# A Superior Optical Performance of advanced S-IPS LCDs with Fine Pitch Electrode and Robust Design

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## Abstract

*We have studied on optical properties of advanced S-IPS with a fine pitch electrode and a new finger design. Transmittance of panel increases with decreasing of width and angle of finger electrode. In order to improve transmittance, fine pitch electrode of ~2㎛ and rubbing angle of 10 degree have been adopted. Various optical performances are defined as the function of finger design and field intensify across the IPS pixel electrodes. We have developed the advanced electrode structures with a high performance. As a result, the optical properties of 42" full HD with 120Hz frequency shows high transmittance over 5%, contrast ratio of 1800:1, gray-to-gray response time of 5.5ms, respectively. And also we have studied that the moving picture quality of IPS LCD is related with design parameters of IPS cells and finger shape.*

## 1. Introduction

Liquid crystal displays have been used widely for applications such as monitors, TVs, and mobile phone display. In particular, S-IPS mode and multi-domain VA mode are used mainly in LCD TVs[1-2]. Multi-domain VA mode has a vertical alignment at dark state. Electric field applying electrodes are located on top and bottom is rotated liquid crystals [3]. However, in S-IPS mode, the liquid crystals are aligned horizontally at the initial state. Applying electric field between two electrodes which are arranged horizontally rotates LC (liquid crystals) [4]. And so, the performances of S-IPS are characterized by cell gap and electrode designs such as distance, width and angle [5].

In this paper, we have studied the electro-optic properties of advanced S-IPS applying by a fine pitch pixel electrode and a rubbing angle. Our study shows decrement of pixel electrode width increases transmittance. Though transmittance efficiency from edge of electrodes is decrease, but the whole aperture area extends. And decrement of rubbing angle improves the transmittance because of increase of transmission efficiency at electrode edge. The contrast ratio of advanced S-IPS increases with improvement of transmittance because of the black luminance in dark states is not changed by a variation of fine pixel electrodes and rubbing angles. And also, primary color shift $\Delta u'v'$ in motion picture with a moving speed of 2ppf~12ppf is improved from 0.015 to 0.01 by rubbing angle of 10 degree.

## 2. Properties of electrode and rubbing angle

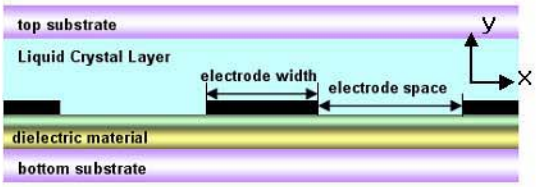
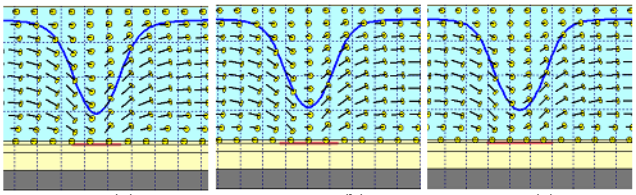



**Fig. 1. The cross sectional structure of S-IPS**

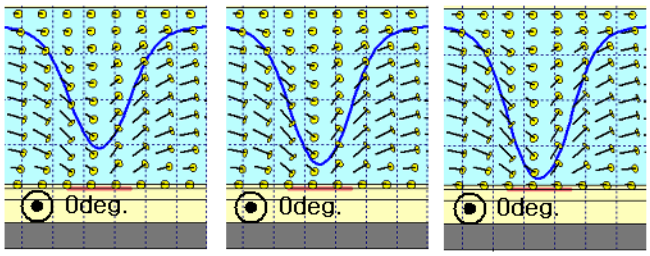
In S-IPS mode, electrodes arrange horizontally above dielectric material layer. The electrodes are arranged in the interval as shown in Figure 1. When the electrode distance was fixed, electrode width is changed from 2.0㎛ to 3.0㎛ with at interval of 0.5um. Figure 2 shows that LC directors tilt more rapidly according to decrement of electrode width. And so, the transmission efficiency is reduced above electrodes. Electrode space increases according to

decrement of electrode width with opaque metal and lower angle. And aperture ratio of advanced S-IPS increases with increasing of electrode distance. As a result, the transmittance via the whole area is increased by the reduction of electrode width with metal. As rubbing angle is reduced, LC directors are tilted rapidly at electrode corner as shown in Figure 3. And so, the transmittance is increased due to a rise of transmission efficiency.



(a) (b) (c)

**Fig. 2. LC director profile on electrode with applied voltage (a) electrode width=2.0μm (b) electrode width=2.5μm (c) electrode width= 3.0μm**




(a) (b) (c)

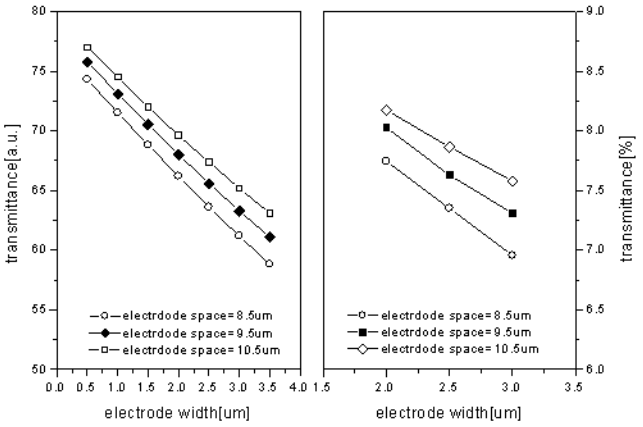
**Fig. 3. LC director profile on electrode with applied voltage (a) rubbing angle= 10deg. (b) rubbing angle= 15deg. (c) rubbing angle= 20deg.**

## 3. Results and discussion

To calculate transmittance, we have performed using LCD master ('Shintech') applied 2×2 Jones matrix. We have simulated optical properties of advanced S-IPS when the electrode width, the electrode space and rubbing angles are varied from 0.5μm to 3.5μm, from 8.5μm to 10.5μm and from 10° to 20°, respectively. And we have made samples to examine properties of electrode width and rubbing angle. Width of electrode is from 2.0μm to 3.0μm at interval of 0.5μm. Rubbing angle is from 10° to 20° at interval of 5°. Conditions which is cell gap, used liquid crystal etc. is identity.

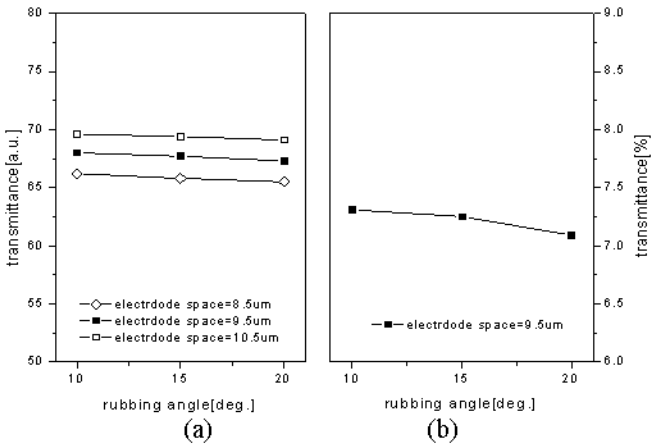
Figure 4 shows the relationship between electrode width and transmittance. When the electrode space is fixed, the decrement of electrode width causes the increase of the transmittance from simulation result and measurement result. When electrode width is reduced from 3.0μm to 2.0μm, transmittance of simulation result is up to 7.4% and measurement result is 9.8% at electrode space 9.5μm. As the electrode space increases, transmittance increases on account of expansion of aperture ratio. For this reason, reduction of electrode width expends to the degree of freedom of design.

Figure 5 shows the dependence of the rubbing angle for transmittance. Although decrement of rubbing angle is not increased aperture ratio, but transmittance improves 1.0% from 20° to 10° from simulation result because of efficiency increase at the electrode edge. Also transmittance from measurement result is up to 3.1%. Figure 6 shows decrement of electrode width from 3μm to 2μm is increased operating voltage about ~6.5% from simulation result at distance space 9.5μm. And measurement result is about ~10.1%.




(a) (b)

**Fig. 4. Electrode width vs transmittance (a) simulation result (b) measurement result**




(a) (b)

**Fig. 5. Rubbing angle vs Transmittance (a) simulation result (b) measurement result**

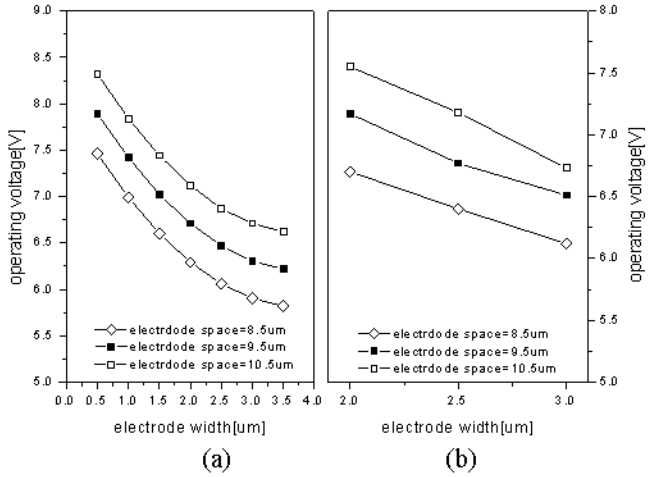



**Fig. 6. Electrode width vs operating voltage (a) simulation result (b) measurement result**

When fine pitch electrode and electrode space are fixed, the relationship between rubbing angle and contrast ratio as shown in Figure 7. Contrast ratio is increased about ~7% by decrement of rubbing angle from 20 ° to 10°. At dark state black transmittance is uniform because of arrangement of LC director to rubbing direction. On the other hand, white luminance is increased by rising of transmission efficiency and improving of contrast ratio.

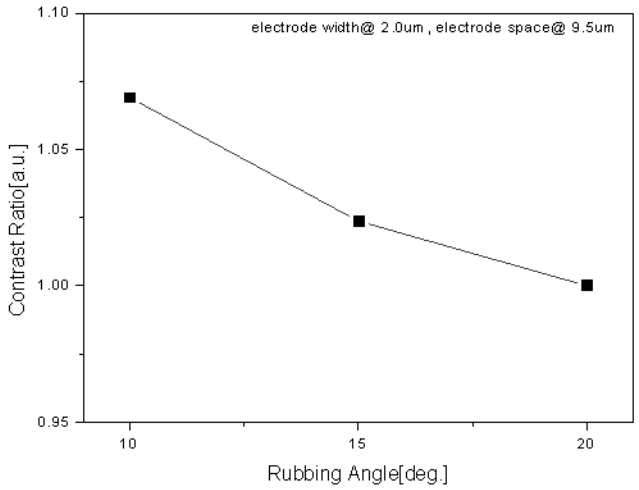



**Fig. 7. Relationship with rubbing angle and contrast ratio when electrode width=2.0um and electrode space=9.5um**

We have made FHD 120Hz 42" proto samples by advanced S-IPS with new pixel design of fine finger electrode of ~2μm and rubbing angle 10 degree. The optical properties were measured brightness of 500nit, CR of 1800:1, gray to gray of 5ms as shown in Table 1. Figure 8 shows images of conventional structure and advanced structure.

**Table 1. Comparison of conventional design spec. and advanced design spec.**

| | Conventional design | Advanced design |
|---|---|---|
| Rubbing angle | 20deg. | 10deg. |
| Electrode width | 3.x um | ~2.0um |
| White Luminance | 500nit | 500nit |
| Contrast Ratio | 1000:1 | 1800:1 |
| Δ u'v' | Max 0.015 | Max 0.010 |

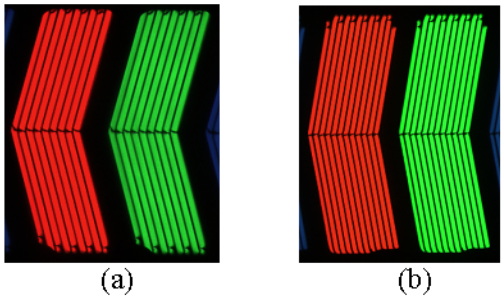



**Fig. 8 The image of (a) conventional design structure (b) advanced design structure**

Figure 9 shows the primary shift of when is primary picture and motion picture using checking of Macbeth charts. The left image show Macbeth checking patterns based for analysis of primary shift. The right is the real image of still primary picture and speed of moving picture (0ppf~12ppf) which is measured by digital camera system. We have measured to change color at moving picture according to LCD's quality.

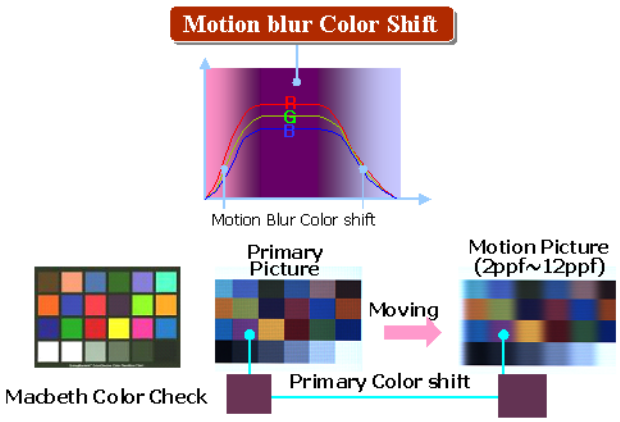
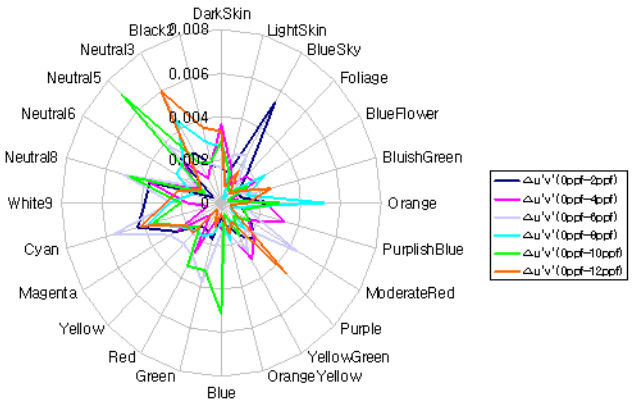


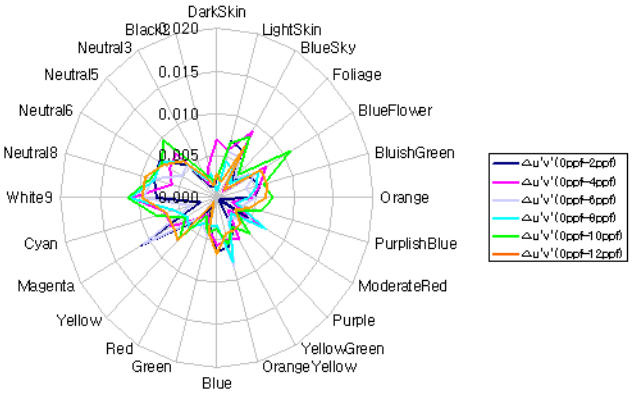

**Fig. 9. Macbeth color check (left) and primary picture (right-left) and moving picture(right-right).**

Figure 10 shows Macbeth color shift in CIE 1976 chromaticity when primary picture becomes moving picture.[6] The primary shift in motion picture color shift of electrode width of 3.xμm and rubbing angle 20° appear a max (2ppf~12ppf) Δu'v'=0.015, but electrode width of 2.0μm and rubbing angle 10° appear max(2ppf~12ppf) Δu'v'=0.010.

In specific color pattern of Macbeth color chart, advanced S-IPS happen nearly no color shift because color change of short wavelength (blue to red) not occurs when liquid crystal is become the On/Off. It's assumed that a color shift to widen wavelength not happens by on-off switching of in plane aligned liquid crystals [6].




**(a)**




**(b)**

**Fig. 10. The color shift characteristic (a) electrode width=3.xμm, rubbing angle=20° (b) electrode width =2.0μm, rubbing angle=10°.**

## 4. Conclusion

We have studied how to design optimization of electrode width and rubbing angle in S-IPS mode. Applying of the fine pitch electrode ~2μm by novel mask design and 10° of rubbing angle leads to improve S-IPS qualities. Transmittance and contrast ratio are up to ~9.8% and CR ~7%, respectively. The moving picture quality of advanced S-IPS is improved by applying optimal pixel design. And also the primary color shift of moving box is not inspected by Δu'v'=0.010. We have believed that advanced S-IPS should become the new standard technology in LCD-TV with CRT like picture quality.

## 5. References

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