate with highly flexibility. The inverter could be bent with radius as small as 4 mm (strain ~1.5 %) with no performance degradation. The schematic structure was sketched in Fig. 1 (b). To achieve the ultra-flexibility, we adopt polymer as gate insulator. The polymer/a-IGZO interface was carefully tuned to avoid plasma damage during a-IGZO deposition. Since the Young's modulus of organic material is generally around 1 GPa, which is rather small than inorganic material (~100 GPa), The stress and structure deformation will relief to polymer insulator during bending, leaving a-IGZO/polymer interface less altered. [6]

2. Experimental Results and Discussion

The process flow for the inverter fabrication was sketched in the Fig.2 (a)-(f). A glass sheet was used as carrier. The plastic substrate, polyethylene naphthalate (PEN) in 125 μm thick was stick on glass by a Gel-Pak film. The polymer insulator was fabricated by spin-coating a mixture of Polyvinylphenol (PVP) and Poly(melamine-co-formaldehyde) (PMF) in a ratio of 2:1. After dried at 135 °C, a 254 nm UV light was used to closs-link the PVP.

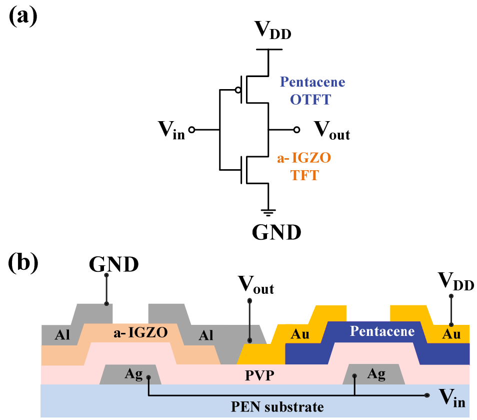

Fig. 1 (a) The logic symbol of a complementary inverter. (b) The schematic structure of the proposed organic/inorganic inverter.

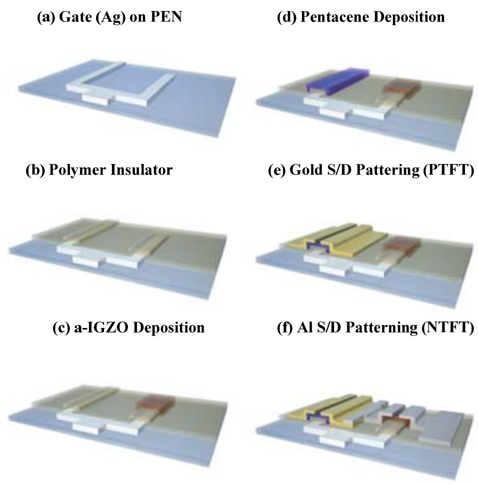

Fig. 2 The schematic process flow for Pentacene/a-IGZO complematary inverter fabrication.

The leakage current for the PVP is around 10^{-8} A/cm^2, which is suitable for TFT. The Id-Vg characteristics for pentacene TFT and a-IGZO TFT on same inverter was shown in Fig. 3. The inverter was measured at input voltage 14. A clear inverter operation was demonstrated in Fig. 4. Remarkably, around 80% noise margin with nearly Vdd/2 operation was achieved. The inverter parameter was listed in Table I. For the bend test, the inverter was bent around a ball-pen with radius 4 mm (strain ~ 1.5 %). At 14 V, the inverter shows very stable operation for on glass, detached and 5 time and 15 times bending, as shown in Fig. 5. The maximum gain, noise margin, switching voltage and transition range were not altered after bending.

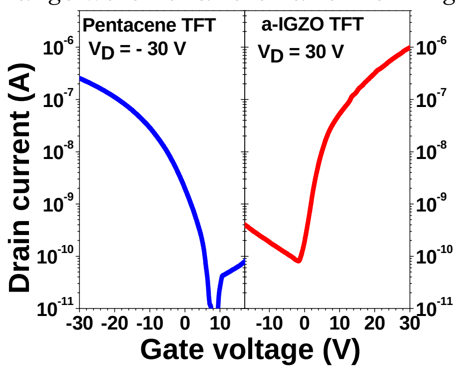

Fig.3 The Id-Vg characteristics of pentacene and a-IGZO TFT on same inverter.

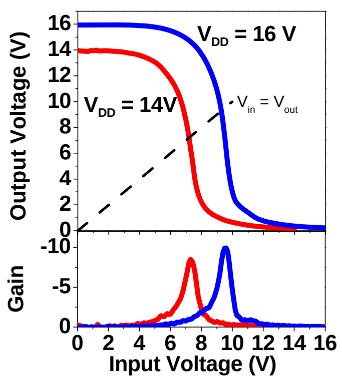

Fig. 4 The inverter characteristics on detached PEN.

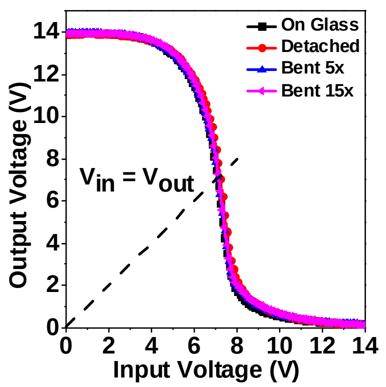

Fig. 5 The properties of inverter operated at 14V with different conditions.

Table I. Switching parameters of complementary inverter

V_{DD} (V)	Maximum Gain	NM_H (V)	NM_L (V)	NM (%)	ΔV_{IN} (V)
14	-8.48	5.56	4.99	65.9	3.23

3. Conclusions

The record-high flexibility (4 mm in radius, and 1.5 % in strain) on organic/inorganic complementary inverter was demonstrated with performance degradation. This result opens a brilliant future for the flexible optoelectronics.

Acknowledgements

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