Study of point defects caused by a thin contamination layer in a-Si TFT-LCD

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Abstract

Analysis of point defects invisible by a microscope has been studied on the a-Si thin film transistor panel. The point defects which were named Invisible Point Defect (IPD) is characterized by no particles or distortion of patterns on a pixel structure and randomly distributed on panels. To investigate the IPD, measurements were carried out: gray level driving, transistor transfer characteristic, focused ion beam (FIB), and secondary ion mass spectrometry (SIMS). The results showed that a contamination layer had a bad influence on an active surface. The contamination layer consisted of oxygen and iron from a water supply line during cleaning process. After the process tuning, IPD has been stabilized.

1. Introduction

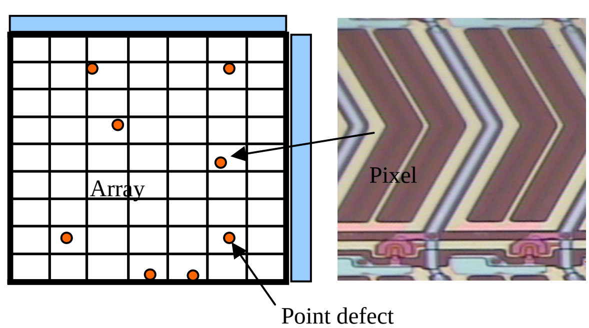
Defects have been one of the subjects in Flat Panel Display (FPD). Control of defects is required for high quality display from ergonomics and yields point of view. LCD fabrication companies are doing their efforts to reduce defects and produce defect-free panels. Defects induced by particles can be repaired by some methods but a few defects are ineluctable. Many researches showed the number of pixel defects acceptable for various panels and pixel sizes. As panel size or pixel size small, the acceptable number of defect was decreased. [1-2] Ofer Saphier et al. showed automatic defects classification for large size LCD TV. [3] Nowadays LCD companies use optic systems to detect any defect.

Despite a lot of defects control, there was a point defect that could not be detected during TFT array process. IPD could not be eliminated because it is not visible even by microscopes or any optic system. High quality of LCD is demanding so it is necessary to clarify and remove the IPD.

2. Invisible Point Defect

The Invisible Point Defect (IPD) is the fail of a dot which cannot be observed through microscope, but observed at final array test. It was difficult to find out the source of defects because any defect could not be seen even by high magnification microscope. Point defects should be removed for quality improvement and high-end products. Characteristics of IPD were summarized in Figure 1.

IPD had a bad influence on yields. According to yield test, yield reduction was induced by IPD. To investigate the characteristics of IPD, measurements were carried out: gray level driving, transistor transfer characteristic, focused ion beam (FIB), and secondary ion mass spectrometry (SIMS).



Panel test shows that some points are failed. Only one pixel does not work at failed position. No damage or contamination is observed.

Fig. 1. Description of Invisible Point Defect

3. Results

IPD showed on only one pixel to be defected and does not affect other surrounding pixels. There were no significant differences between modes such as TN, IPS. IPD could be detected when gray level test. IPD is significantly different to the normal pixel when same AC voltage applied. As shown in Figure 2, the luminance was same at the gray level 90%, but as gray level decreased, the luminance of IPD diminished faster than the luminance of normal thin film transistors (TFTs).

The dependence of s-factor or off-current (I_{off}) in TFT on charging characteristics was shown in figure 3.(a), where V_g, V_{lc}, V_{com}, V_d is gate voltage, liquid crystal drive voltage, common voltage, drain voltage, respectively. The leakage caused by a shift of s-factor, I_{off} in low gray level makes charging characteristics to be degraded. Therefore, it is supposed that luminance have been degraded as shown in Figure 2. The V_{lc} degradation is related to leakage current, resistance and parasitic capacitance in TFT. It was thought that leakage was related to gray level degradation. The transfer characteristics of TFT device were measured in Figure 3.(b). It showed that s-factor, I_{off} and threshold voltage (V_{th}) had degradation curve. That phenomenon was also same at the condition of light irradiation (photocurrent). The luminance decrease of the IPD can be explained by the degradation of holding characteristic identified TFT characteristic degradation. From the TFT characteristic result, it was expected that a-Si:H (active) layer could be damaged during TFT fabrication process. The reason of I_{off} increase was considered through theoretical study. The I_{off} could be increased when localized states distributed in the a-Si energy gap, [4] and when a current passage exist in the active layer. [5]

Focused ion beam (FIB) was performed to investigate an internal defect of TFT. The cross section of IPD and normal TFT were shown in Figure 4. A very thin layer was detected between active (a-Si) and source metal (Molybdenum_Mo). In the case of IPD, Mo and a-Si did not show inter-diffused structure compared to normal TFT. The contamination layer at the interface of active and source metal is considered to prevent Mo from diffusing to a-Si layer. It was expected that this phenomenon related device characteristics.

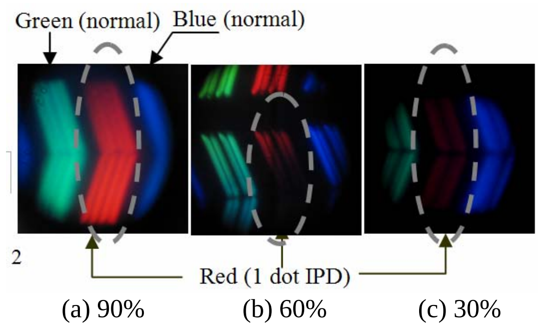


Fig. 2. The voltage driving test results of Invisible Point Defect (IPD) device comparing normal devices at both sides. IPD device shows a decrease in luminance at low gray level.

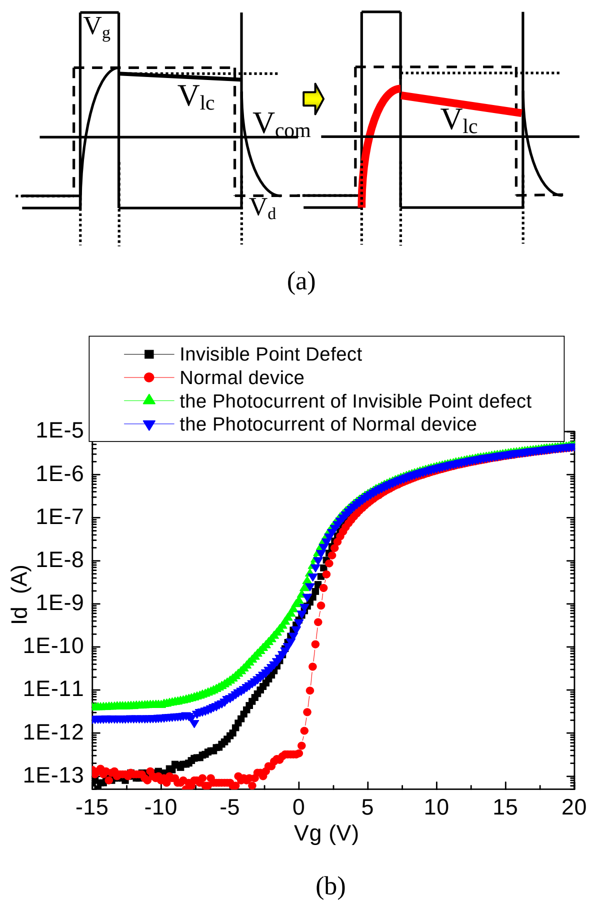


Fig. 3. (a) Prediction of charge characteristic change by voltage drop model in the case of IPD (b) Current-voltage characteristics of normal and IPD devices

Mo and a-Si can not be silicidation under 320℃ that is LCD panel anneal temperature.[6-7]. The slight inter-diffusion between Mo and a-Si was found just physical interface formation during Mo sputtering process. Through some tests, it showed that Argon (Ar) amount is dependent for physical contact between Mo and a-Si during sputtering process. As Ar amount increased, inter-diffusion length slightly increased.

Figure 5 showed secondary ion mass spectrometry (SIMS) profiles of the same sample in Figure 4. SIMS depth profile tests were performed in the source metal and channel region of TFT. In Figure 5.(a), the Mo and a-Si intensities of IPD device were changed compared to normal device at the interface of those layers. Peaks of IPD device were decreased at the interface. This indicated that inter-diffusion, between Mo and a-Si, was blocked by a very thin contamination layer. In Figure 5.(b), the Mo peak increased more than normal device and Fe peak showed more high level intensity than normal device at the active surface region. The TFT degradation, shown in Figure 3, could be expected that the surface of channel was contaminated and the components of contamination layers were remained in the channel region. So, I_{off} current could be increased by contamination component.

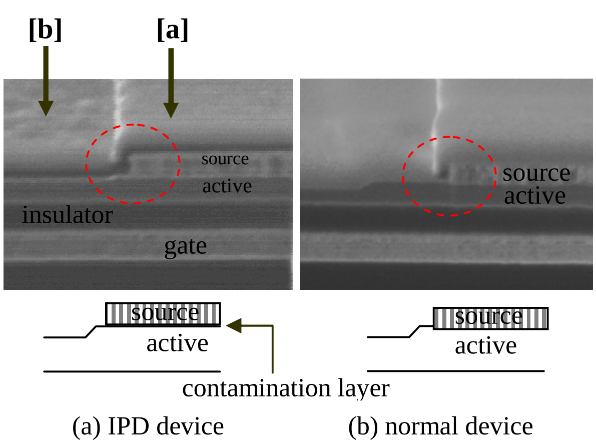
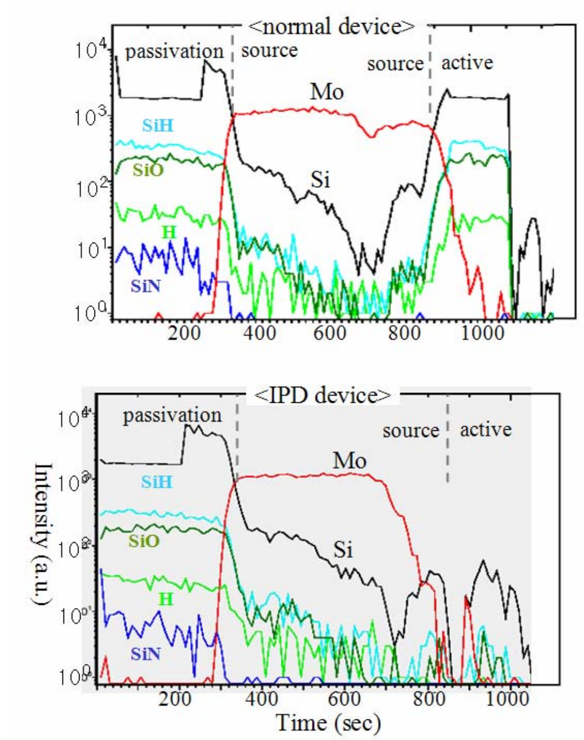
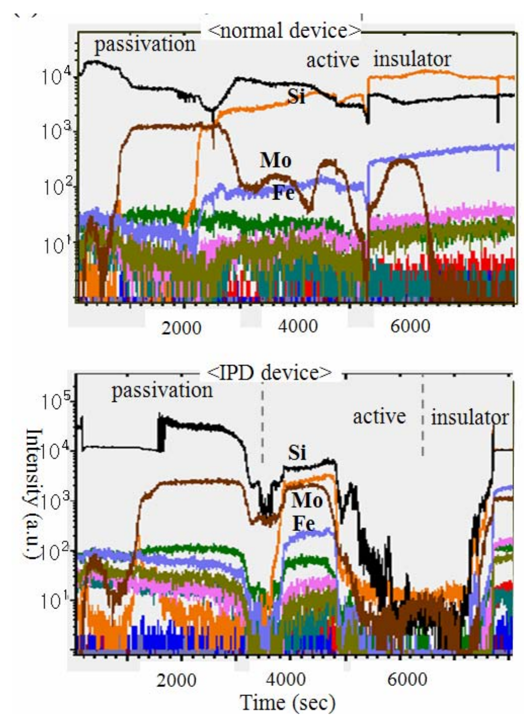


Fig. 4. FIB analysis-the cross section of TFT



(a)



(b)

Fig. 5. (a) SIMS analysis-between TFT layers of IPD and normal device ([a] region in Fig. 4.)
(b) SIMS analysis-between TFT layers of IPD and normal device ([b] region in Fig. 4.)

4. Action point

Further analysis showed the contamination layer components consisted of oxygen and iron and these were from water supply line during the cleaning process. After cleaning nozzle and any modification, the IPS defect decreased as shown in Figure 6.

As the number of point defects decrease, high-end quality and yield panel would be attained. Also, less number of point defects, visual performance would be better. The results provided near zero of invisible point defects to the previous some point defects. (Figure 7) Ergonomic requirement could be satisfied with the results and pixel faults tolerance limit [8] could be also satisfied.

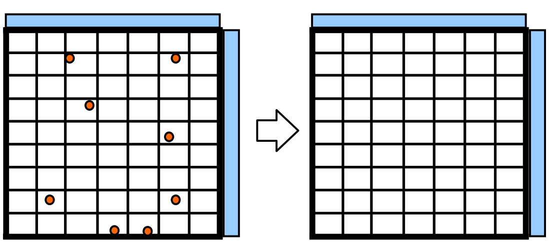


Fig. 6. A status of zero invisible point defect for improved visibility

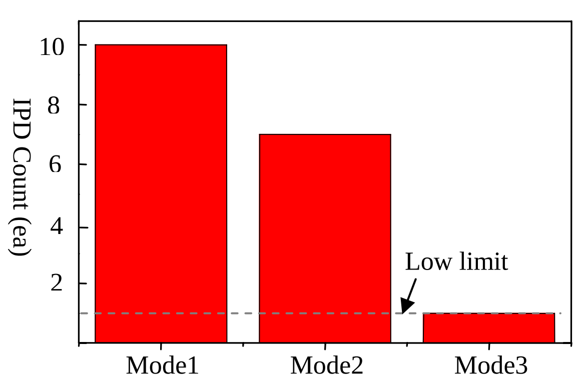


Fig. 7. A status of decrease of invisible point defect by cleaning process modification

5. Summary

The invisible point defect, IPD, characterized no particle or distortion pattern on pixel structure and distributed randomly on panel. To analyze defect mechanisms, measurements were carried out: gray level driving, transistor transfer characteristic, focused ion beam (FIB), and secondary ion mass spectrometry (SIMS). The results showed that active surface contaminated and it caused device degradation. That contamination came from the water supply line during cleaning process. After process tuning, IPD has been stabilized.

6. References

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