# Super High Contrast Ratio of TN mode TFT- LCD by Taguchi Design

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## Abstract

*A new high contrast LCD structure for TN mode T FT-LCD, of which the contrast ratio is 1.2 times hi gher than that of the conventional one, has been de veloped. The contrast ratio of TFT-LCD display can be improved by some modified materials, which like as polarizer, liquid crystal, color filter and light enhancem ent film. In order to know which condition can get the major contribution for the upgrade of the contrast ratio, we used Taguchi method and analyzed the contribution ratio for each composition and succeed to build up the formula of contrast ratio. From this study, we could achieve the highest CR value as 1200:1 of TN mod e TFT-LCD nowadays.*

## 1. Introduction

Recently, high-quality and large size TFT-LCD display have been developed speedily. Therefore, there are some important optical properties such as viewing angle, MPRT, color shift, contrast ratio would be reconsider how to improve. [1]

The contrast ratio means white value divides by black value, so how to reduce the light leakage in black level is a crucial and important issue.

In order to reduce the light leakage in dark status or increase the luminance in bright level, it is necessary to choose some materials or novel pixel structure designs to prevent the light leakage by modifying polarizer, CF, LC and light enhancement film.

In order to figure out the optimum composition of materials and pixel design, we tried to use Taguchi method and found out the contribution ratio for each composition.

In this paper, our study that is by using Taguchi metho ds not only provided the robust design but also pointe d out the contribution factors of each composition.

## 2. Theoretical Model

### 2.1 The application of polarizer

As we know, the Rth and Alignment angle of polarizer are the important parameters to control the view angle and contrast ratio.

Fig. 1 shows the standard TN mode compensation film structure that is WV model by Fujifilm. In this film, the compensation theory is by using hybrid discotic LC to compensate the dark level of TN mode TFT-LCD. So the Rth value and alignment angle is very important to match different retardation design and pretilt angle by different panel maker. It is necessary to find out the optimum Rth and alignment angle value to get the higher contrast ratio by compensating cell condition well.

Fig.2 shows not only Rth and alignment angle could improve the contrast ratio of polarizer but the truly black polarizer also could achieve this requirement. The one of the methods is to improve the PVA material. The new PVA material could make the I-ion alignment well like as fig. 3. That could increase the polarization efficiency to reduce the light leakage of black state.

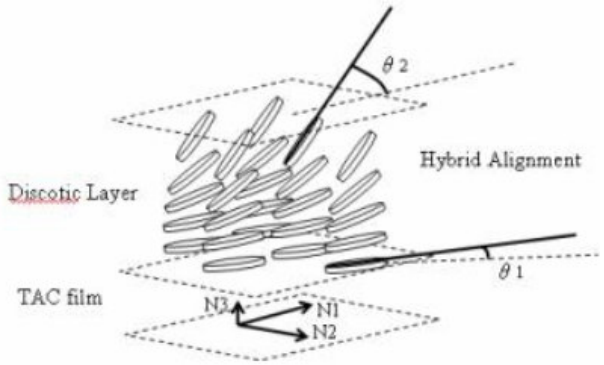



**Fig. 1. The Rth and Alignment angle of polarizer**

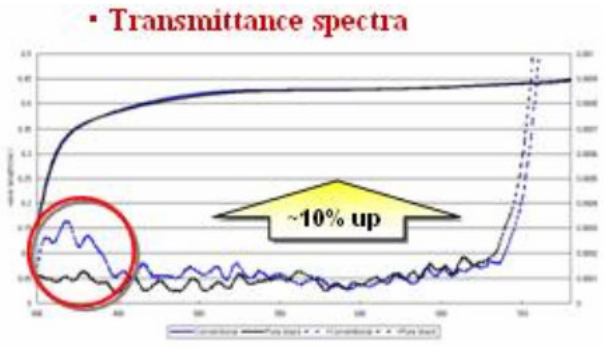



**Fig. 2. The comparison of normal polarizer and truly black polarizer**

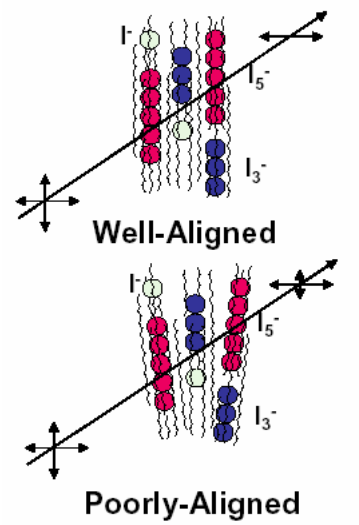



**Fig. 3. New PVA alignment condition**

### 2.2 Reduced Thickness of Black Matrix

The thickness of overlap between black matrix and color layer will affect the alignment of liquid crystal liked as fig. 4. This will cause weakly rubbing and increase the light leakage on pixel's edge. To reduce the weakly rubbing phenomenon, we chose the high optical density black matrix. This high OD BM could reduce the thickness that also could keep high OD value [2].

### 2.3 High contrast ratio of CF

The aggregation and coarse particle size dispersion will cause serious de-polarization when the light across through the CF in the dark status. Light scattering caused by a pigment of CF is thought of as one of the major factors [3, 4]. Then in order to reduce the light scattering, it is necessary to decrease not only the size of primary particles that are obtained by finely dividing pigments, but also the size of secondary particles that are dependent on the dispersion condition shown as fig. 5.. So, the uniform and fine particle size dispersion are essential to achieve reduced light scattering.

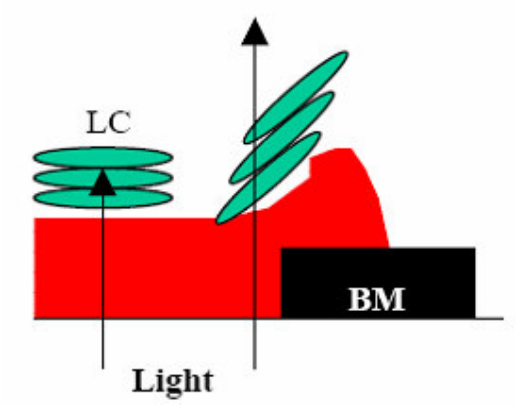



**Fig. 4 Weakly rubbing of LC alignment**


**Fig. 5 The comparison of the uniform and aggregation**

### 2.4 LC Delta nd Modification

As the section 2.1 mentioned, for higher contrast ratio, we need to optimize the Rth and alignment angle of polarizer. So we also need to optimize the retardation of cell condition.

Another one thinking, the variable delta nd of LC will change the luminance .It means we can upgrade the contrast ratio in the bright status by increasing the delta nd.

### 2.5 The Apply of Light Enhancement Film

Light enhancement films usually use to enhance the total efficiently of backlight in the center of panel. Fig.6 shown the brightness gain of the center of panel has 2 times upgrade when we changed the normal film to BEF film. In our experience, the BEF film will increase the contrast ratio by upgrading the center brightness.

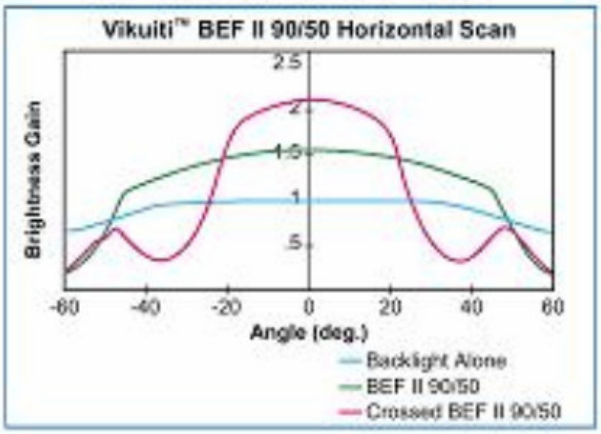
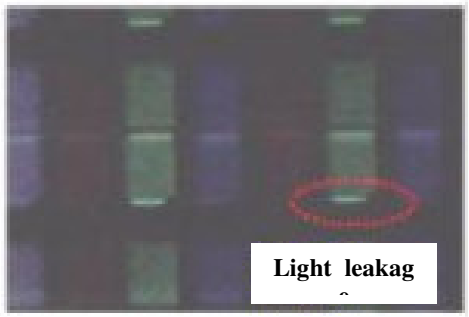


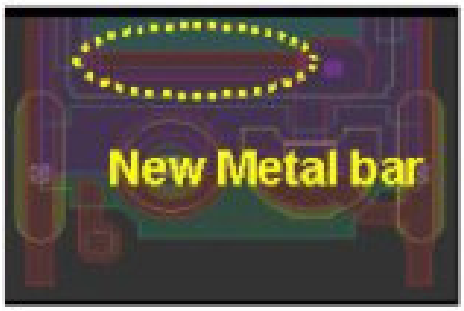

**Fig. 6.**
**the comparision for different light recycling film**

### 2.6 The Novel Pixel Design

Fig.7 (a) shows the light leakage of reverse domain be caused by rubbing condition. This light leakage phenomenon will cause the CR decreasing dramatically. In order to avoid the light leakage issue, we introduce a novel pixel design structure that add the new metal bar in TFT side to block the light leakage area shown as fig. 7 (b).




**(a)**




**(b)**
**Fig 7. Dark level light leakage**

## 3. EXPERIMENT AND DISCUSSION

Taguchi method is the best way by using the orthogonal arrays and S/N( signal-to Noise) ratio to find out the contribution of each composition. We setup a L8 orthogonal arrays with 5 kinds of controllable factors and 2 kinds of noise factors for our experiment to get the analysis data. First of all, table 1 shows there was 5 kinds of variable including polarizer alignment angle, polarizer Rth, LC delta-nd ,BM thickness and light enhancement film as the control factors ,also defined the new array design and high contrast ratio CF as the noise factors.

**Table 1. The orthogonal Array of experiment table for high contrast ratio**

| No. | Variables | Levels | Level setting |
|---|---|---|---|
| 1 | POLWCF Rth | 2 | A,B |
| 2 | POLWCF AA | 2 | A,B |
| 3 | BM Thickness | 2 | A,B |
| 4 | LC delta nd | 2 | A,B |
| 5 | BEF | 2 | A,B |
| 6 | Array bar design | 1 | A |
| 7 | High CR CF | 1 | A |

The second, as shown in table 2, the analysis result was calculated by minitab. The S/N ratio and means data show the sequence of contribute BM, BEF(light enhancement film), WV AA, WV Rth and LC delta-nd. This calculation result represent that a major contribution to high CR is the thickness of BM.

**Table 2. The Response Table for S/N ratios and Means**

Response Table for Signal to Noise Ratios
Larger is better

| Level | WV Rth | WV AA | Delta nd | BM | BEF |
|---|---|---|---|---|---|
| 1 | 60.48 | 60.24 | 60.36 | 60.95 | 60.07 |
| 2 | 60.25 | 60.49 | 60.37 | 59.78 | 60.66 |
| Delta | 0.23 | 0.25 | 0.01 | 1.18 | 0.59 |
| Rank | 4 | 3 | 5 | 1 | 2 |

Response Table for Means

| Level | WV Rth | WV AA | Delta nd | BM | BEF |
|---|---|---|---|---|---|
| 1 | 1064.2 | 1031.0 | 1044.4 | 1119.2 | 1010.2 |
| 2 | 1031.3 | 1064.5 | 1051.1 | 976.3 | 1085.3 |
| Delta | 32.9 | 33.5 | 6.7 | 142.8 | 75.1 |
| Rank | 4 | 3 | 5 | 1 | 2 |

Finally, we could find out the relationship of formula of contrast ratio by using POE tolerance analysis spread sheet as equation 1.

**CR=2718.32 - 8.23 * Rth + 67 * AA +**
**0.34 * Delta nd- 476.08 * BM + 75.1 * BM** ..(1)

By using the Taguchi method, we could find out the relationship between CR and materials and design parameter. So we could use the equation to predict the optimum CR value of our design. Table 3 shows the factor levels setting for optimum CR predictions. From this table, we could see the optimum CR value that is 1193.26. Our actual measurement data is 1219.2. From these data, we could say our study and prediction is reliable and accuracy. Otherwise, our panel could achieve CR 1200:1 that is the highest value of TN mode TFT-LCD nowadays.

**Table 3. Factor levels for optimum CR predictions**

Predicted values

| S/N Ratio | Mean | StDev | Log(StDev) |
|---|---|---|---|
| 61.4965 | 1193.26 | 51.8486 | 4.00409 |

## 4. Conclusion

In order to attain high contrast ratio, it's necessary to realize how to reduce the light leakage in the dark state or enhance luminance in the bright state by modifying polarizer, CF, LC and light enhancement film. Taguchi method not only provided the robust design but also pointed out the contribution factors of each composition. We have used the Taguchi methods to build up the optimum formula of contrast ratio successfully.

## 5. Acknowledgements

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## 6. References

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