Chromatic and Optical Characteristics of LCD TV

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Abstract

HDTV will be the future TV system. LCD TV, accompanying with the progress of HDTV, rapidly grows up these years. Beside, several technologies and fabricating techniques have greatly enhanced resulting high quality display is easy to achieve. This paper will discuss video decoder, color filter, and backlight which is to know their functions, operating methods, and the chromatic and optical characteristics.

1. Introduction

The development and manufacturing technique have dramatically progressed on conventional flat panel display (FPD) technology these years. Due to these progresses, customer can enjoy high resolution, high color saturation, high color contrast, high brightness, high color purity, high response time, wide viewing angle, low reflective and low production cost products on thin film transistor (TFT)-based liquid crystal display (LCD) monitor and LCD TV. Especially LCD TV, this product has become consumer electronic product since new technologies significantly grow up and improve every year[1]. Beside, high definition TV (HDTV) will become the regular TV system in the near future. All companies in FPD field or related to FPD field have input a lot of force in order to propose better products to the market. Technical and manufacturing companies have investigated manpower and capital on establishing newest facilities and developing newest technology. Brand companies have put a lot of force on designing outstanding appearance to attract users' focus. Hence, companies which step faster than others will have better opportunity to conduct the technology and market[2].

Display quality is the most important factor of LCD TV. It can separate to chromatic and optical characteristics. To attract users' focus, improving chromatic and optical characteristics can enhance display quality which will also increase users' purchasing demand. Inside LCD TV, there are five elements related to chromatic and optical characteristics. These elements are panel, backlight, color filter, video signal processing, and display setting. Figure 1 indicates the relationship between chromatic and optical characteristics, five elements, and customer request on display quality.

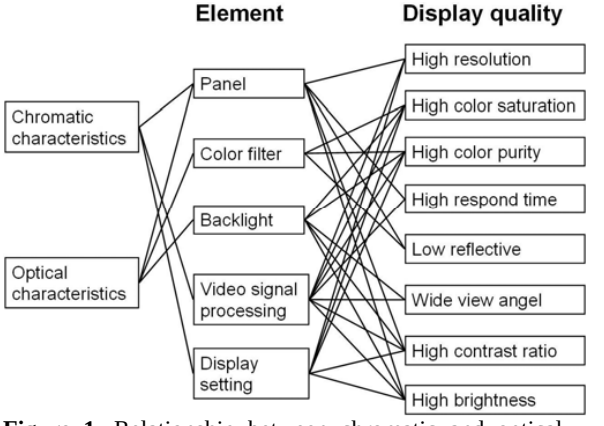


Figure 1. Relationship between chromatic and optical characteristics, 5 elements, and display quality

Referring to Figure 1, any improvement of chromatic and optical characteristics will change the display performance since display quality enhancement is an integrated and complicated technology. Thus, it is necessary to overview improvement target and then micro-view the related elements and components. This article will explain the function of LCD TV and discuss the display performance on LCD TV from different point of views[3].

2. Chromatic Characteristics of LCD TV

Chromatic characteristics are the most important factor dominating the display quality of LCD TV. There are several components which can improve or enhance the chromatic characteristics. Figure 2 is a brief block diagram of TFT-based LCD TV which illustrates the operating function and signal flow inside LCD TV.

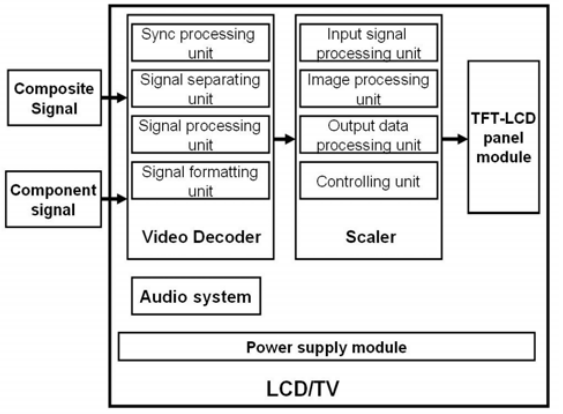


Figure 2. Block diagram of LCD TV

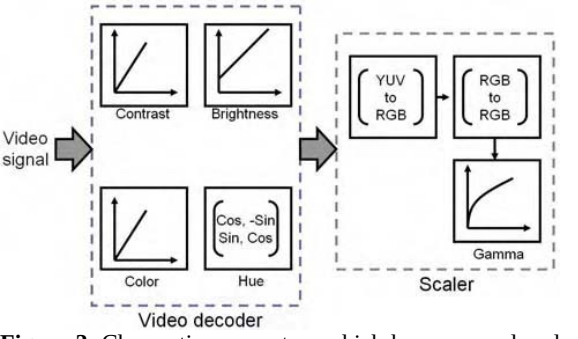


Figure 3. Chromatic parameters which be processed and generated inside video decoder and scaler

Referring to Figure 2, video decoder is the key component to dominate the chromatic characteristics of input video signal. The task of video decoder is to convert composite or component video signal to YCbCr, YUV, or YIQ signal, and then forward to scaler. Inside video decoder, there are four operating units which are sync processing, signal separation, signal processing, and signal formatting unit. When composite signal input to video decoder, sync detection unit will lock the timing which will synchronize clock between input signal and video decoder internal clock. Signal separating unit is to separate the composite signal to Y and C signal by using comb filter. Signal processing unit will process Y signal and demodulate C signal. Signal formatting unit will transfer signals to YUV signal to scaler[4-5]. When YUV signal transmitted to scaler, input signal processing unit will process YUV signal and write to frame buffer. Image processing unit will de-interlace and scale image following by the instruction inside controlling unit. Output data processing unit will convert YUV signal to RGB signal and transmit to TFT-based LCD panel module. Figure 3 is a brief operating explanation described the parameters will be processed and generated in video decoder and scaler. These parameters will be the key factors controlling the chromatic characteristic.

Video decoder is to process and convert the input video signal to YUV signal, so signal separation (Y-C separation) and signal processing (demodulation) unit are the two most important operating units which will affect the display quality. Y-C separation is operating based the sync relationship between subcarrier frequency and horizontal line rate. Basically there are three kind of Y-C separation method by using filter, and these filters include 2D comb filter, 3D comb filter, and traditional bandpass and lowpass filter. Most of video decoders content 2D and 3D comb filter on NTSC system. Since noise will mix with composite signal, before Y-C separation starts to separate Y and C signal, signal detection unit can recognize the video signal and noise by multiple to next horizontal line or frame. When noise can be greatly reduced and video signal can be clearly separated, display quality will raise[6].

3. Optical Characteristics of LCD TV

A good LCD TV will perform real and actual color display with high quality chromatic characteristics. However, if optical devices cannot maximize or optimize the optical characteristics, display quality will be restricted. In LCD TV, backlight and color filter are the essential devices which fabricated by optical technology. Backlight is the light source providing the white light, and color filter, adhesive with three primary color resists, is a penetrated component which allows the light passed through. When the display quality enhancement is requested from optical characteristics, these two devices will be discussed.

3.1 Color filter

The construction of color filter includes a non-alkali glass substrate, a black matrix film, three primary color films, the protrusions or bumps for multi-vertical alignment (rib wall), the photo-spacer, an indium-tin-oxide film, and an overcoat film. The traditional color filter fabricating technique is using spin-coating technology. This technique is easy to implement and fast to manufacture, but since high color saturation and high production yield rate are desired, spin-coating technology is unable to satisfy with these requirements. Beside, the production process of spin-coating technology is complicate which will raise the cost and time. Inkjet printing

technology has become the main color filter fabrication technology these years. This technology is a maturate technology and is widely adopted at office apparatus. Furthermore, color filter implementing with inkjet printing technology can satisfy with the chromatic characteristics on LCD TV. Figure 4 is the color filter block diagram of inkjet printing technology[7].

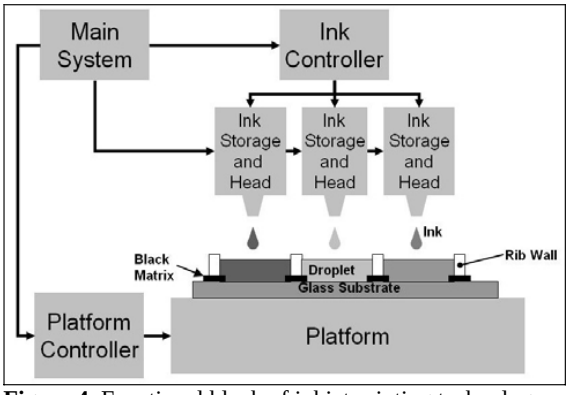


Figure 4. Functional block of inkjet printing technology

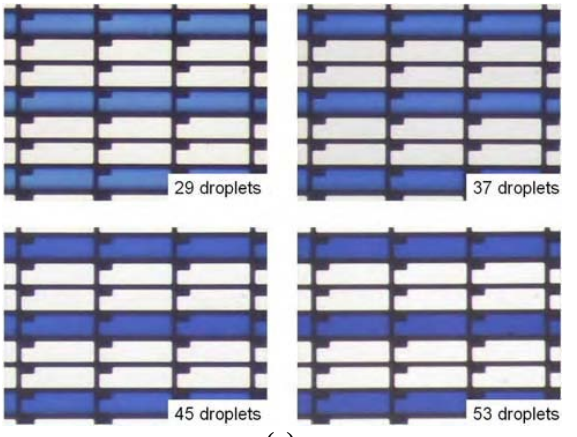
Drop-on-demand technology is widely implemented on ink injecting procedure of inkjet printing technology since pigment dispersion method has used on commercial mass production. Especially for the large size TFT-based color filter fabrication, this technology is providing reliable manufacturing method with better surface characteristics. Referring to Figure 4, the red, blue, and green ink droplets were produced in the orifice of the inkjet head and then injected in the pixel cell. To prevent ink splash symptom and to ensure smooth ink surface, inkjet printing head shall be well controlled, which allows the inkjet printing head directly used to inject the required colorant inks into the separated pixels. Thus, inkjet printing head is the core component in the inkjet printing technology.

Different inkjet droplets will perform different chromatic characteristic. Figure 5(a) indicates different droplets of blue color photo resist injected in the pixel cell. According to Figure 5(a), different droplets will have different chromatic characteristics. Table 1 shows the chromatic characteristic of different droplets corresponding to CIE 1931 coordination. From Table 1 indicates that high quantity droplets will have better chromatic characteristic. However, since color filter is a penetrated component, the thickness of the photo resist will affect the transmitting ratio. Thus, the chromatic characteristic of high quantity ink droplet is better, but the light transmitting ration of high quantity ink droplet will be worse. Optimal quantity of ink droplet will be decided by the expected chromatic characteristic and ink ingredient.

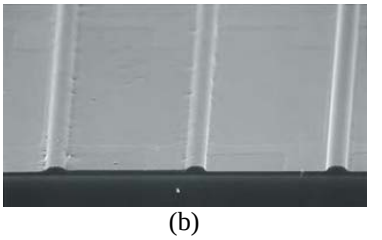
Table 1. CIE 1931 coordination of different droplets

Droplets	x	y	Y	Transmitting rate
29	0.1692	0.1577	18.105	78.3%
37	0.1537	0.1191	11.420	72.7%
45	0.1477	0.0940	7.823	68.1%
53	0.1454	0.0741	5.349	62.6%

Figure 5(b) shows the scanning electron microscopic photographs of blue color nano-particle ink which is injected into the individual pixel cell, under the magnification of 350X. Due to the surface characteristic of photo resist will affect the color filter optical characteristics, this figure can help to observe the surface characteristics and physical adhesive capability.



(a)



(b)

Figure 5 (a) different droplets of blue color photo resist and (b) scanning electron microscopic photographs of blue color ink under the magnification of 350X

3.2 Backlight module

Most of the lighting source of LCD TV

backlight module is using cold cathode fluorescent lamp(CCFL) since CCFL has good characteristics on brightness, uniformity, and optical-electronic transferring rate. However, due to life time and environmental issue are the weaknesses of CCFL, the new LCD backlight module is selecting light emitting diode (LED) as the light source. There are several kinds of LEDs, but only super brightness type can be selected and used on the backlight module. Beside, most of LED can only emit signal wavelength when input steady DC voltage, like red, green or blue LED. To provide stable and uniformity backlight, there are two methods can use, which are RGB mixed type and white LED (WLED)[8].

The RGB mixed method is to use different kind of arrangement to uniformly mix RGB colors. Basically the arrangement can classify to row type and die type. Figure 6 indicated these two types of arrangements.

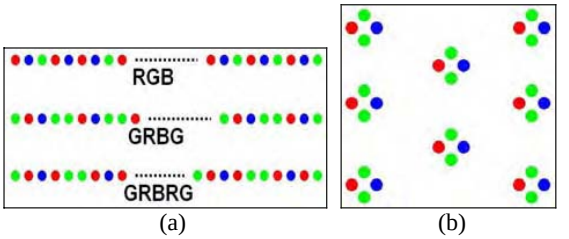


Figure 6. (a) Row type and (b) die type RGB LED arrangement

WLED is developed and become prospered after blue light LED (GaN) technology became prosperously in 1993. It has already used on several small size TFT-based products, like mobile phone, PDA, and so on. Due to cost and heat dispersed issue, WLED backlight is not widely applying on the large size TFT-based product. Since these two issues have been greatly improved, WLED backlight LCD monitor has been developed and will launch to the market soon. WLED will become the main stream of LCD TV backlight.

Basically there are three color mixture methods to generate white light, and these methods are magenta mixed with green, cyan mixed with red, and blue mixed with yellow. These three methods are adopted in WLED manufacturing technique. Especially blue mixed with yellow method, it is widely adopted on several WLED fabricating technique. According to these three methods, there are five WLED manufacturing techniques addressed below[9].

(1) Blue LED and fluorescence composition

Blue (InGaN) LED is the base component covering with yttrium aluminum garnet (YAG, $Y_3Al_5O_{12}$) as fluorescence composition to generate white light. YAG is composed by Y_2O_3, Al_2O_3, Gd_2O_3, Ga_2O_3, and CeO_2. When current surges into blue LED chip, the blue light will be emitted and then evoke YAG to generate yellow-green color light. White color light is mixed by blue and yellow-green color light. Figure 7(a) indicates the structure and wavelength combination.

(2) Group II-VI semiconductor

This technique is to mix blue light and yellow light to be the white light, and this technique was developed by Nichia Chemical. ZnSe, as reflector, is the base lying on ZnSe n-electrode. CdZnSe is emitting layer covering with ZnSe. When current is input, blue light will be emitted from emitting layer. If the blue light goes up, it is still blue light; if blue light goes down, due to photo recycle and reflect skill, the light will become yellow. White light is mixed by blue and yellow color light. Figure 7(b) explains the structure and wavelength combination.

(3) Group III-V semiconductor

This technique combines with color mixture and current adjustment skill to generate white light. Red (AlInGaP), green (GaP), and blue (InGan) LED chip are the color emitter and put in one LED lead frame. To emit each LED chip, current adjustment unit will individually input different current to each LED chip. White light will be generated by mixing three color lights. However, since the life times of three LED chips are different, and circuit design of current adjustment is complex, the cost of this technique is high and the color efficiency is unsatisfied. Thus, this kind of WLED still needs to be improved. Figure 7(c) shows the structure and wavelength combination.

(4) Binary complementary white

This technique is a typical bi-wavelength mixture method by using two LED chips to generate white light. There are two popular mixture methods. The first method is to use blue-green light (InGaN) and amber light (AlInGaP) LED chip to generate white light, and the second method is to use blue light (GaN) and yellow light (GaP). Due to the luminosity of two lights are different, the LED chip quantities will not be the same. For instance in blue-green and amber light method, four LED chips of amber light and two LED chips of blue-green light are the appropriate combination for human lighting system while in reading according to the experiment result.

(5) UV light technique

This technique is similar to blue light LED covering with YAG fluorescence. UV light LED generates blue and yellow light by YAG fluorescence, and then mixes these two lights to be white color light. In UV LED chip, GaN will emit long UV wavelength, and ZnS, ZnO, and AlN will emit short UV wavelength. and fluorescence composition to generate white light. This technology is the same as blue light LED covering YAG fluorescence composition, referring to Figure 7(d), but since the fluorescence is not matured enough, this technique still needs to improve.

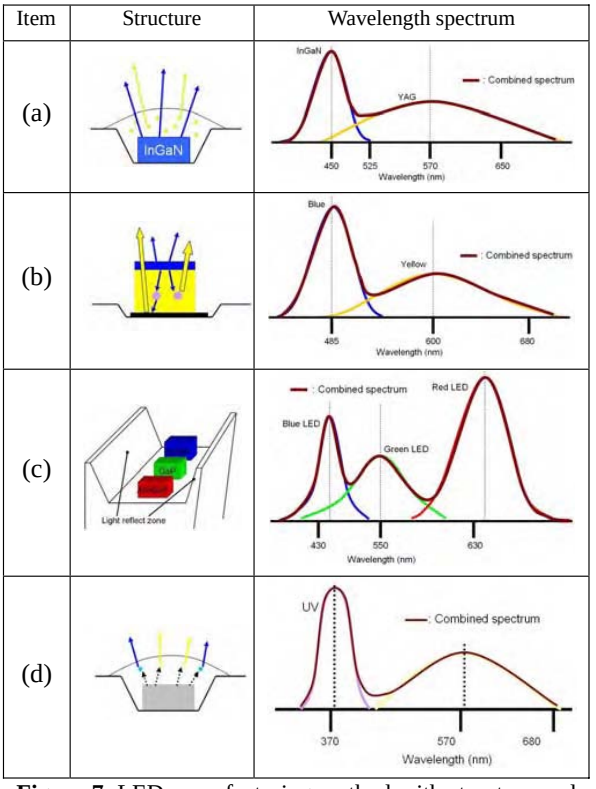


Figure 7. LED manufacturing method with structure and wavelength spectrum

4. Conclusion

The development and technology of LCD TV is prosperously growing up these years. Users can be easy to enjoy high display without pay a lot of expense. Since LCD TV is a complicated and integrated technology, when high quality display is desired, it is necessary to look into chromatic and optical characteristics in component level.

For the chromatic characteristic, we have discussed the operating units of video decoder. The function of video decoder is to process and transfer composite video signal to YUV signal, but it is difficult to recognize the video signal and noise. To enhance chromatic characteristic, considering new and better Y-C separation and demodulation algorithm can improve this issue. For the optical characteristic, we have discussed color filter and backlight. Backlight is the light source of LCD TV. Although CCFL provides uniform and bright white light, lifetime and environment issue are the weaknesses. LED and WLED not only can resolve these two issues, but also can provide better optical characteristic than CCFL. Color filter is a penetrated component adhesive with three primary color resists. This paper introduces inkjet printing technology which will be the main stream fabricating technique. Due to inkjet printing is using drop-on-demand technique, the chromatic/optical characteristics and transmittance ratio can be determined by the different ink droplet and ingredient.

5. Acknowledgement

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