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A Study on the Relationship Between Photo Leakage Currents of a-Si:H TFT and Photon Energy Transmittance of Various Color Spectrum Filters

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A cold cathode fluorescent lamp (CCFL) and various color spectrum filters were used in the investigation of photoelectric characteristics of hydrogenated amorphous silicon thin film transistor(a-Si:H TFT). From the photo leakage currents of a-Si:H TFT for the transmitted backlights through the various color spectrum filters, it was possible to conclude the photo leakage currents are not directly related to the luminance of the transmitted backlights. The photoelectric characteristics were well described in terms of photon energy spectrums calculated from the photon energy and the energy transmittance of backlight through the color spectrum filters.

Keywords a-Si:H TFT; color spectrum filters; energy transmittance; photo leakage current; photon energy spectrum

Introduction

Recently, it is considered necessary to maintain the high luminance of thin film transistor-liquid crystal display (TFT-LCD) panel at the demand of high contrast and high brightness for the application to TV system. It is therefore required to obtain high luminous backlight system in LCD module. However, hydrogenated amorphous silicon (a-Si:H) layer of TFT has a high photo conductivity and a higher luminous backlight can bring about a high photo leakage current of a-Si:H TFT panel [1]. By the high photo leakage current, the optical parameters such as contrast ratio are degraded and the leakage power of the whole TFT-LCD panel is increased. Therefore, it is necessary to reduce the photo leakage current of a-Si:H TFT in reverse gate bias and to investigate the mechanism of the photoelectric characteristics of a-Si:H TFT for the improvement of a TFT-LCD panel. A few articles have reported the improved fabrication process to reduce the photo leakage current such as the minimization of the thickness of a-Si:H layer and the additional active layers

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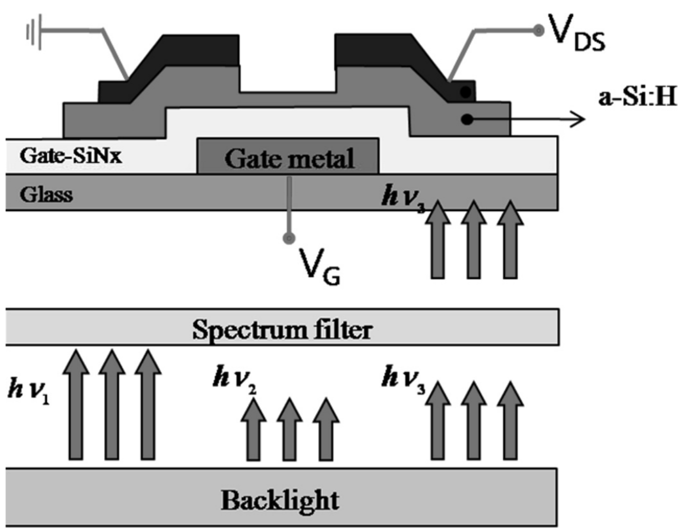

Figure 1. A schematic diagram of the proposed electrical measurement by using color frequency filter.

[2–5]. However, the photoelectric effect of the backlight on a-Si:H TFT has not been fundamentally considered and analyzed in terms of the spectral characteristics of light sources. In this paper, the photoelectric characteristics of a-Si:H TFT were obtained and analyzed for each color spectral characteristics of a cold cathode fluorescent lamp (CCFL) by a new experiment and a new calculation.

Experimental

An a-Si:H TFT was fabricated on $600 \times 900\,mm^2$ sized glass substrate with a protruded active pattern by using a conventional 5 mask fabrication process [6–8]. Figure 1 shows the fabricated TFT with a conventional back channel etched (BCE) inverted staggered structure. The width and the length of fabricated TFT were designed as $20\,\mu m$ and $4\,\mu m$, respectively.

For the measurement of the photo leakage current of a-Si:H TFT, active layers were designed to be protruded outside gate electrode and directly exposed to back-side illumination. Transfer characteristics of the fabricated TFT were measured by using Agilent 4156C and a CCFL backlight. three different (red, green, blue: R, G, B) spectrum filters were used in the measurement and were inserted between TFT substrate and CCFL backlight during the measurement as shown in Figure 1.

Results and Discussion

With a measurement by a MiNOLTA CD-100A, the CCFL backlight showed the luminance value of $1698\,cd/m^2$ without any color spectrum filtering. For each green, red, and blue filter, the luminance value of the transmitted light was 423.1, 286.6, and $108\,cd/m^2$, respectively. From the CIE chromaticities of the transmitted lights, it is possible to confirm the range of wavelength in which the light is transmitted through each spectrum filter. The transmittance of the filters was 24.35, 16.34, and 7.73% for each green, red, and blue filter, respectively. The ratios of the luminance of the transmitted light through each filter to that of the CCFL backlight without filters were calculated as 24.9, 16.9, and 6.4% for the green, red, and blue filters, respectively. The ratios were practically the same as the transmittances of the various color spectrum filters.

Figure 2 shows the spectral characteristics of CCFL backlight when the lights are transmitted through the color spectrum filters used in the experiment. Photo Research 670 Spectrascan Colorimeter was used in the measurement. Without any filtering, the three high intensity peaks were investigated at 436 nm (blue), 544 nm (green), and 612 nm (red) and the two small intensity peaks were additionally investigated at about 490 nm and 580 nm. For the transmitted light through the green filter, the spectral characteristics have a relatively high intensity from 470 nm to 560 nm with the intensity peaks at 490 nm and 544 nm compared with those of the transmitted lights through the other filters. The magnitudes of intensity peaks of the transmitted light through the filters were much smaller than those of the non-filtered CCFL backlight because of the lower transmittance of the filters. In case of red filter, the spectral characteristics showed a relatively high intensity from 570 nm to 720 nm and the intensity peak has a little smaller magnitude at 612 nm than that of the non-filtered backlight. For the blue filter, the transmittance of the light was restricted in a range of the wavelength from 420 nm to 510 nm and two small intensity peaks were investigated at 436 nm and 488 nm.

Figure 3 shows the transfer characteristics of the fabricated TFT under the backside illumination through the color spectrum filters. Without any illumination from the CCFL backlight, a threshold voltage of 5 V, a subthreshold swing of 1.27 V/dec, and an on/off current ratio of 2.15×10^5 were obtained when the on current and off current were defined as the current at the gate voltage of 20 V and -10 V, respectively. With the backside illumination from CCFL backlight, the photocurrent of TFT was higher than dark current without any illumination in the negative gate bias by about a factor of 10^1 or more. For the transmitted lights through the various

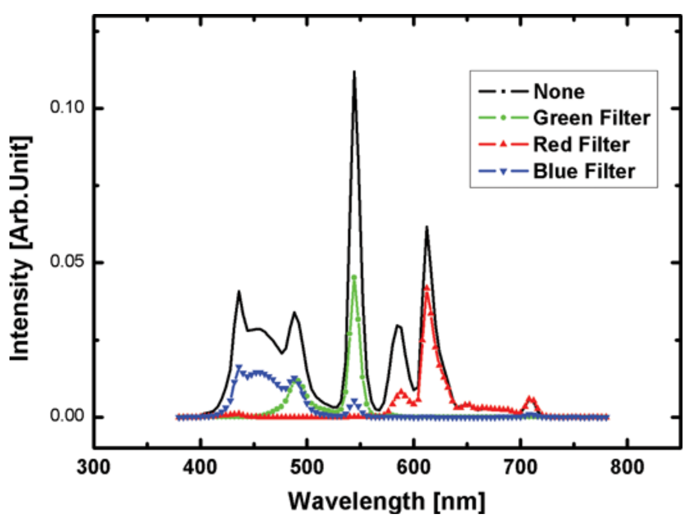

Figure 2. Spectral characteristics of color frequency filters used in the experiment.

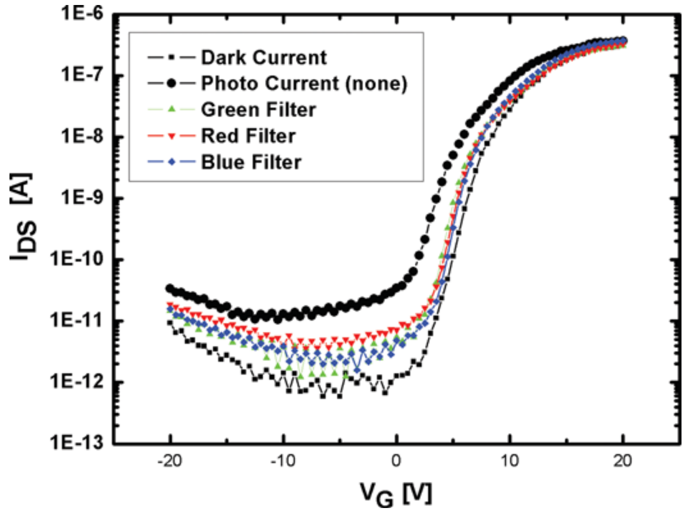

Figure 3. Transfer characteristics of a-Si:H TFT under the transmitted light through the frequency filters of Figure 2.

color spectrum filters, the photocurrents were smaller than that of non-filtered backlight because of the luminous transmittance of filters. However, there were no differences in the photocurrents for the transmitted lights through the different color spectrum filters. Considering the difference in the luminance of the transmittance lights, it is difficult to describe the similar photocurrents and to make an adequate explanation of the reason. It is required to consider in terms of each selected wavelength by filtering instead of luminance.

Figure 4 shows energy transmittances of the transmitted lights in the range of visible rays through the filters of Figure 2. The energy transmittance was obtained as a ratio of the energy spectral characteristics of the transmitted light to those of

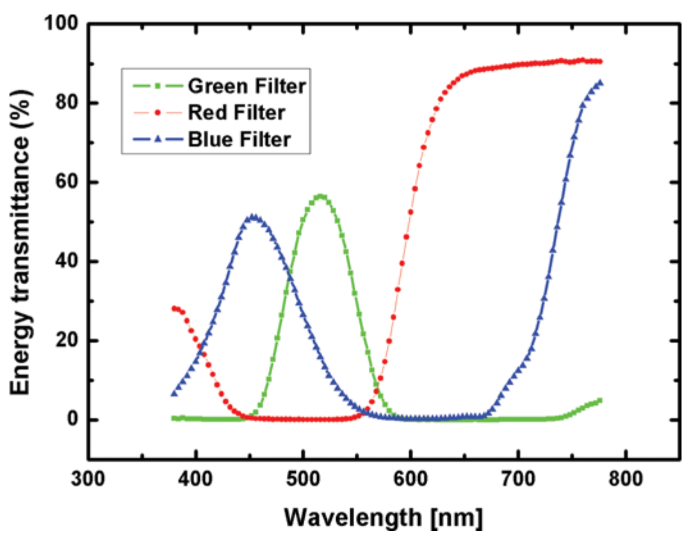

Figure 4. Photon energy transmittance of the color frequency filters used in the experiment.

the non-filtered light. In the measurement of the energy spectrums, a LRS462 source with a luminance of 3426 cd/m^2 was used as a light source in a range of visible rays (380~780 nm). For the green filter, the energy transmittance was relatively high from 468 nm to 564 nm and transmittance peak of 56.4% was obtained at 516 nm. For the red filter, the transmittance was apparent above about 570 nm and was maintained at about 90% above 716 nm. In case of the blue filter, the transmittance was relatively apparent from 392 nm to 524 nm and transmittance peak of 51.1% was obtained at 452 nm. Then the transmittance was again increased above about 700 nm.

In terms of the energy transmittance of the color filtered light, the photon energy of the transmitted light was calculated by using the multiplication of each photon energy, spectral intensities of CCFL backlight, energy transmittance through each color spectrum filter, and the integration for the wavelength of CCFL backlight as following.

$$\begin{aligned}
Photon\,Energy(\mathrm{Red}) &= \int_{380nm}^{780nm} \frac{hc}{\lambda} \cdot (CCFL\,Spectral\,Characteristics) \\
&\quad \cdot (Energy\,Transmission\,through\,R\,filter)\,d\lambda \\
Photon\,Energy(\mathrm{Green}) &= \int_{380nm}^{780nm} \frac{hc}{\lambda} \cdot (CCFL\,Spectral\,Characteristics) \\
&\quad \cdot (Energy\,Transmission\,through\,G\,filter)\,d\lambda \\
Photon\,Energy(\mathrm{Blue}) &= \int_{380nm}^{780nm} \frac{hc}{\lambda} \cdot (CCFL\,Spectral\,Characteristics) \\
&\quad \cdot (Energy\,Transmission\,through\,B\,filter)\,d\lambda \qquad (1)
\end{aligned}$$

By using Figures 2 and 4, the integrations of calculated photon energy spectrums were 5.12×10^{-28}, 8.23×10^{-29}, 8.93×10^{-29}, and 1.06×10^{-28} for non-filtering, green filter, red filter, and blue filter, respectively. Figure 5 shows the comparison

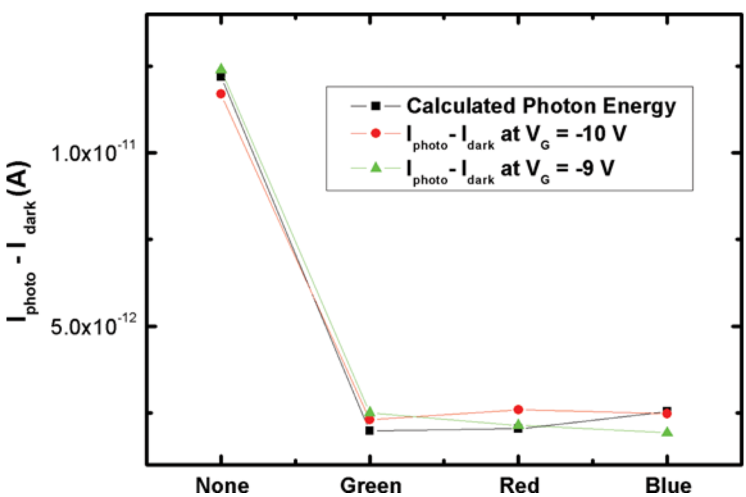

Figure 5. Fitting of the calculated photon energy for the color frequency filters to the photocurrent of a-Si:H TFT at the gate voltage of −10 V and −9 V.

of the integrated photon energies and the photoelectric portion obtained as the difference between the photocurrent by transmitted light and the dark current without any filtering of Figure 3. The photocurrent was defined at the gate voltage of $-10\,V$ and $-9\,V$. For the fitting of the photon energy to the photoelectric portion, a constant factor was considered. From Figure 5, it is presumable that the integrated photon energy comparatively fits to the experimental results. It is hence possible to conclude that the energy spectrum plays more important role than the luminance in the photoelectric characterization of a-Si:H TFT.

Conclusions

Green, red, and blue backlights were respectively formed by the transmittance of CCFL backlight through various color spectrum filters and they were applied to the photoelectric characterization of a-Si:H TFT. The obtained photo leakage currents were not related to the luminance of the transmitted backlight. For more appropriate analysis, the photon energies of the transmitted backlights were obtained by integrating the energy transmittance spectrums through the color filters with the CCFL backlight intensities and were fit to the experimental photoelectric currents. From the comparison, the photoelectric effect of a-Si:H TFT was well described in terms of photon energy spectrums of backlight.

Acknowledgments

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