Fabrication of High Performance Plastic MIM-LCDs

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Abstract

We have developed flexible MIM LCDs by using plastic film substrate. MIM array and cells were fabricated with low temperature process and material technology. As an insulator of MIM, SiNx was introduced at the low temperature allowable for plastic substrate. The fabricated MIM devices show high electrical performance for LC driving. We discuss its process and characteristics.

1. Introduction

In recent years, various mobile displays have been developed and coming into wide use. Plastic LCDs are favorable for mobile displays due to their advantages: thinner, lighter and more robust than conventional glass LCDs. Therefore, many works have been carried out[1].

PMLCDs(STN-LCD) based on plastic substrate came into the market for mobile display applications. As multimedia is growing rapidly, needs for AM-LCDs are also increasing. TFT and MIM devices have been developed for plastic AM-LCDs.

In TFT process, the degradation of deposited amorphous silicon at low temperature and the substrate deformation caused by 4~5 step of mask processes might be problems for the application to plastic LCDs. On the other hand, MIM devices can be fabricated at low temperature process with relatively low degradation, and has simpler structure and less processes than TFT. Also, because MIM-LCDs commonly have high aperture ratio, the power consumption is lower than that of TFT-LCDs. This implies that MIM can be a good candidate for plastic AM-LCDs and portable displays.

But a major problem in the MIM-LCD is the image sticking phenomena, which deteriorate the display quality. This phenomena is caused by the asymmetry of the I-V characteristics of the MIM devices[2]. In order to improve the I-V symmetry, we investigated materials and deposition condition of insulator.

2. Experimental

We designed MIM-LCDs and fabricated high performance MIM (Metal-Insulator-Metal) structures for suitable for plastic LCDs.

PES films were used as plastic substrates in this work. Mainly because of its tolerance of high process temperature and its low thermal expansion, PES film is a preferable plastic[3]. After we tested various materials for an electrode metal, Al with a ductile and a low elastic modulus properties was adapted for an electrode material. SiNx was adapted with PECVD process at a temperature below 150℃ as an insulator material. SiNx could be fabricated at a low temperature with a low dielectric constant. Thus, SiNx-MIM has a low cross-talk and also a steeper I-V curve that can lead to manufacturing of high resolution and low power consumption displays[3],[4]. We deposited SiNx with focusing on decreasing film stress and increasing electrical properties. In order to meet the current density and I-V symmetry requirements of the MIM, we controlled deposition condition of SiNx film precisely.

We fabricated the prototype panel through cell and module processes with MIM array substrate. Processes and materials were tested to optimize for low temperature process. Finally, reliability and display performance of the panels were examined.

3. Results and discussion

3-1. MIM device fabrication

The structure of fabricated MIM device is shown in Figure 1. Al was deposited on PES film using sputtering as a scan line electrode. To avoid the

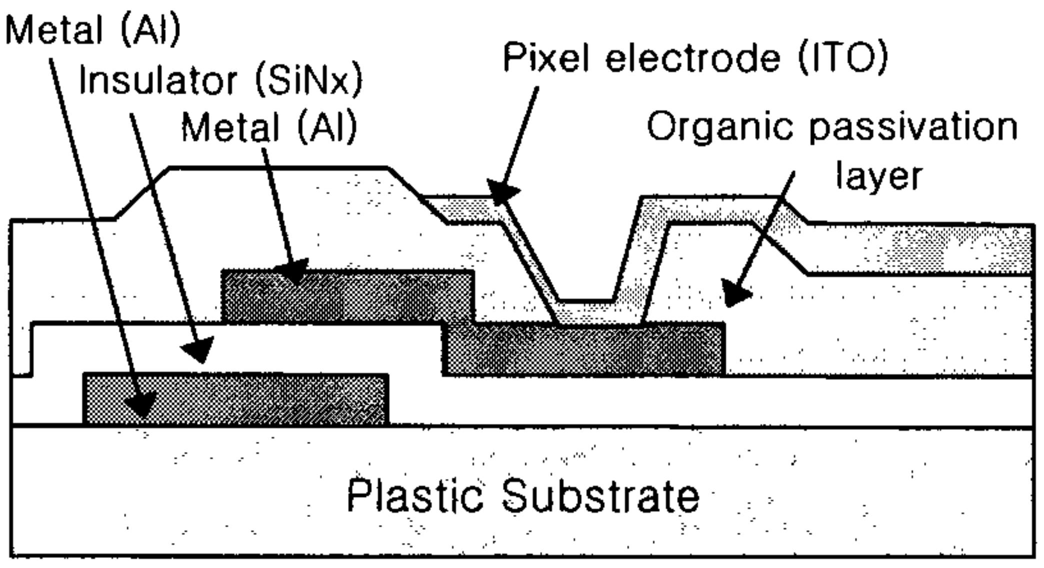

Figure 1. Cross-section of MIM device on plastic substrate

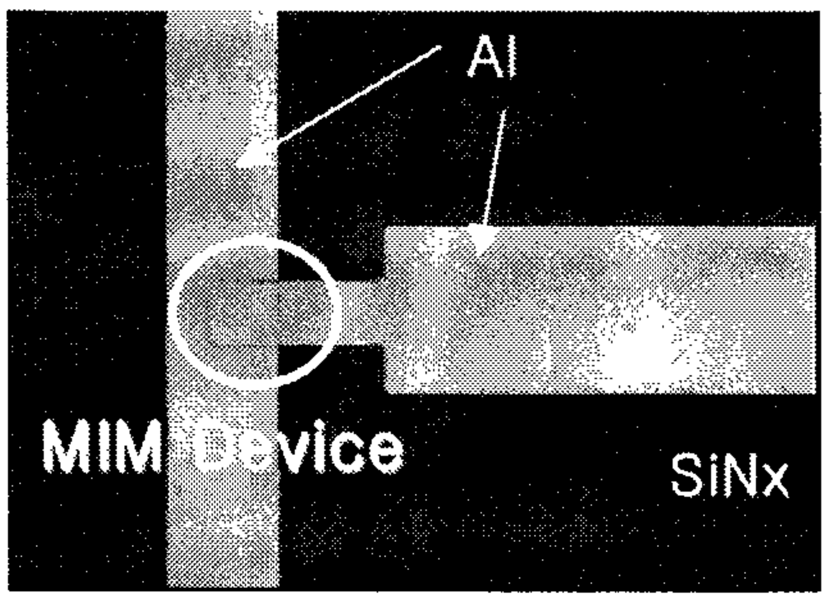

Figure 2. Photo-image of fabricated MIM device

damage of Al against ITO etchant.

So, we designed via-hole structure and used BCB (BenzoCycloButene) as a organic passivation layer. SiNx as an insulator was patterned in the shape of island to prevent stress generation.

Figure 2 shows the plane view of patterned MIM device. There was no crack and mechanical damage. The substrates were maintained flat without warpage after finishing processes. In order to decrease stresses all layers were formed in low deposition power range.

3-2. I-V characteristics

As a switch, MIM can be driven into one of on-state and off-state. When charging pixel during select period the MIM must be in a high current on-state while during non-select period the MIM must be maintained in off-state where the leakage current is sufficiently low[5].

We obtained stable threshold voltage and on-current characteristics as shown in figure 3. The I-V characteristics were achieved by controlling of gas ratio of SiH_4 and NH_3. In order to obtain high current density, gas ratio (SiH_4/NH_3) was increased in the PECVD process. Increasing the SiH_4 ratio the current

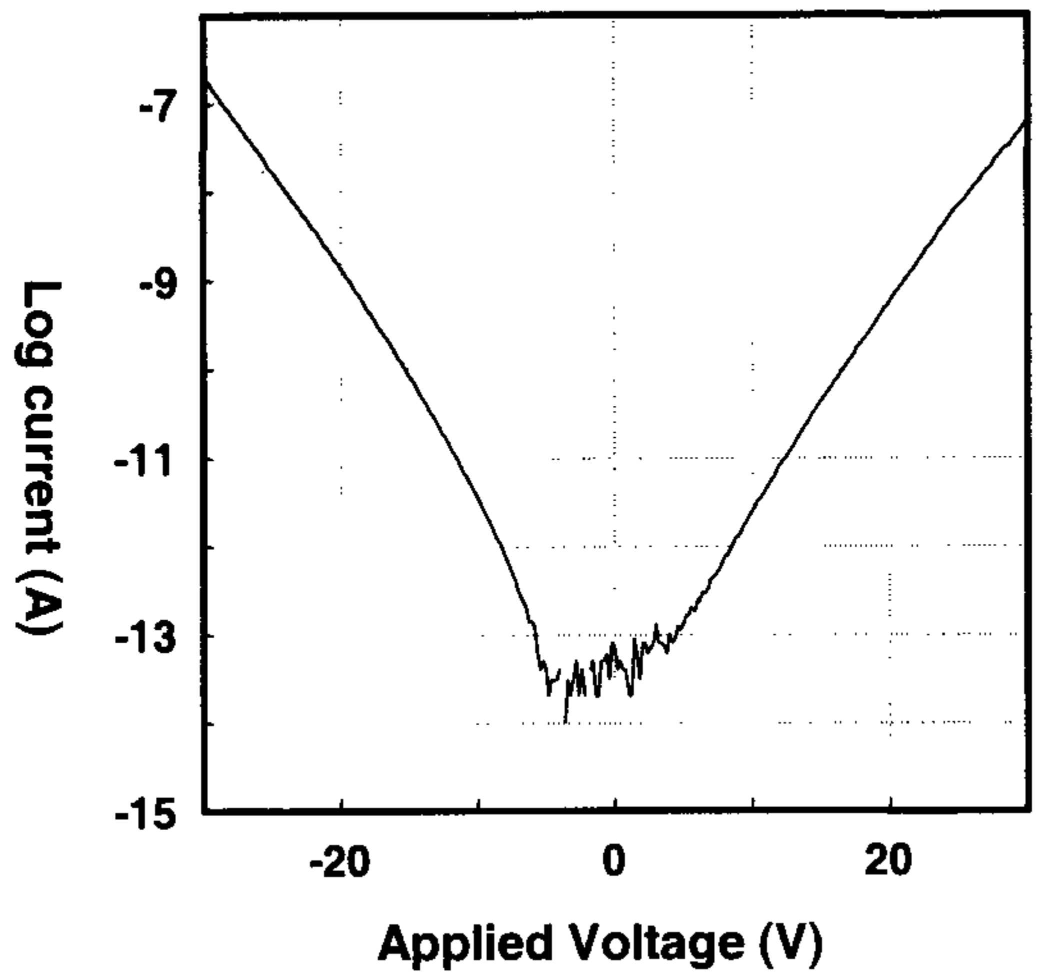

Figure 3. I-V characteristics of the MIM devices

density became higher and threshold voltage became lower. It seems that the composition percentage of amorphous silicone (α-Si:H) in SiNx film is increased. This means that SiNx characteristics is close to semiconductor-like SiNx film[6]. But the current density of manufactured SiNx-MIM is less than that of typical SiNx diode on glass substrates. The SiNx for plastic LCDs deposition temperature is lower than for glass LCDs, so that the current density is lightly decreased but sufficient for driving LCD.

Figure 3 shows fairly symmetrical I-V characteristics of the MIM devices. In order to obtain such I-V curve, we controlled deposition parameter. The I-V characteristics implies that the interfaces of Al (bottom electrode) / SiNx and SiNx / Al (upper electrode) were made very similar in terms of electrical properties..

3-3. Simulations

Pspice simulations were performed to confirm the MIM-LCD characteristics. Firstly, I-V characteristics of the MIM devices were modeled using the following equation:

$$I = I_S \left[\exp\left(\frac{V}{V_C}\right) - \exp\left(\frac{-V}{V_C}\right) \right]$$

Is($=2.36\times10^{-15}$A) and Vc(= 1.67V) were extracted from the I-V curve. Modeling equation was very close to I-V data.

Secondly, simulations for one pixel were performed to confirm charging and discharging characteristics of the pixel. Figure 4 shows equivalent circuit for estimating the pixel charging behavior. Figure 5 shows a stable holding property of pixel voltage with applying scan and data voltages. Also, It shows that the pixel voltage is symmetric and enough to charge the pixel according to the forward and reverse biases. For select time, the pixel voltage is maintained on a constant level. This means that leakage current of the MIM is negligible. It is expected that AC cross-talk between the pixels is very low. As shown in figure 5,

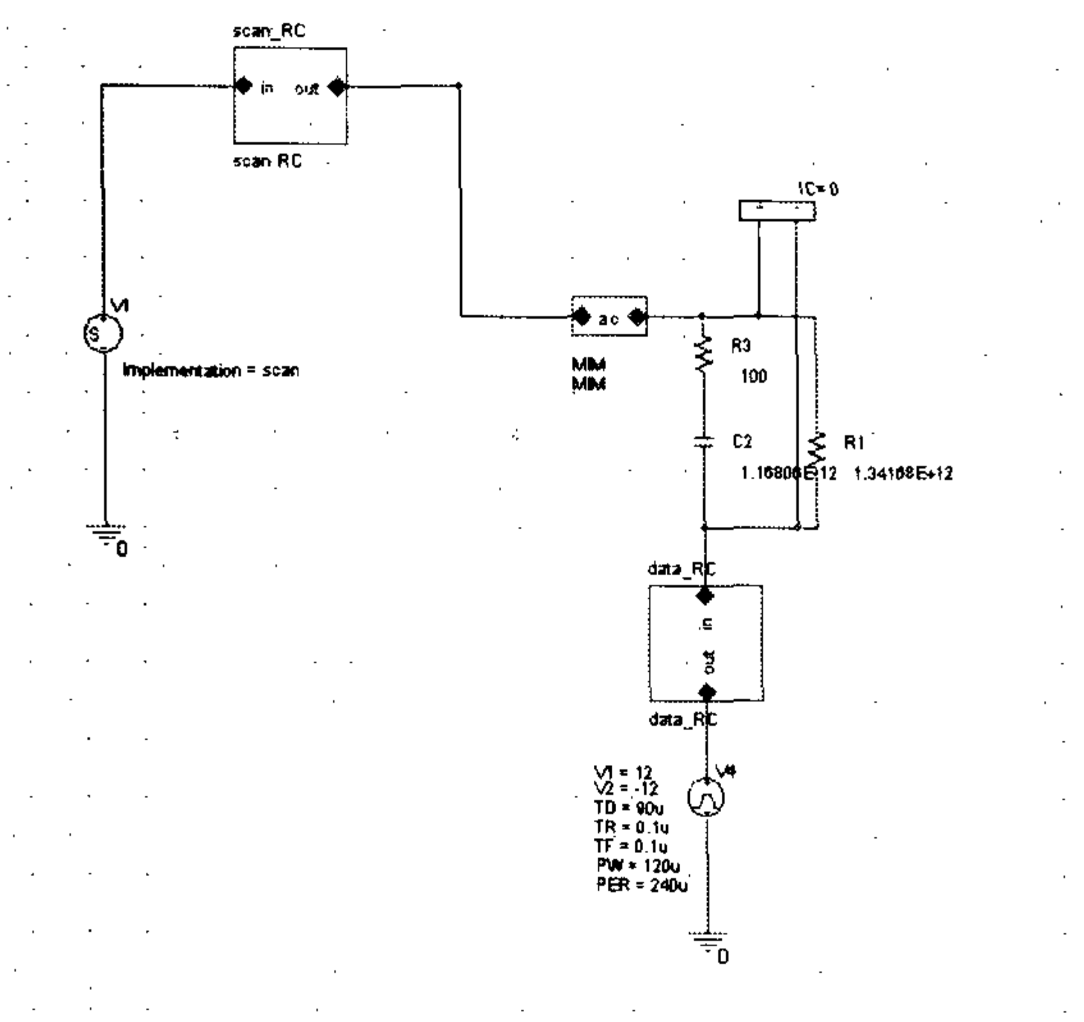

Figure 4. Circuit modeling using OrCad to estimate pixel charging behavior of the MIM

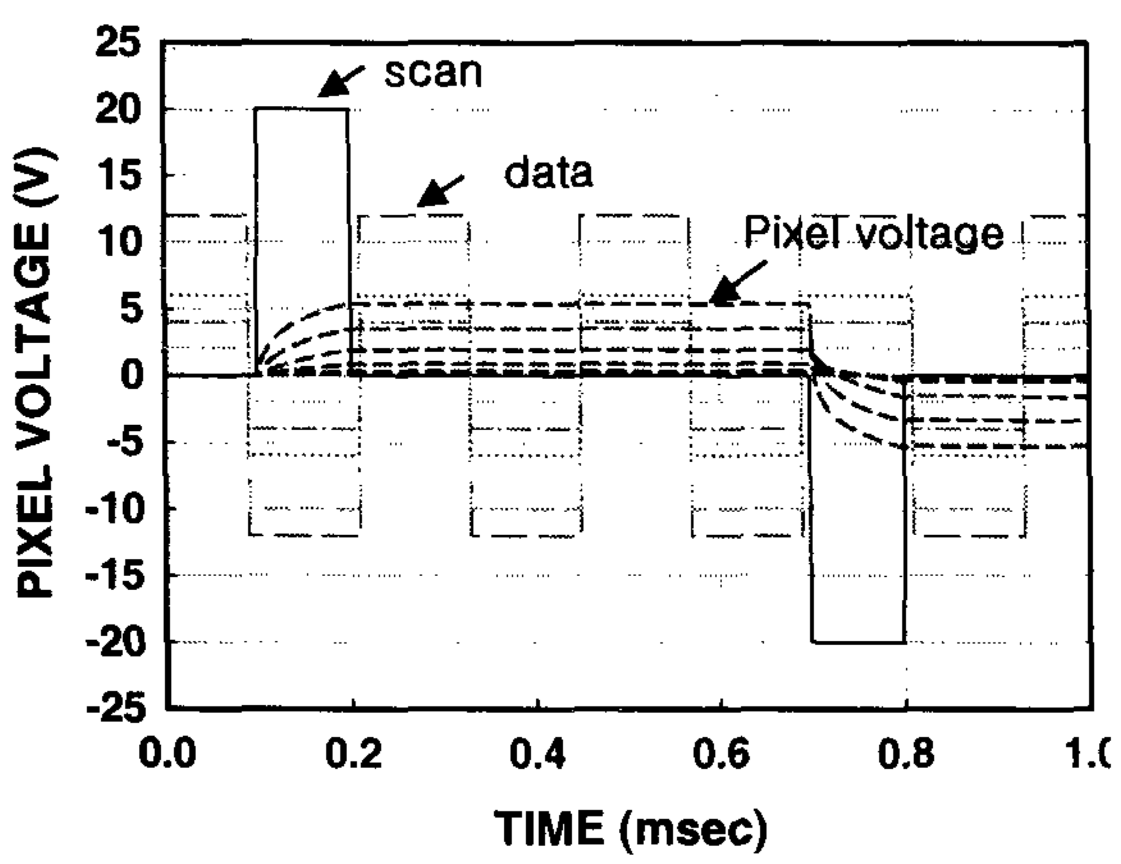

Figure 5. Simulations result of the pixel voltage

the pixel voltage changes proportionally to the variation of the data voltage. This means that grey scales can be achieved for LCDs.

3-4. Fabrication of display panel

The feasibility of the plastic MIM-LCD is demonstrated by manufacturing panels. We designed and fabricated MIM-LCDs with 3.5inch diagonal QVGA format.

In the BM and color filter processes, the design adjustment was carried out for compensating the size deformation of substrate caused by thermal and chemical stress. The materials in cell process such as polyimide and sealant were handled below 150℃. We manufactured the cells with dark spot free. After reliability test, the dark spot and any defect did not appear.

4. Conclusion

In this study, we have developed plastic MIM-LCD processes, which can be handled at a low temperature for plastic LCD. It has been confirmed that the MIM devices have adequate current density and symmetry of I-V characteristics. We have performed plastic LCD based on the MIM device with good electrical properties and physical stability.

Taking into account the process temperature, power consumption and production cost, the MIM-LCD could be a substantial solution for plastic active matrix LCDs. We believe that plastic the MIM-LCDs would be a realistic solution for active matrix plastic LCDs and plastic MIM-LCDs would be able to be commercialized shortly.

6. Acknowledgements

This work was carried out in "Part and Material Technology Development Project" with support of MOCIE (Ministry Of Commerce, Industry and Energy)

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