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Optical feedback system with integrated color sensor on LCD

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Abstract

TFT LCDs have the largest market share of all digital flat panel displays. A three color RGB LED LCD backlighting system is very attractive considering wide color gamut, tunable white point, high dimming ratio, long lifetime and environmental compatibility. But the high intensity LED has thermal and time-based dependencies. Color and white luminance levels are not stable over a wide range of temperature due to inherent long-term aging characteristics. In order to minimize color point and brightness differences over time, optical feedback control is a key technology for any LED backlighting system.

In this paper, we present the feasibility of an optical color sensing feedback system for an LED backlight by integrating the amorphous silicon color sensor onto the LCD panel. To improve the photoconductivity degradation of amorphous silicon, a new LASER immersion treatment has been applied. The integrated color sensor optical feedback controlled LED backlighting system improved the color variation to less than 0.008 $\Delta u'v'$ (CIE1976) compared with 0.025 for an open loop system over the temperature range of 42–76 °C.

Keywords: Color sensor; Amorphous silicon; LED backlight; TFT LCD

1. Introduction

LCDs with LED backlighting will be obvious candidates for flat panel displays as TV applications rather than PDPs or CRTs in terms of vivid color reproduction. Combining red, green and blue (RGB) LED can provide nearly any color with compact white light source and unique features such as instant color variability [1,2]. It is very attractive considering wide color gamut, tunable white point, high dimming ratio, long lifetime and environmental compatibility. However, the high intensity LED has thermal and time-based dependencies in Fig. 1 [3]. Color and white luminance levels are not stable over a wide range of temperature due to inherent long-term aging characteristics.

In order to minimize color point and brightness differences over temperature and time, optical feedback control is a key technology for any LED backlighting system. Their practical implementation involves many issues such as photo sensor placement, sampling of light signals for feedback, the effect of driving current waveform on sensing, and control system design. A three color RGB LED backlighting system with integrated color sensor on LCD panel is depicted in Fig. 2.

To accurately detect color and luminance in large size (>40″) panels using LED backlights, at least two color sensors are needed, one each for the upper and lower portions of the display. Measurement accuracy is affected by the degree to which the color sensor is tilted from its mounting pad during the assembly process. The best place to attach the color sensor is either at the corner or along the edge of the backlight module. Furthermore, the best place for measuring the RGB light mixture from the backlight source would be on the LCD panel itself. However, the sensor and its circuitry are very difficult to attach on the small side area black matrix (BM) of the panel. Moreover, doing so would increase production cost and process time.

In this paper, we present a new technology for measuring the color point and white luminance of the LED backlight by using an amorphous silicon photoconductive sensor integrated onto the LCD panel as shown in Fig. 3.

2. Photosensitivity

Amorphous silicon has inherently well known photosensitive properties [4,5]. A-Si:H is an excellent material from the view-

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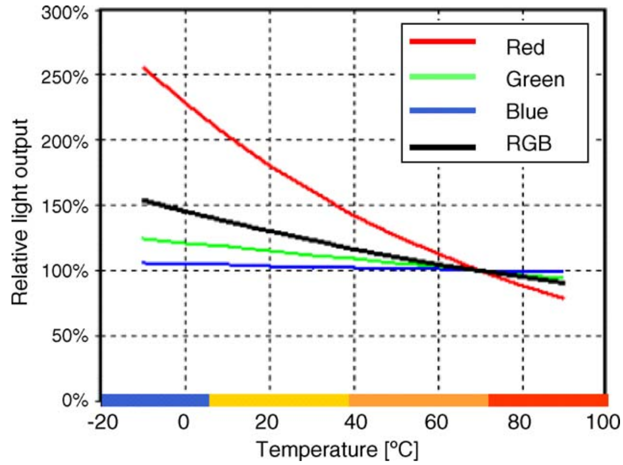

Fig. 1. RGB LED light output swings vs. temperature. This leads to significant color shifts over the life of the products [1].

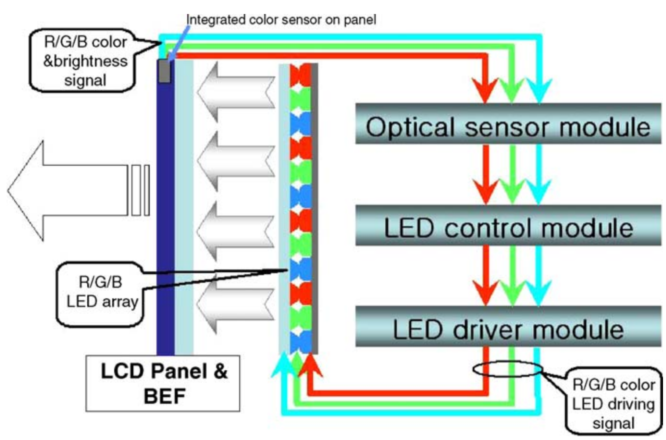

Fig. 2. LED LCD backlight system with optical feedback control system.

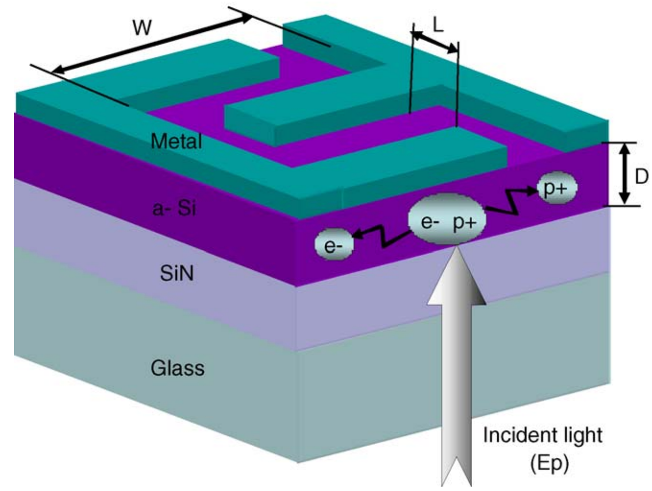

Fig. 4. Photon-induced mobile carrier generation of amorphous silicon optical sensor depend on the intensity of incident light.

point of high photosensitivity in the visible light region, short response time, thermal stability, low processing temperature and high production yield. To prevent the photosensitive TFT properties from adversely affecting the switching characteristics of the LCD, nearly all LCD manufacturers are applying the bottom gate topology, wherein bottom gate metal covers the active region of a-Si:H.

The change in photo-induced mobility for the various light intensities is shown in Fig. 4. Carrier generation depends on the monochromatic photon flow rate (1/cm^2 s) induced from the intensity of light I_L (W/cm^2) to the incident light photon energy E_P (=$h\upsilon$, W s) as shown in Eq. (1) [6]. The incident light energy determines the carrier density of the amorphous silicon optical sensor. For simplification, we could treat electrons as photo-induced carriers. In Eq. (2), photoconductivity (σ) is derived from electron mobility (μ), the electron lifetime

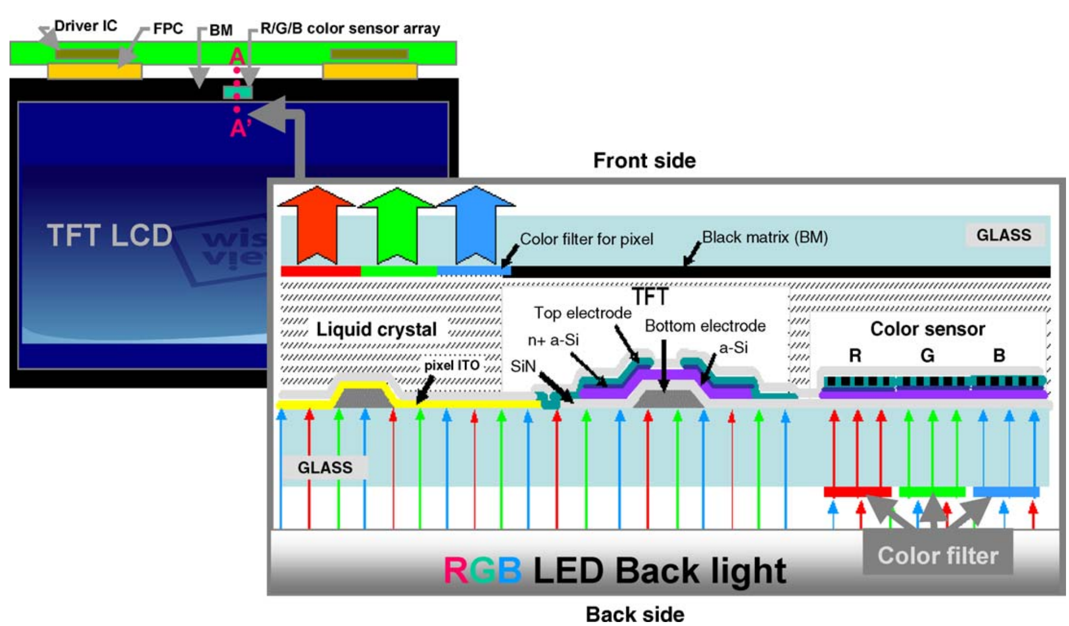

Fig. 3. Amorphous silicon photoconductive color sensor integrated onto LCD panel.