Analysis and improvement of the "red/blue spot" of TFT-LCD

Yuanyuan Li[1,2], *Xu* Zhang[1,2], *Jianming* Wang[1], *Huasheng* Yan[2], and *Zaijun* Cheng[1,*]

[1]School of Opto-electronic and Communication Engineering, Xiamen University of Technology, Xiamen 361024, China
[2]Consumer Quality Department of Tianma Microelectronics Co., Ltd, Fujian Xiamen 361000, China

Abstract. "Red/blue spot" is a common undesirable phenomenon in small and medium-sized TFT-LCD products, which directly affects the display quality of the product. It has always been a difficult problem in the display industry, which greatly reduces the market competitiveness of corresponding products. In this work, pressure tests are carried out on liquid crystal panels with different sizes and resolutions. The effects of different factors such as the flatness of the photo space, the distribution density of the spacers, and the glass thickness on the "red/blue spot" are compared. By increasing the flatness of the PS station, the septum distribution density, and the thickness of the glass, the sample's anti-extrusion ability can be increased by 46.1%, 30%, and 23.1%, respectively. The experimental results can provide the basis for industry to further improve quality of products.

1 Introduction

With the rapid development of science and technology, thin film transistor liquid crystal display (TFT-LCD) has gradually replaced traditional displays with its many advantages such as low power consumption, high image quality and light weight[1-2]. Various LCD panel companies focus on improving the display quality of their products[3]. Among them, "red/blue spots", as one of the many common poor picture quality in the display industry, has received extensive attention from researchers.

In the manufacturing process of the LCD panel, in order to ensure the uniformity and stability of the cell thickness of the liquid crystal cell, the photo spacer (PS) between the color film (CF) substrate and the TFT array substrate plays an irreplaceable role[4-5]. The PS prepared in the liquid crystal display can better control the uniformity of the cell thickness to prevent related display defects.

The main reason for the occurrence of "red/blue spots" is that when the LCD panel is subjected to an unbearable external force, the PS in the box scratch the alignment film and cause light leakage. The influencing factors include the design of the flatness of the PS station, the distribution of main/supplement (M/S) PS, and the glass thickness. This work compares the pressure test results of different LCD panels, explores the influence of different factors on the "red/blue spots", and proposes a solution to the "red/blue spots".

* Corresponding author: 2011111002@xmut.edu.cn

 https://doi.org/10.1051/e3sconf/202130001017

2 Stress test methods and the mechanism of "red/blue spots"

2.1 Stress test method

The experiment test uses a universal tester (Shimadzu, AG-X plus5kN/1kN, 1N~4800N/980N). The outer packaging of the sample should be removed before test, and the tester will inspect the appearance and electro-display effect of the sample.

Installation of indenter and jig: Choose a rubber indenter with a pressure rod Φ 10 mm and an indenter Φ 15 mm ball head. The fixture platform requires a flat stage with a hollow center and a diameter of 30 mm. As shown in **Fig. 1(a)**, the pressure gauge is vertically and positively pressed against the center of the liquid crystal panel.

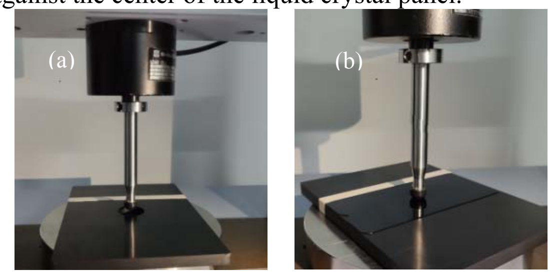

Fig. 1. (a) PS fixture test point; (b) Sample fixing method.

Sample fixation: As shown in **Fig. 1(b)**, the sample is placed on the stage with the CF side facing up and the indenter to the center of the sample.

Test conditions: The descending speed of the pressure rod is 5 mm/min, the force value starts from 0.5 kgf, and the dwell time is 5s each time. After each test, remove the sample from the fixture and check if there is any "red/blue spot". If yes, record the force value as the critical force value of the sample; if not, increase by 0.1kgf until it appears.

2.2 "Red/Blue Spots" Phenomenon

The picture in **Fig. 2(a)** shows the macroscopic phenomenon of red spot, and **(b)** shows the microscopic phenomenon of it. Put the squeezed sample on the fixture that has been lit, and red spots can be observed when the screen is switched to the dark state. Under the microscope it can be seen that small colored bright spots are close to the black matrix.

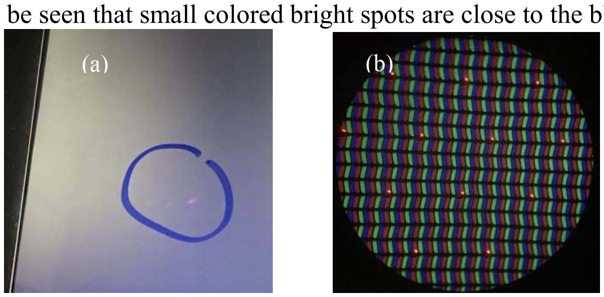

Fig. 2. (a) Macro picture of Red spot; (b) Micro picture of Red spot.

2.3 Analysis of the mechanism of "red/blue spots"

Photo spacers are used in the manufacture of liquid crystal panels to largely control the cell thickness of the liquid crystal panel and to further control the display quality of the liquid crystal panel[6-7]. When the liquid crystal panel is subjected to an external force, the spacer is compressed, and if the external force is removed within its elastic recovery limit, it will return to its original state. If the external force exceeds the elastic recovery limit, the PS will scratch the alignment film in the light-transmitting area on the TFT array substrate, and then lose the liquid crystal alignment ability[8-9]. Due to people's demand for high-resolution products, the width of the black matrix will be designed to be smaller as required, so the position of the scratched alignment film cannot be blocked, and colored spots will be observed under the black screen[10].

In order to ensure a better display effect of the LCD screen, the PS will be designed on the blue and red pixel units after comprehensive consideration of the test. If the PS position of the red pixel unit scratches the alignment film, it will appear red spots, and if the alignment film at the PS position of the blue pixel unit is scratched, blue spots will appear.

3 Experimental results and discussion

The above-mentioned stress tests were carried out for liquid crystal panels of different designs, and the influence of PS station flatness design, PS distribution density and glass thickness design on the adverse effects of "red/blue spots" on the sample were analyzed. **Fig. 3** is a schematic diagram of the stress test experiment.

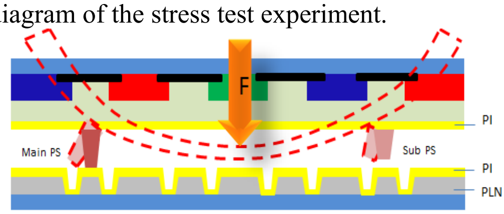

Fig. 3. Schematic diagram of PS extrusion test.

3.1 The impact of PS station position flatness (PLN) on "red/blue spots"

Fig. 4 shows the SEM images of the flatness of the PS station position of different schemes. From top to bottom, the PS station flatness of plan A is the best, the PS flatness design of plan B is second, and the PS design of plan C has no flatness. Since the PS station positions of the three schemes are the same, the schematic diagram of the PS station position is marked in scheme B in the figure.

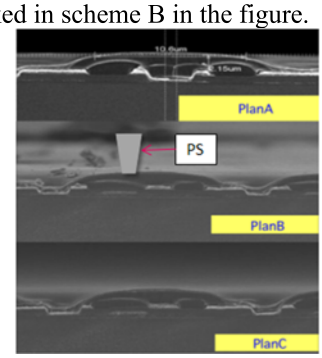

Fig. 4. SEM images of the flatness design of different PS stations.

Table 1. PS anti-extrusion force during flatness design of different PS stations.

condition	flatness	angle	PS Fight pressure
Plan A	10.8	50.37	1.4kgf
Plan B	9.8	43.17	1.1kgf
Plan C	8.6	39.51	0.8kgf

Experimental test the size of the anti-extrusion force of different PS station flatness, and the experimental results are shown in **Table 1**. The flatness design of plan A is 10.8, and the PS anti-extrusion force measured by the experiment is 1.4 kgf. The plan C is designed without any flatness, and the experimental PS anti-extrusion force is 0.8 kgf, which shows that the flattening of PLN can make PS anti-extrusion force increased by 46.1%.

3.2 The influence of PS distribution density on "red/blue spots"

As shown in **Table 2**, this work uses experiments to verify the relationship between the different M/S PS distribution densities (um^2/mm^2) of different products and the maximum force that the product can withstand without red/blue spots. It can be seen from **Table 2** that as the support density of the septum increases, the PS compression resistance increases by 30%. This shows that when the PS density is increased, the probability of "red/blue spots" will decrease under the same pressure value.

Table 2. The experimental values of PS density and compression force of each sample.

sample name	(M/S)PS density(%)	PS **Fight pressure**(kgf)
A1	0.083/2.56	1.3
A2	0.085/2.62	1.4
A3	0.088/2.66	1.5
A4	0.09/2.94	1.5
A5	0.082/3.05	1.6
A6	0.083/3.506	1.6

Increasing the PS density can effectively improve the "red/blue spots", but with the increase PS, the probability of the appearance of low-temperature bubbles also increases[11]. Under the action of external force, the excessive density of the PS will make the fluidity of the liquid crystal worse, resulting in the phenomenon of vacuum bubbles.

3.3 The influence of glass thickness on "red/blue spots"

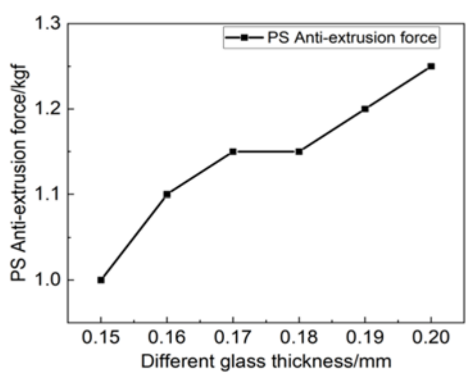

Fig. 5. The maximum pressure value of the "red/blue spots" non-appear in different glass thicknesses.

In order to meet the current market demand for smart wearable products, small-size LCD panels need to be thinner and lighter without affecting the display. At present, the thinning of TFT-LCD mainly uses thinning technology (Slimming)[12], and major panel manufacturers can reduce the thickness of the box to 0.15 mm or 0.20 mm. As shown in **Fig. 5**, the squeezing force value with the glass thickness of 0.15 mm and 0.2 mm is 1kgf and 1.3 kgf, respectively. The PS squeezing force value has increased by 23.1%, indicating that as the glass thickness increases , PS anti-extrusion ability is improved.

4 Plan to improve "red/blue spots"

According to the above experiments and analysis, it is known that the effective method to improve the red/blue spots is to increase the flatness design of the PS station, the PS distribution density, and the thickness of the glass. When the box is vacuumed, it is necessary to consider the offset of the box, the size of the PS and the position accuracy of the PS. The flatter the PLN, the greater the compression resistance of PS. On black screen, the probability of "red/blue spots" appearing is smaller. For TFT-LCD products with high resolution and high transmittance, it is necessary to reasonably increase the density of spacers on the color film substrate without reducing the aperture ratio and low-temperature bubbles. The current demand for lightness and thinness of small-sized products requires an appropriate increase in the thickness of the glass on the basis of relatively lightness and thinness, so as to resist the destructive force of external forces on the liquid crystal panel.

5 Conclusion

In conclusion, when the LCD panel is subjected to an irresistible pressure, the PS scratch the alignment film on the TFT array substrate, making it impossible to align the liquid crystal normally. Therefore, the phenomenon of "red/blue spots" can be observed under a black screen, while under a microscope it is a colored bright spot. According to the experimental results, with improving the flatness of the PS station, increasing the spacer distribution density and the thickness of the glass, the anti-extrusion ability of the sample can be increased by 46.1%, 30% and 23.1%, respectively. This work expounds the influencing factors of the "red/blue spot" phenomenon of the LCD panel under the action of pressure and proposes improvement plans to provide help for the improvement of the products' quality.

Acknowledgments

This research was supported by Natural Science Youth Innovation Fundation of Xiamen City (Grant No.3502Z20206077), the Scientific Research Climbing Project Foundation of Xiamen University of Technology (Grant No.XPDKT20011) and Postgraduate Science and Technology Innovation Project Fund of Xiamen University of Technology (Grant Nos. YKJCX2019062 and YKJCX2019071).

References

1. Q G.Ma.Electronic Industry Press.**90-92,418-419**(2011)
2. ZH Y.SHEN, CH Y.Dong.Publishing House of Electronics Industry. **222-227**(2012)
3. Y.AI,L P.LIU,J D.ZHOU. Liquid crystal and display.**02**(2015)
4. H ZHOU.Shanghai Jiaotong University.(2014)
5. S. LU, J G.LU,J.ZHU. Shanghai Jiaotong University.**04**(2015)
6. C Q. CHEN .South China University of Technology.(2017)
7. X J.LI ,Y L.ZHAO ,P.LI.LCD and display.**07**(2017)
8. Y CH.WANG ,ZH.LI ,R.LI .Modern Display, **20(06): 25-28**(2009)
9. W CH. CHEN ,Q.LING ,Q.JIANG .Electronic world.**16**(2019)
10. ZH.CHEN ,H.LI ,X.CHEN.Application of Electronic Technology.**37(06): 123-126**(2011)
11. SH.CHENG ,T.WANG ,M.ZHANG.LCD and display.**05**(2011)
12. Y G.FAN ,J P.LI ,S X.SONG.2014 China Flat Panel Display Conference. (2014)