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Degradation of Sub-Threshold Characteristics in a-Si TFT with Polyimide Passivation

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Among various factors affecting off-characteristics in a-Si TFT-LCDs, one of the most important factor is the degradation of sub-threshold characteristics in a-Si TFTs. By testing the reliability of the TFT-LCDs under actual operating conditions, we have found that the polyimide film used as an alignment layer causes the degradation of sub-threshold characteristics of the TFT.

§1. INTRODUCTION

Image qualities of LCD-TVs using amorphous silicon thin film transistors (a-Si TFTs) have become comparable to CRT images by the recent remarkable LCD technology advancements[1]. Projection system using TFT-LCDs is one of the most promising techniques for high resolution and large screen TV[2]. TFT-LCDs for this use must endure intense light and resulting temperature rise, therefore, higher stabilities on a-Si TFTs as switching elements should be assured than in conventional uses.

A threshold voltage shift ($\triangle V_T$) under prolonged gate bias stress is the familiar degradation observed in a-Si TFTs[3]. However $\triangle V_T$ can be reduced to a negligible small change by optimizing driving conditions[4].

Degradation of sub-threshold characteristics in a-Si TFTs is a more important and complicated issue. This degradation leads to the degradation of off-characteristics[5] in TFT-LCDs. By testing reliabilities of the TFT-LCDs under actual operating conditions, we have found that the polyimide film used as an alignment layer causes the degradation of sub-threshold characteristics of the TFT.

In this paper, the degradation mechanism of sub-threshold characteristics and the way to reduce this effect are presented.

§2. EXPERIMENTAL

The a-Si TFT employed in our experiments is the inverted-staggered structure with polyimide passivation as previously reported[1]. The polyimide film which has a function of an alignment layer is formed by an off-set printing method to a thickness of about 1000(A). By changing the molecular structure or the curing temperature, the percentage imidization of the polyimide film was varied between 0-100 (%).

To investigate the off-characteristics under the actual operation of the TFT-LCD, we introduce a new evaluating parameter $V_{GB}{}^{\emptyset}$. Figure 1 shows the definition of $V_{GB}{}^{\emptyset}$ which is the maximum possible value of off-level for the gate pulse without causing degradation of display performance.

The TFT-LCD was operated under reliability testing conditions of V_G=21(V), V_{SC}= 11.4(V), and V_S=4 or 6(V), and at 60(°C). The definitions of these driving parameters are described in the previous report[5]. $V_{GB}{}^{\emptyset}$ was always measured at room temperature.

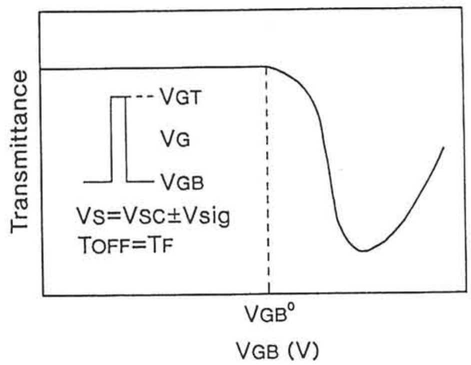

Fig. 1 Definition of off-parameter V_{GB}^{0}.

§ 3. RESULTS AND DISCUSSIONS

Figure 2 shows the operating time dependence of V_{GB}^{0} shift ($\triangle V_{GB}^{0}$) under the actual operation of the TFT-LCD. As operating time increases, V_{GB}^{0} shifts to the negative. When V_{GB}^{0} rise down below the initial off-level for the gate pulse, the degradation of display performance can be observed. And this critical point is seen in the shorter time range with increasing temperature.

We now consider possible mechanisms to account for this negative shift of V_{GB}^{0}. Hole conduction, which is commonly seen in the TFT with no ohmic layer between i-a-Si and source/drain metal, can be dismissed. Because in our TFT-LCD, as seen in FIG. 1, transmittance is saturated and almost constant with decreasing V_{GB}. If hole conduction occurs, it should decrease rapidly with decreasing V_{GB}.

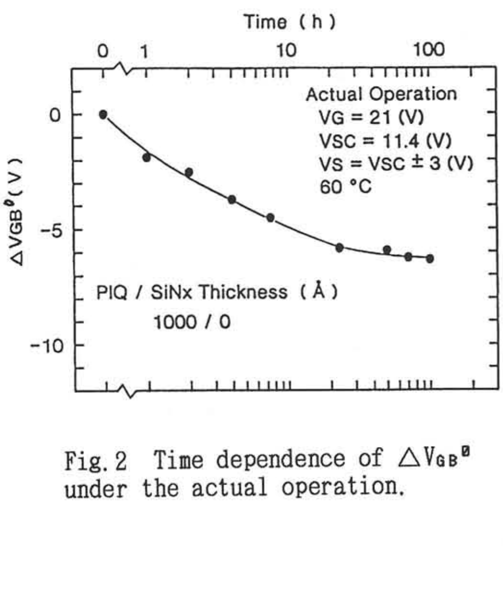

Fig. 2 Time dependence of $\triangle V_{GB}^{0}$ under the actual operation.

Negative shift of V_T is a popular interpretation to account for the effect seen in our experiments, but negative shift of V_{GB}^{0} can be observed even when V_T shift can not likely occur. Figure 3 shows the operating time dependence of $\triangle V_{GB}^{0}$ with no bias stress to the TFT. V_{GB}^{0} shifted to the negative under the DC bias stress between gate and counter electrodes (negative bias on gate) with no bias stress to the TFT($V_G = V_S \sim V_D$). This experiment is not under the actual operation, but the experimental result suggests that negative shift of V_T is not a dominant mechanism for V_{GB}^{0} shift.

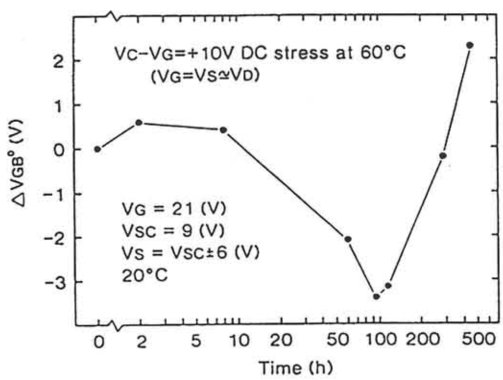

Fig. 3 Time dependence of $\triangle V_{GB}^{0}$ with no bias stress to the TFT.

Direct leak between source to drain electrodes through the polyimide film also can be considered. Figure 4 shows the gate bias dependence of $\triangle V_{GB}^{0}$ after 100 hours of actual operation and figure 5 the signal voltage bias dependence. As seen in figures 4 and 5, ΔV_{GB}^{0} increased with the increase in the negative gate bias stress, while ΔV_{GB}^{0} was almost independent of the voltage between source and drain electrodes. These experimental results dismiss the possibility of direct leak through the polyimide film.

We propose that the negative shift of V_{GB}^{0} observed in our experiment [FIG. 2] is due to the degradation of sub-threshold characteristics in a-Si TFT. This interpretation is quite reasonable in considering the above experimental results. But we still must answer the question of what causes this degradation.

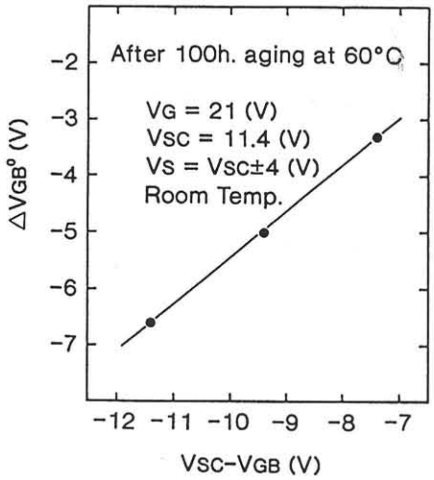

Fig. 4 ΔV_{GB}^{0} as a function of gate bias under the actual operation.

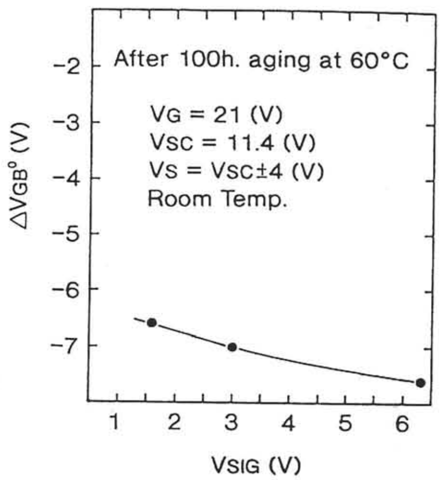

Fig. 5 ΔV_{GB}^{0} as a function of signal voltage bias under the ac tual operation.

The experiments conducted showed an intriguing effect. Figure 6 shows that ΔV_{GB}^{0} increases with the decrease in the percentage imidization of the polyimide film which lies on the a-Si TFT as an alignment layer. To understand this result, we have investigated the electric properties of polyimide film in detail.

Figure 7 shows the frequency dependence of dielectric constant ε for the polyimide films of various imidization 40-100(%). As the percentage imidization decreases, ε increases. And as frequency decreases, ε increases for any kind of polyimide film, and this tendency is more distinguised in the low-imidized polyimide film. It is evident from Fig. 7 that the lower imidized polyimide film contains more dipoles and the slow increase of ε in the low frequency region corresponds to surface polarization.

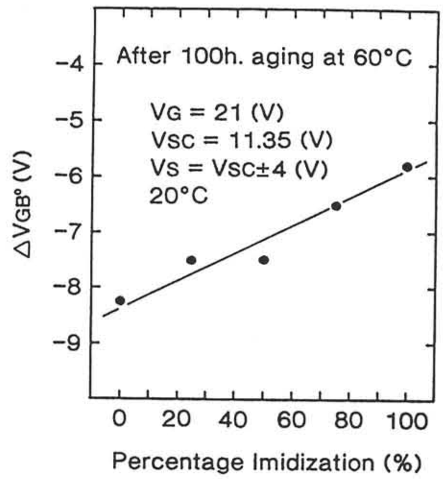

Fig. 6 ΔV_{GB}^{0} as a function of percentage imidization of polyimide film under the actual operation.

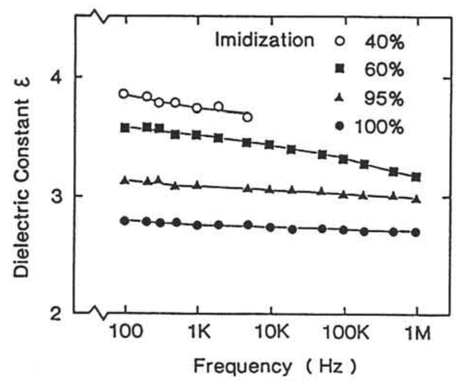

Fig. 7 Frequency dependence of dielectric constant ε for the polyimide film of various imidization.

Based on these experimental results, we can explain the degradation mechanism of sub-threshold chacteristics in a-Si TFT with polyimide passivation as follows: The a-Si TFT is biased to the negative except for very short on-pulse in the actual operation. At the back surface of the TFT, the dipoles in the polyimide film causes the surface polarization which induces electrons in a-Si (back-gate effect) and causes the degradation of the sub-threshold characteristics. Figure 8 shows the degradation mechanisms schematically.

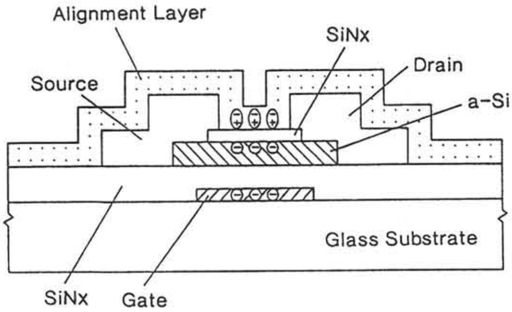

Fig. 8 Schematic model accounting for degradation mechanism of sub-threshold characteristics.

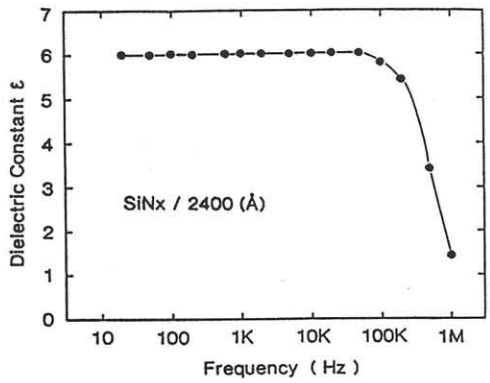

Fig. 9 Frequency dependence of dielectric constant ε for passivation nitride.

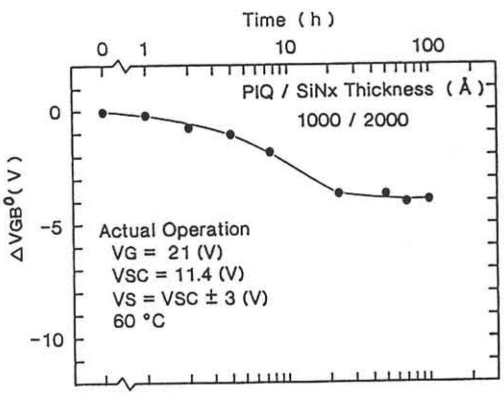

Fig. 10 Time dependence of ΔV_{GB}^{0} for the TFT-LCD with passivation nitride on the TFT under the ac-tual operation.

To reduce this effect, it may be effective to lay a good insulator, which causes no surface polarization, between the TFT and polyimide film. We have tried PECVD silicon nitride (SiNx). Figure 9 shows the frequency dependence of ε for SiNx. ε is almost constant below 100(kHz) and no surface polarization is observed. Figure 10 shows the operating time dependence of ΔV_{GB}^{0} on the TFT-LCD in which SiNx lies on the a-Si TFT. As seen in FIG. 10, ΔV_{GB}^{0} is reduced compared with the result in FIG. 2.

§4. CONCLUSIONS

By testing the reliability of the TFT-LCDs under the actual operation, we have found that polyimide film which lies on the TFT as an alignment layer causes the degradation of sub-threshold characteristics of the TFT.

At the back surface of the TFT, the dipoles in the polyimide film causes the surface polarization which induces the electrons in a-Si (back-gate effect) and causes the degradation of the sub-threshold characteristics.

To reduce this effect, it has been effective to grow a layer of SiNx between the TFT and polyimide film.

§5. ACKNOWLEDGEMENT

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