Active-Matrix Driven Flexible mini-LED Displays based on High-Performance Organic Single-Crystal TFTs

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ABSTRACT

A newly developed technologies of flexible active-matrix mini-LED displays are presented. The backplane is based on high-performance organic single-crystal TFTs laminated on screen-printed large-area plastic substrates. The devices are suited to the application for large-area signages.

1 INTRODUCTION

Images as large as large mammals have impacted psychology of human species since the beginning of their history. Therefore, demand is essentially very high for technologies of large-area digital advertisement, though the current devices are not well-prevailed because of their high cost, large weight, and high power consumption. We developed a method to produce LED pixels on printed backplanes of active matrices based on high-mobility organic semiconductors. Due to the light-weight film-based materials of low-cost printed organic active matrices, which is also very effective in reducing power consumption, the present technology meets the requirement for the large-area digital signage.

Fig. 1
An image of a large mammal which feared human beings.

The present devices are formed on a sheet of PEN film with the thickness of 0.1 mm, so that the large-area movies can be shown even hung on the ceilings of buildings

Fig. 2
An illustration to indicate the usage of the developed flexible mini-LED panels for large-area signage.

2 EXPERIMENT

To demonstrate the concept of the large-area LED display sheet, we fabricate modules of 37 cm x 47 cm films with 3-mm pitch active matrix pixels. The modules are tiled up to any size without visible boundaries, maintaining the same distance between LED chips in the whole multi-module panels.

2.1 Base panels of printed matrices

The matrix wirings of silver paint are printed by a large-area screen printing method, so that the vertical and horizontal lines are electrically separated by an insulating layer. The dimensions of the lines are typically 100 μm and the accuracy of the positions is within 50 μm.

2.2 Organic single crystal TFTs

The organic TFTs are separately formed on a polyimide film using photolithography. Since their speed and on-current is crucial on flexible films to operate LED chips with sufficient brightness, we employ a newly developed high-performance organic single-crystal transistors [1]. The value of the mobility exceeds 10 cm^2/Vs, which is already significantly higher than the values of amorphous silicon TFTs.

We crystalize the organic semiconductor films during the coating process on the film substrate at elevated temperature up to 80℃. The solution crystallization

technique is already established with the newly synthesized semiconductor compound of 3,11-alkyl dinaphtho[2,3-d:2',3'-d']benzo[1,2b:4,5b']dithiophene (C_n-DNBDT) [1-5]. A large area film grown by this method exhibits excellent homogeneity in nearly 10 cm x 10 cm area, so that the pieces of TFTs are used to drive each LED pixel homogeneously.

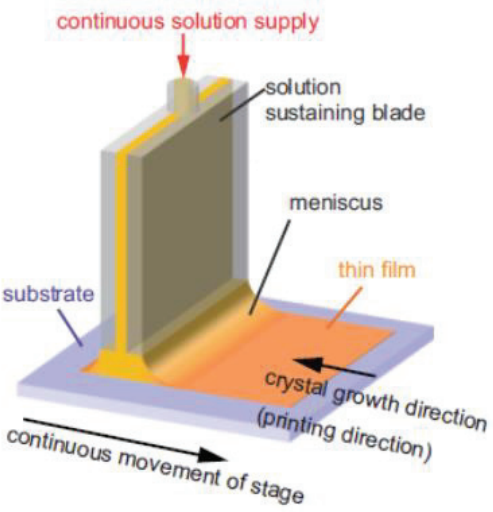


Fig. 3
A schematic illustration of a method of continuous growth of crystal organic semiconductor films.

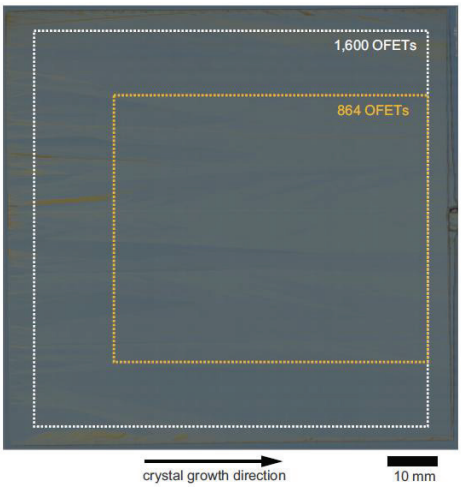


Fig. 4
An optical image of continuously growtn crystal organic semiconductor films.

Figure 4 shows an image of typical single crystal film of the organic semiconductor, indicating very homogenious thickness and connectivity. Therefore, the transistor performances of the semiconductors formed from the single-crystals are highly uniform as shown in Fig. 5.

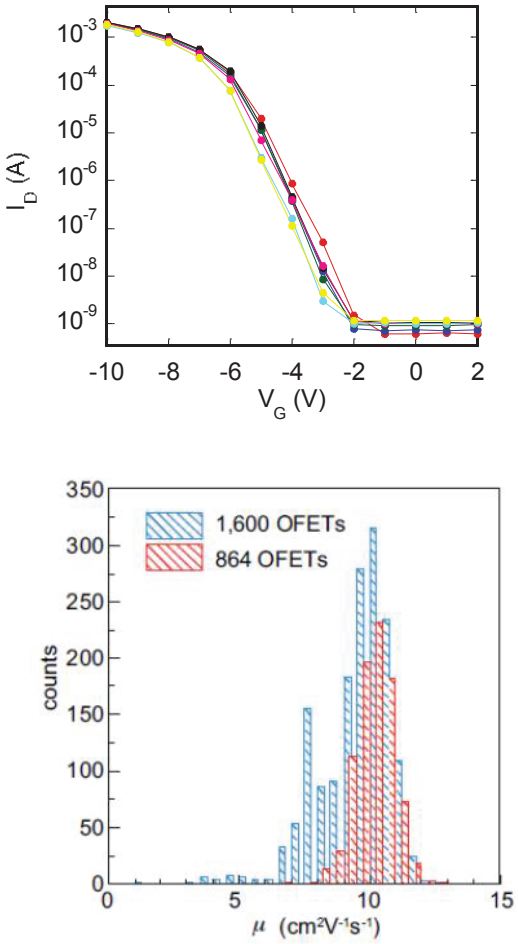


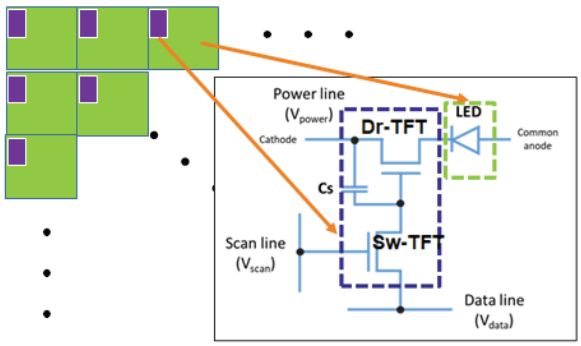
Fig. 5
Distribution in performance of the organic single-crystal semiconductor transistors.

2.3 Active matrix LED panels

The active matrix LED panels are formed by laminating the high-performance organic single crystal TFTs and mounting commercially available LED chips on the screen-printed base films. A set of TFTs are incorporated in each unit on a laminated film to illuminate red, green, and blue LEDs, so that the typical circuits are formed in each pixel. A rolling equipment is used to laminate the TFT films in an efficient way. The LED chis with the size of 1 mm x 1 mm are mounted one by one using a chip mounter.

Finally, outer driving circuits are designed and attached to the edge of the panels, so that any image of

100 x 100 pixels with the RGB colors are transferred to the present flexible LED display panel.



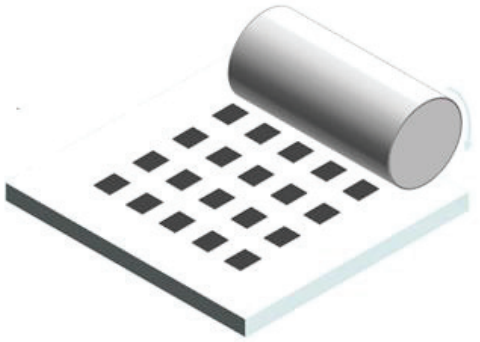


Fig. 6
A schematic illustration of a method to fabricate pixels of the large-area flexible LED display.

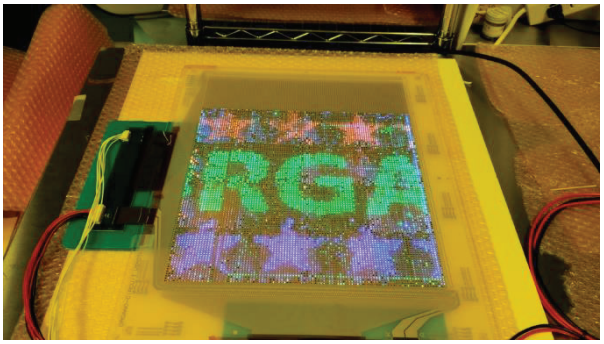


Fig. 7
A picture of the flexible mini-LED module (30 cm x 30 cm).

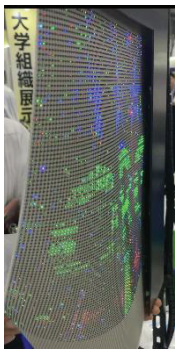


Fig. 8
A side view of the flexible mini-LED module (30 cm x 30 cm).

3 Conclusion

We demonstrate a novel flexible LED display for large-area signage employing technologies of high-performance solution-processed organic single crystals and an efficient method of laminating TFT chips to mount on the all pixels. The fabrication is on the way for mass-production, so that products such as 10-m size display sheets hung from the ceiling appear in the market in near future.

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