Active-matrix Flexible Display on Plastic Substrate Fabricated by Glass Line

Cheng-Chung Lee[1], Yung-Hui Yeh[1], Tzong-Ming Lee[2]

[1]Display Technology Center, [2]Material and Chemical Research Laboratories,

Industrial Technology Research Institute,

E000 DTC/ITRI, No. 195, Sec. 4, Chung Hsing Rd., Chutung Hsinchu, Taiwan 310, ROC

Tel: 886-3-5913384; E-mail: leecc@itri.org.tw

ABSTRACT

A pure polyimide substrate and polyimide substrate with nano-silica additive have been formed on glass by coating. The a-Si:H TFT arrays have been formed on such polyimide substrate for driving TNLCD.

INTRODUCTION

A light, thin and flexible panel can be achieved by low temperature a-Si:H TFT fabricated on plastic substrates [1-4]. Applications of flexible displays include electronic papers, smart cards, cell phones and PDAs, etc. In order to realize the flexible a-Si:H TFT, a typical plastic substrate is needed for overcoming the all processes of a-Si:H TFT. Commercial plastic substrate such as polyimide seems to be suitable for this goal. Polyimide has high chemical resistance, high glass transition temperature (>350 ^{o}C), low coefficient of thermal expansion [5]. However, color of polyimide is brown and light transmission is low. Therefore, this kind of brown polyimide is limited to be used for self-emitting or reflective-type displays [2,6]. In addition to the performance of plastic substrate, handling of flexible substrate during process is another issue. Conventionally, the plastic substrate is bonded onto the glass by glue material. However, there are two major drawbacks such as low process temperature which is limited by the glue material with low Tg and residual glue on the back side of plastic substrate after debonding.

In this paper, a transmissive-type TFT-LCD on polyimide substrate which is formed directly on glass by coating has been fabricated and investigated through the batch process of conventional TFT-LCD glass line.

RESULTS AND DISCUSSION

Plastic substrate

In order to fabricate a-Si:H TFT and OTFT arrays on plastic substrate, a stable plastic substrate composed by polyimide (PI) has been coated and cured on glass substrate. Glass substrate became the carrier for transporting plastic substrate into equipments of batch-type glass line. By modifying PI material, the transmittance of pure PI substrate is increased to be 89 % (Figure 1), the coefficient of thermal expansion (CTE) is 70 ppm/^{o}C and the Tg is 350 ^{o}C (Figure 2).

In order to reduce the cost and CTE, nano-silica of 20 nm was blended uniformly with the clear PI (Figure 3). The transmittance of PI/silica mixed substrate is kept to be 90 %, even though the composition of nano-silica inside PI/silica mixture is more than 60 wt% (Figure 1).

The coefficient of thermal expansion (CTE) of PI/silica mixed substrate is reduced to be 28 ppm/^{o}C and there is a little dimension change till 400 ^{o}C (Figure 1).

There are advantages for PI/silica mixed substrate by adding nano-silica, but, in some cases, maybe the surface roughness of plastic substrate would be high after adding inorganic powder. The high roughness will cause the damage on TFT which is fabricated on such plastic substrate. By AFM analysis, the average surface roughness of pure PI and PI/silica mixed substrate is 2.64 and 2.42 nm, respectively (Figure 4) which is suitable for making TFT.

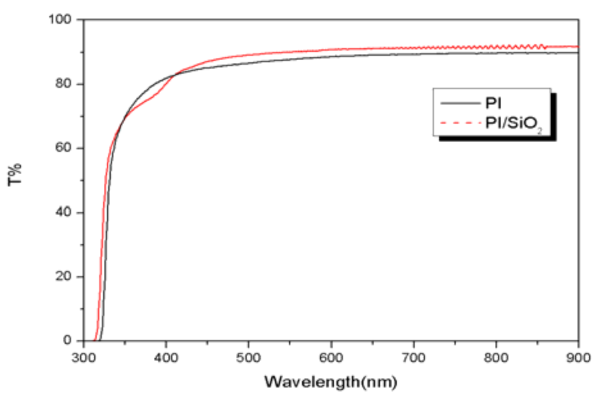

Figure 1. The light transmittance of the PI and PI/silica mixed substrate with thickness of 57 μm.

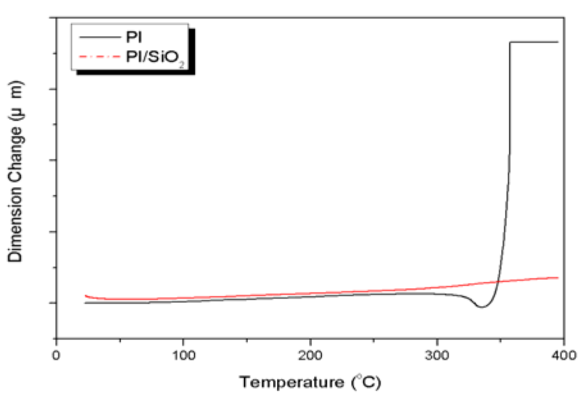

Figure 2. The dimension change of the PI and PI/silica mixed substrate with thickness of 57 μm.

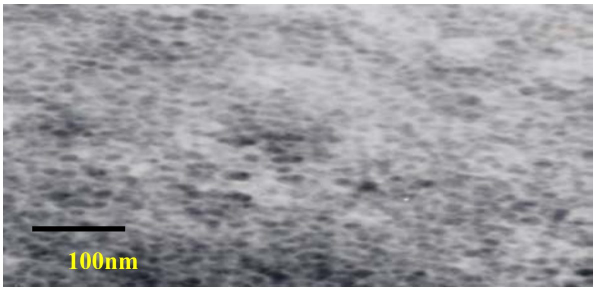

Figure 3. The SEM image of the mixture of PI and nano-silica.

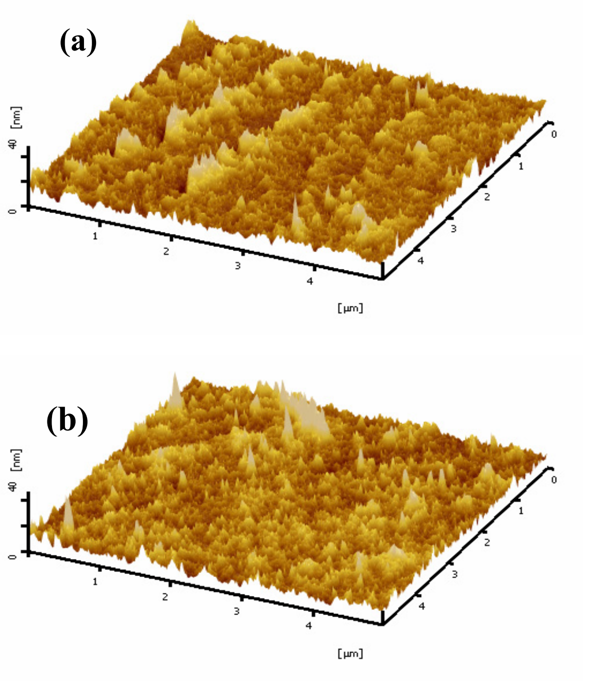

Figure 4. The AFM image of surface of (a) pure PI and (b) PI/silica mixed substrate.

a-Si:H TFT arrays and active-matrix display on PI substrate

According to a-Si:H TFT arrays on PI substrate, there is the possibility that metal electrodes would be damaged under strain. In order to prevent the crack issue, typical design of metal electrodes is needed. The obvious variation of resistance for Ti/Al/Ti and ITO electrodes with the design of straight, saw and step line couldn't be measured under strains (Figure 5). The Ti/Al/Ti and ITO electrodes of saw and step line could sustain more than 5x10^3 bending cycles under strain (Figure 6).

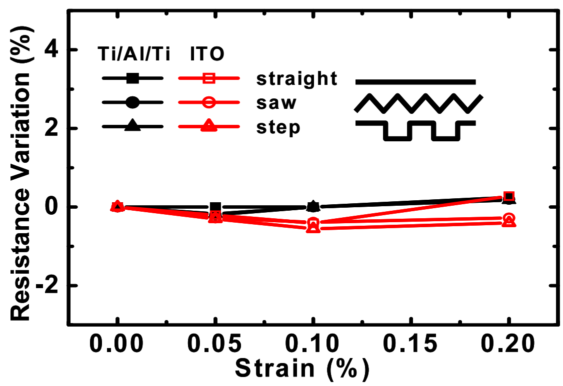

Figure 5. The variation of resistance of electrodes under strain.

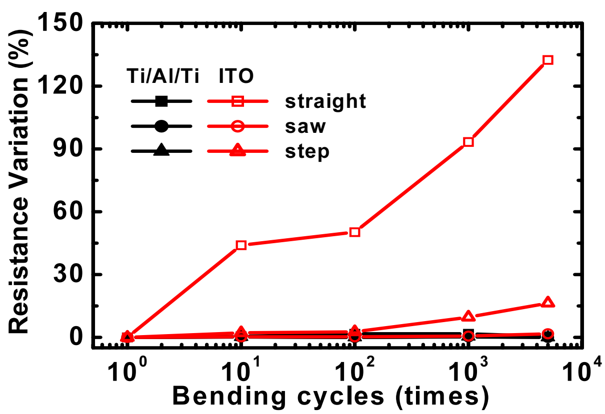

Figure 6. The variation of resistance of electrode after bending cycles.

Figure 7 shows the transfer characteristics of a-Si:H TFT arrays fabricated by 200 °C process on PI substrate. The mobility of a-Si:H TFT is 0.42 cm^2/V-s, the subthreshold swing is 0.58 V/decade, and the threshold voltage is 2.8 V, respectively. The a-Si:H TFT has the good capability for switching, because the off current is lower than 10^{-12}A and the I_{ON}/I_{OFF} current ratio is larger than 10^7 at V_{DS}=10 V.

Figure 8 shows the threshold voltage shift under electrical stress at V_{GS}=20V and V_{DS}=15V. The shift of a-Si:H TFT on PI substrate is lower than a-Si:H TFT on glass, even though the strain is 0.2 %.

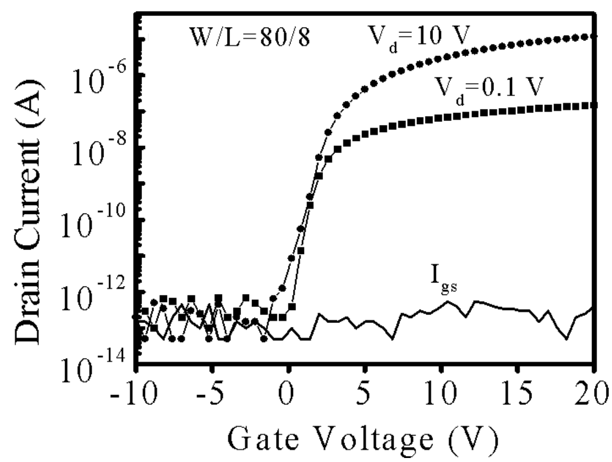

Figure 7. The transfer characteristics of a-Si:H TFT arrays fabricated by 200 °C process on PI substrate

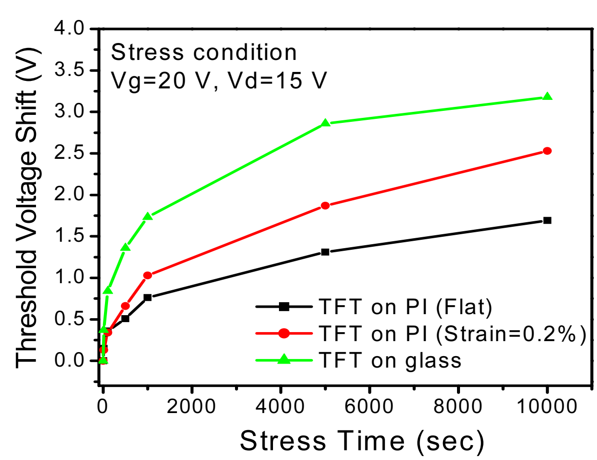

Figure 8. The threshold voltage shift under electrical stress

Finally, after fabricating 7-inch a-Si:H TFT arrays on PI substrate and color filter on PC substrate with VGA resolution, a color a-Si:H TFT-LCD has been integrated (Figure 9) . The image of this a-Si:H TFT-LCD on PI substrate is shown in Figure 10.

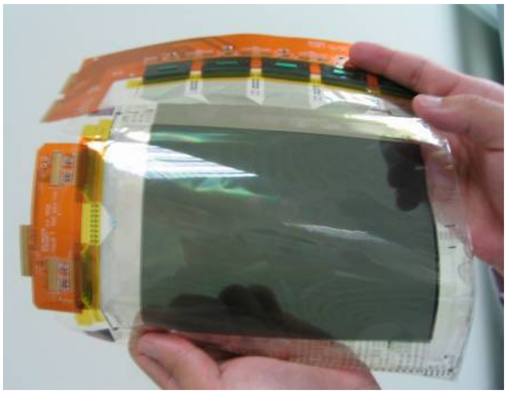

Figure 9. Top and side-view of flexible panel

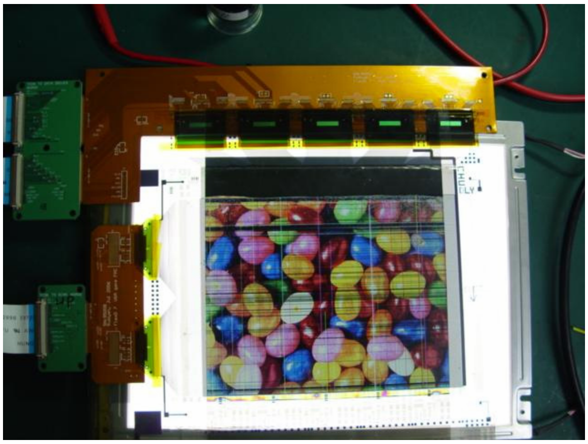

Figure 10. The image of 7-inch a-Si:H TFT-LCD on PI substrate

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