Analysis of Influencing Factors of Gamma in TFT LCD VA Display

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ABSTRACT

In this paper, we have found several important factors affecting gamma through simulation data and experimental comparison . so as to quickly analyze which process is causing gamma shift. And without auto P gamma, how to control the gamma specification within 2.2±0.3 through process control.

1 Introduction

Liquid crystal display (LCD) has been widely used for TV, monitor, notebook, pad and mobile phone due to its good optical performance and low cost [1-3].

The sensitivity of the human eye to changes in the brightness of the display screen is related to the brightness of the screen. The curve of the relationship between the perception of the human eye and the brightness is called the Gamma curve. Generally, when the Gamma is 2.0~2.4, it is in line with the changes in the brightness and grayscale of the human eye. The requirements of the curve relationship, generally Gamma takes the center value of 2.2

There are four types of common LCD display modes: TN (Twist Nematic), VA (Vertical Alignment), IPS (In-Plane Switching), FFS (Fringe Filed Switching).In this article, we mainly do research on VA mode LCD. Through simulation and a large number of experiments, we have found the main factors that affect Gamma in VA mode. Once the product's gamma shifts, we can quickly analyze which process is causing gamma shift. In addition, the specification of Gamma in the actual product is within 2.2±0.3, so we have also studied how to ensure that the final Gamma reaches the specification of 2.2.±0.3 without auto-P Gamma through process control.

2 Simulation

The calculation method of Gamma value commonly used in the industry is as follows (take 8bit 256 gray scale as an example) [4]:

$$\gamma = \log_{\left(\frac{L_n}{255}\right)} \left(\frac{IL_n - IL_0}{IL_{255} - IL_0} \right)$$

γ is Gamma, L_n is the number of nth gray scales (0~255), IL_n is the brightness of gray scale L_n; IL_0 is the brightness of gray scale L_0; IL_{255} is the brightness of gray scale，

$L_{255}T_r = \left(\frac{IL_n - IL_0}{IL_{255} - IL_0} \right)$, T_r is the transmittance of the liquid crystal display.

According to the calculation formula of Gamma, T_r is the main factor that affects Gamma. Therefore, we analyze the influence factor of Gamma from T_r.

$$T_n = t1 * AR * \rho_n * t2 * t3 * \tau_n$$

T_n is the transmittance under the nth gray scale; t1 is the transmittance of the lower polarizer; AR is the aperture ratio, ρ_n is the liquid crystal efficiency; t2 is the transmittance of the color film absorption; t3 is the transmittance of the polarizer; τ_n is a coefficient related to the pretilt angle and related to low gray scale.

$$\rho_n \propto \frac{\sin^2(2\theta)\sin^2\left(\frac{\Delta n d\pi}{\lambda}\right)}{2} * k_n \rho_n$$

θ is LC orientation angle ; Δn is LC optical retardation ; d is Cell gap ; λ is wavelength ; kn is Parameters associated with ITO CD and Δnd

According to the relevant influence factors of Tr, t1, t2, and t3 are mainly determined by the material, AR is determined by the design, and ρ_n and τ_n are mainly affected by the process. Based on this, we mainly analyze the Pretilt angle, Cell gap, and ITO CD. The degree of influence.

We use the controlled variable method to change one of the factor and keep the other factors unchanged to study the relationship between gamma and its correspondence.

We use optical simulation software Expert LCD to simulate.

Considering that the Pretilt angle of LCD VA products ranges from 88° to 89.5° in the actual manufacturing process, Pretilt angle is strongly related to the contrast and response time of products, the specifications of Pretilt angle are different for different products. So we chose 88.5° as the central value; In the actual manufacturing process, the range of Cell gap is 2.9~3.5um, and Cell gap is strongly related to Tr and angle of view of products, different products have different Cell gap specifications, so we choose 3.3um as the center value. ITO CD is related to transmittance and affected by process capacity. Most TV products range from 3.0 to 3.5um, so we choose 3.2um as the central

value.

2.1 The relationship between Pretilt angle and Gamma

When Cell gap =3.3um and ITO CD=3.2um, change the Pretilt angle from 87° and increase the interval by 0.5° to 90°. The simulated curve is shown in Figure 1. Every 0.1° increase in Pretilt angle increases Gamma by 0.023.

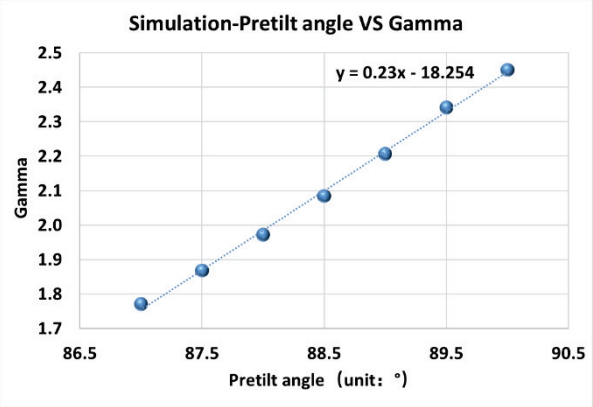

Fig. 1 The relationship between Pretilt angle and Gamma

2.2 The relationship between Cell gap and Gamma

When Pretilt angle =88.5° and ITO CD=3.2um, the Cell gap was changed from 2.9um to 3.7um at an interval of 0.1um.The simulated curve was shown in FIG.2. It was found that the cell gap and Gamma changed linearly. For every 0.1um increase in Cell gap, Gamma decreases by 0.107um.

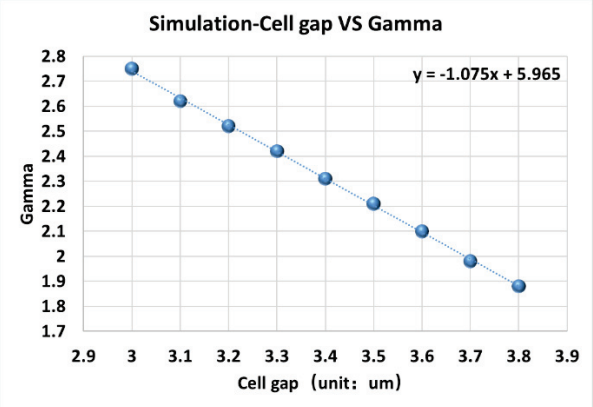

Fig. 2 The relationship between Cell gap and Gamma

2.3 The relationship between ITO CD and Gamma

When Cell gap =3.3um and Pretilt angle =88.5°, change ITO CD from 2.8um to 3.6um with an interval of 0.1um. Observe the change in Gamma, and the simulated curve is shown in Figure 3. We find that ITO CD and Gamma change linearly. For every 0.1um increase in ITO CD, Gamma decreases by 0.06um.

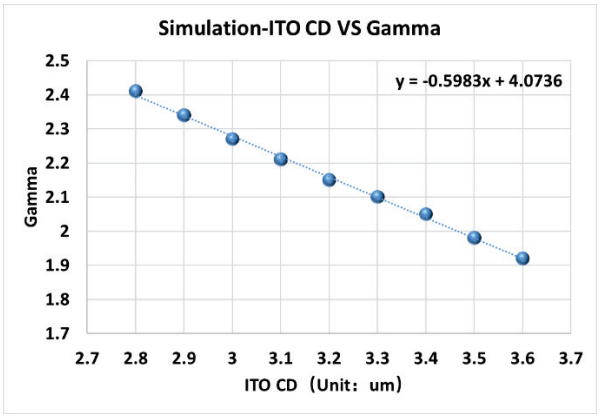

Fig. 3 The relationship between ITO CD and Gamma

3 Experiment

In the above, we simulated the relationship between Gamma and several major factors, but what is their relationship in the real production? Is it the same as the simulation? We take HKC 32 inch TV as the experimental sample and also use the control variable method to study the relationship between them. The experimental conditions are shown in Table1.

Table. 1 Experimental conditions

√: indicates the use of parameters

×: indicates that the parameter is not used

experiment		Pretilt angle	Cell gap	ITO CD
		88°	3.5um	3.13um
Pretilt angle	89°	×	√	√
	87°	×	√	√
Cell gap	3.6um	√	×	√
	3.4um	√	×	√
ITO CD	3.53um	√	√	×
	2.73um	√	√	×

In Table 1, we take the specification values of the actual products as the central condition, and take the upper and lower limits of the process capacity as the limit experimental conditions to study their relationship with Gamma.

3.1 The relationship between Pretilt angle and Gamma

Control Cell gap is 3.5um, ITO CD is 3.13um, Control Cell gap is 3.5um, ITO CD is 3.13um, and ensure that the Array in the production process, CF, other parameters of the Cell manufacturing section were consistent, Pretilt angle center specification value was 88°, and the upper and lower limits of the manufacturing process specification were 88°±1°. We found that the

Pretilt angle and Gamma changed linearly, consistent with the trend of simulation, as shown in FIG. 4. When the Pretilt angle increases, the Gamma increases as well, but each 0.1° increase in Pretilt angle increases the Gamma by about 0.05, which is larger than the simulated effect.

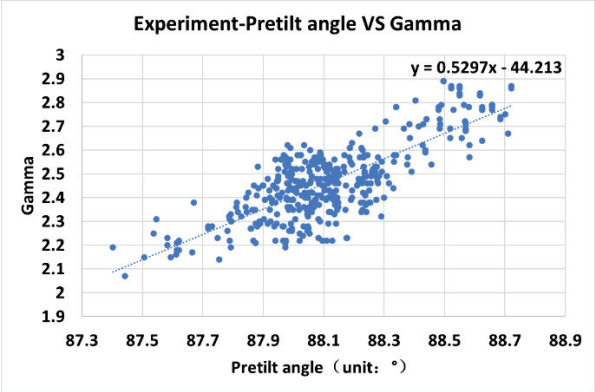

Fig. 4 The relationship between Pretilt angle and Gamma

3.2 The relationship between Cell gap and Gamma

Control Pretilt Angle to 88°, ITO CD to 3.13um, and ensure that other parameters of Array, CF and Cell process are consistent, Cell gap center specification value is 3.5um, and the upper and lower limits of the process specification are 3.5±0.7um. As shown in Figure 5, Gamma decreases when cell gap increases. For every 0.1um increase in Cell Gap, the Gamma decreases by 0.1. The calculated results are in good agreement with the simulation results.

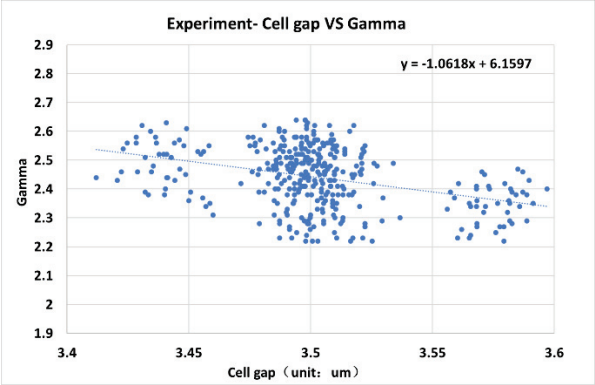

Fig. 5 The relationship between Cell gap and Gamma

3.3 The relationship between ITO CD and Gamma

Control Pretilt angle to 88°, Cell gap to 3.5um, and ensure that other parameters of Array, CF, and Cell are consistent in the production process, ITO CD center specification value is 3.13um, and the upper and lower limits of the production process specification are 3.13±0.4um. consistent with the trend of simulation. As shown in FIG 6, when ITO CD increased by 0.1um, Gamma decreased by about 0.04, but the influence value was smaller than that of simulation.

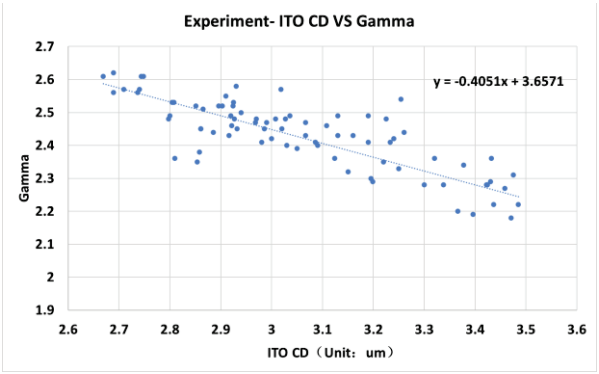

Fig. 6 The relationship between ITO CD and Gamma

4 Conclusions

The influence tend of Pretilt angle, Cell Gap and ITO CD on Gamma was the same in both simulation and experiment. Based on the actual experiment, Pretilt angle has the largest impact on Gamma, followed by Cell gap and ITO CD. According to the experimental results, after data fitting, it was found that Pretilt angle increased by 1° and Gamma increased by 0.5. When Cell gap increased by 0.1um, Gamma decreased by 0.1, and when ITO CD increased by 0.1um, Gamma decreased by 0.04.

In addition, according to the results of this experiment, in the absence of Auto Pgamma and combined with the process capability, we can develop the process specification of Gamma2.2±0.3 by controlling the process specification of these major impact factors, and control the Pretilt angle within target±0.5° ,Cell gap was controlled within target±0.1um, ITO CD was controlled within Target ±0.4um. Pretilt angle, Cell gap, ITO CD target values will affect the optical specifications, so the specific product depends on the situation.

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