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# Characteristics of Photo Leakage Currents of a-Si:H TFT Caused by the Illuminations from CCFL and White LED Backlight

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# Characteristics of Photo Leakage Currents of a-Si:H TFT Caused by the Illuminations from CCFL and White LED Backlight

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*The photo leakage currents of a conventional hydrogenated amorphous silicon (a-Si:H) thin film transistor (TFT) were investigated and compared when the a-Si:H layer was exposed to the illumination from cold cathode fluorescent lamp (CCFL) backlight and white light emitting diode (LED) backlight. The photo leakage characteristics showed the difference in the leakage level and in the on/off current ratio in spite of the similar luminance. From the spectral analysis of backlight systems, the leakage level is expected to be related to the absorption of photons at lower wavelength, the generation of electron–hole pairs in a-Si layer.*

**Keywords:** amorphous silicon thin film transistor (a-Si TFT); cold cathode fluorescent lamp (CCFL); electron–hole generation; photo leakage current; spectral analysis; white light emitting diode (LED)

## INTRODUCTION

Hydrogenated amorphous silicon TFTs(a-Si:H TFTs) have been widely used as the active matrix devices to drive the liquid crystal display (LCD). Since LCD panels were used for TV application, it has been expected to obtain the high luminous backlight because of the demand of high contrast and brightness. But, the a-Si:H TFTs have characteristics of the high off-state photo leakage current

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under high illumination from backside as a result of high photo conductivity of a-Si:H [1]. Moreover, it has been inevitable for the a-Si layer to be directly exposed to the illumination from backlight as a result of the reduction of photo mask in the recent fabrication of a-Si:H TFT [2–3]. The photo leakage current may make an effect on the contrast ratio and other important parameters of LCD TV. Therefore, there have been a lot of attempts to minimize the photo leakage current of a-Si:H [4–6] and it is necessary to investigate the effect of the illumination of backlight system on the a-Si:H layer.

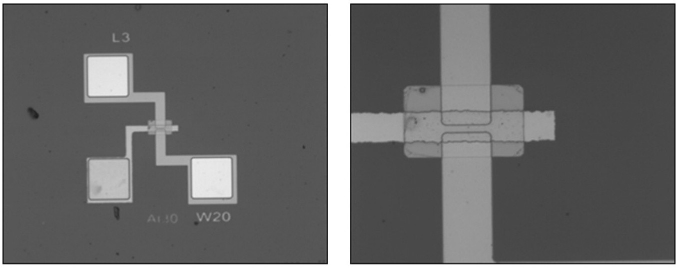
In this article, photo leakage currents of a-Si:TFT will be investigated when it is exposed to the illumination from CCFL backlight, which has been widely used as a backlight system of LCD module, and white LED backlight, which is expected to be mainly used as backlight systems of LCD TV because of a lot of merits such as wide color gamut, high dimming ratio, long lifetime, and environmental compatibility [7]. The results and the mechanism of photo leakage current will be described in terms of the light sources.



## EXPERIMENTAL

### Fabrication of a-Si:H TFT

For the effective measurement of photo leakage current, a-Si:H TFT with an exposed active pattern was fabricated on glass substrate. The fabricated TFT has a structure of a conventional back channel etched (BCE) inverted staggered type [8]. As a gate electrode and source/drain electrode, Cr was sputtered with a thickness of 2000 Å and was patterned. After gate patterning, silicon nitride (SiNx), a-Si:H and n-type doped hydrogenated amorphous silicon ($n^+$ a-Si:H) layer was deposited with the thicknesses of 3500 Å, 2000 Å, and 200 Å, respectively. When a-Si:H and $n^+$ a-Si:H were patterned by reactive ion etch (RIE) using $SF_6$ plasma, the active pattern were designed outside gate pattern to be directly exposed to the illumination from the backside of glass as shown in Figure 1(a) and (b). The area of the exposed active area was $2 \times 30\,\mu m \times 10\,\mu m$. On the active pattern, source and drain were patterned with the width of 20 μm and the length of 3 μm. After source/drain patterning, the $n^+$ a-Si:H layer in the TFT channel was etched by using RIE in a condition of $SF_6$ gas and the contact pad were patterned and etched about gate and source/drain.




(a) (b)

**FIGURE 1** Optical micrographs of (a) the fabricated TFT pattern and (b) expanded TFT channel of (a). Active layers are designed to be exposed to the illumination from backside.



## CCFL and White LED Backlight

Figures 2(a) and 2(b) show the structures of CCFL backlight and white LED backlight used in this experiment, respectively. The light sources are located at the edge of backlight in both cases. When a high voltage is applied to CCFL, an infrared light is radiated as a result of the

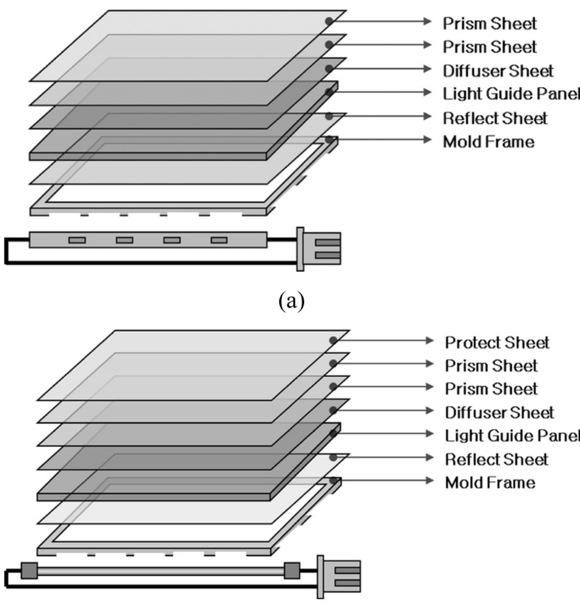



**FIGURE 2** Schematic diagram of CCFL backlight and white LED backlight.

ionization of Hg atoms in CCFL. Through the fluorescent layer on lamp, the light is emitted and uniformly distributed to the whole area of backlight system through the Light Guide Plate (LGP). Then the distributed light are reflected on the reflect sheet which is located under the LGP and the direction of reflected light are adjusted. Through the diffuser sheet and the prism sheet, the uniformity of luminance is obtained in a wide viewing angle and the luminance of the front side view is improved. The protect sheet is used to protect the prism sheet.

In case of edge type white LED, the structure of backlight system is the same as that of CCFL except the method of light generation. When a forward voltage is applied to the LED, light and thermal energy are emitted as a result of the combination of electrons and holes. The white LED is composed of a blue LED and yellow phosphor and the combined visible light is generated. The light is improved through the same sheets as those of CCFL backlight system.

## RESULTS AND DISCUSSION

The transfer characteristics of fabricated TFT were obtained by using Agilent 4156C as shown in the dark current of Figure 3. The TFT

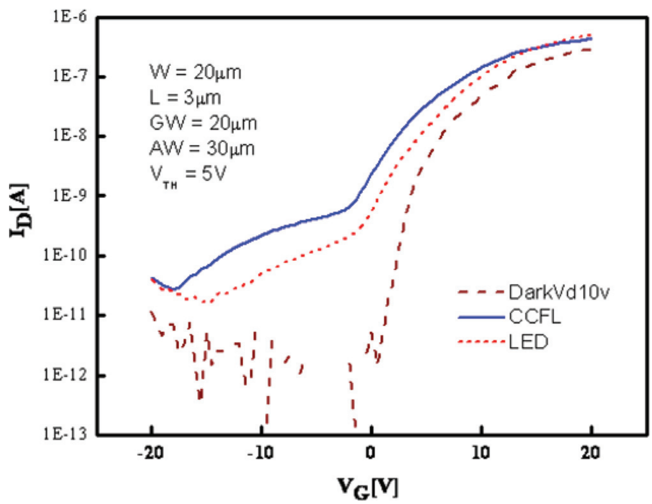



**FIGURE 3** The photo leakage currents when a-Si:H TFT was illuminated from CCFL and white LED backlight. The width and the length are 20 μm and 3 μm, respectively. The area of the a-Si:H layer which is exposed to the illumination ftom backlight was $2 \times 30\,\mu m \times 10\,\mu m$.

**TABLE 1** Color Characteristics of the Backlight Systems

| Light source | Luminance (cd/m$^2$) | Chromaticity (x, y) |
|---|---|---|
| CCFL | 2280 | (0.294, 0.286) |
| White LED | 2320 | (0.293, 0.284) |



exhibited a threshold voltage of 5.0 V and an on/off current ratio of $1.84 \times 10^5$ when the on-current and off-current were defined as the currents at the gate voltage of 20 V and $-10$ V, respectively. Table 1 shows the color characteristics of the CCFL backlight and the white LED backlight. The luminance values of the light sources were investigated by using MINOLTA CS-100A. The CCFL backlight and the LED backlight showed the luminance of 2280 and 2320 cd/m$^2$, respectively. The LED backlight was driven by a DC voltage and its luminance was fixed. The operation of CCFL was driven by an inverter system and the luminance of CCFL backlight was adjusted to the same value as LED by using a variable resistor. The fabricated TFT glass was located on top of the backlight systems and the transfer characteristics of TFT were characterized.

Figure 3 shows the transfer characteristics when the active is exposed to the illumination from the backlights. Although the backlight systems have similar luminance values, the measured transfer characteristics showed the different photo leakage characteristics from different backlight systems. The leakage currents caused by LED were higher than dark current by about one order when negative bias was applied. However, that was lower than the leakage current caused by CCFL by one order. The similar characteristics were obtained from the other TFT patterns. Figure 4 shows the on/off current ratios from the Figure 3. It is much important to keep the on/off current ratio high because it is related to the contrast in the driving of LCD. The on/off current ratio was $1.97 \times 10^3$ in case of the CCFL backlight and that was $9.88 \times 10^3$ in case of LED backlight. The difference is almost related to the level of photo leakage current.

For the understanding of the mechanism of the difference in photo leakage characteristics, the spectral analysis were characterized for both CCFL and LED backlight by using Photo Research 670 Spectrascan Colorimeter as shown in Figure 5. For CCFL, the peaks of intensity were obtained at 436 nm (blue), 544 nm (green), and 612 nm (red). On the other hand, a peak was obtained at 458 nm (blue) and a small and broad peak about $560 \sim 566$ nm as a result of phosphor emission for white LED.

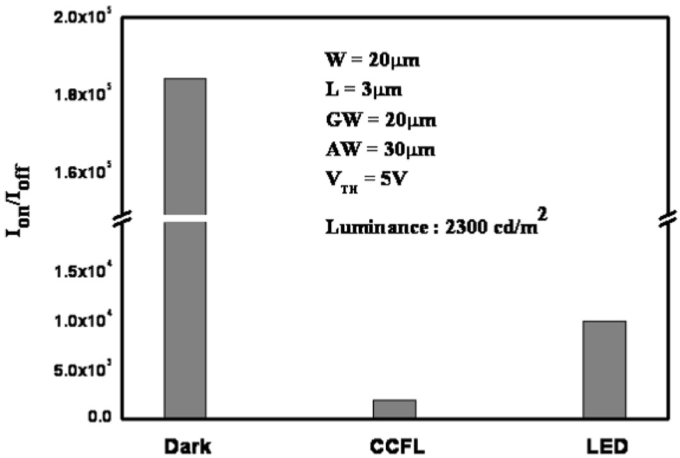



**FIGURE 4** Comparision of the ratio $I_{on}$ ($V_G = 20\,V$) to $I_{off}$ ($V_G = -10\,V$) in case of dark current, photo current caused by CCFL, and photo current caused by white LED.

Figure 6 shows the mechanism of the generation of electron–hole pairs caused by the illumination from backlight. The electron–hole pairs are generated from the photons which are absorbed to a-Si:H layer and the absorption coefficient is proportional to the energy of each photon *hv*. Therefore, the absorption coefficient is larger at

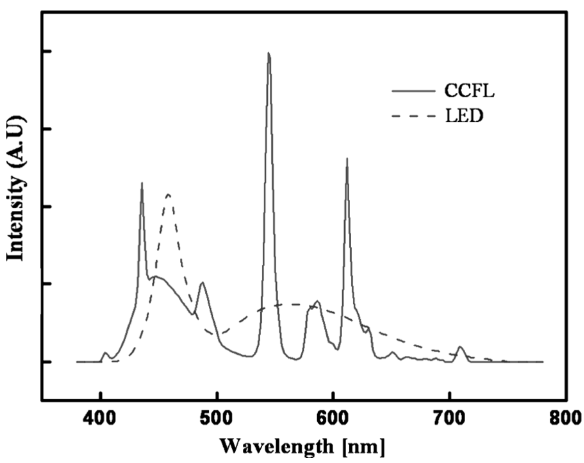



**FIGURE 5** The spectral analysis of the illuminated lights from CCFL backlight and white LED backlight.

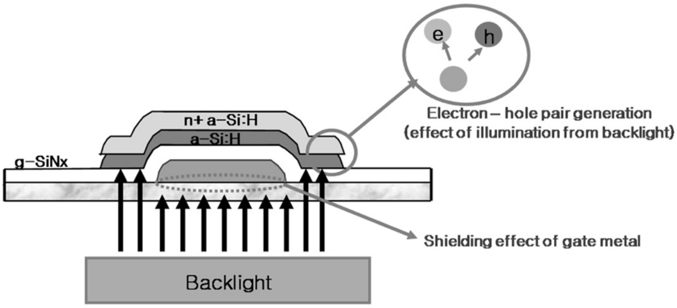



**FIGURE 6** The mechanism of the electron–hole pair generation caused by backside illumination.

shorter wavelengths and more electron–hole pairs are generated from photons in a narrow region of a-Si:H near the interface between g-SiN$_x$ and a-Si:H [9]. The generated holes are moved to the interface and lead to the photo leakage current [6,10]. From the Figure 6, CCFL has the shorter wavelength of peak intensity than LED in case of blue color and is expected to generate more holes at the interface between g-SiN$_x$ and a-Si:H, the main current path of a-Si:H TFT. Therefore, for the reduction of the photo-leakage current of a-Si:H it is necessary to control the spectral characteristics of backlight as well as the material characteristics of TFT. The effect of wavelength of light on photoelectric characteristics has been also presented in case of other materials such as ZnO based TFT [11].

## CONCLUSIONS

An inverted staggered type a-Si:H TFT was fabricated with exposed a-Si:H layer and its photo leakage characteristics were compared and described about both CCFL and white LED backlight system. In spite of the same luminance, it was possible to investigate the photo leakage current caused by CCFL backlight has a larger value than that caused by LED backlight. The difference in photo leakage current also brought about the on/off current ratio. When the spectral analysis were obtained from both backlight systems, the leakage level of CCFL backlight was thought to be larger than that of LED backlight because CCFL has a lower wavelength of peak intensity and the wavelength is related to the energy of absorbed photons to a-Si:H layer and the generation of electron–hole pairs. The result is expected to be applied to the usage of backlight system and the driving method of LCD panel.

## REFERENCES

[1] Yoon, J. K., Jang, Y. H., Kim, B. K., Choi, H. S., Ahn, B. C., & Lee, C. (1993). *J. Non-Cryst. Solids.*, *164–166*, 747.
[2] Yoo, S. Y., Choi, H. S., Ryu, J. I., Lee, W. B., & Lee, J. Y. (2005). *IDW'05*, 1121.
[3] Kido, S., Yamashita, M., Akagami, K., & Mutayama, Y. (2005). *IDW'05*, 983.
[4] Choi, J. H., Kim, C. S., Lim, B. C., & Jang, J. (1998). *IEEE ED.*, *45*(9), 2074.
[5] Kim, K. W., Cho, K. S., & Jang, J. (2000). *J. Non-Cryst. Solids.*, *266–269*, 1265.
[6] Choi, Y. J., Lim, B. C., Woo, I. K., Ryu, J. I., & Jang, J. (2000). *J. Non-Cryst. Solids.*, *266–269*, 1299.
[7] Lee, K.-C., Moon, S.-H., Berkeley, B., & Kim, S.-S. (2006). *Sensor and Actuactor A*, *130–131*, 214.
[8] Powell, M. J. (1989). *IEEE ED*, *36*(12), 2753.
[9] Yang, E. S. (1994). *Microelectronics Devices*, McGraw-Hill, 357.
[10] Martin, S., Kanicki, J., Szydle, N., & Rolland, A. (1997). *AMLCD'97*, 211.
[11] Bae, H. S. & Im, S. (2004). *Thin Solid Films*, *469–470*, 75.