IPS-TFT-LCDs Technology Trends

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Abstract

Recent progress of the in-plane switching (IPS) TFT-LCD technologies is reviewed. We call the improved new technology `advanced super IPS TFT-LCD(AS-IPS)`. After suppressing the viewing angle dependency of essential display characteristics, recent brightness, viewing angle and motion picture quality has been highly improved. The stage is now introducing it into consumer information appliance for higher display performances, by which we could open a large size digital LCD TVs application.

1. INTRODUCTION

For the past decade, the market of TFT-LCD has been growing rapidly. The replacement of CRTs to LCDs in monitor application is rapidly proceeding now. Significant progress of the wide viewing angle TFT-LCDs technology is an important factor as well as manufacturing innovations. Among many candidates display modes for a wide viewing angle characteristic, three major ones, the compensation film, the Multi-domain Vertical Alignment (MVA) mode, and the IPS are mainly commercialized. In the case of the compensation film, we do not need to change the TFT-LCD panel structures. This is the reason why so many panel manufactures are introducing them in their products. Since both of the MVA and IPS need largely different design rules causing different structures, market share was behind in the early stage of the penetration of Wide Viewing Angle (WVA) technology to the market. However, now shares of both of these technologies are increasing in products with a larger size than 26 inches and high performance application such as digital TV's.

The first products with the IPS-TFT-LCD panel appeared in the market in the middle of 1996 [1-3]. This consisted of the normal, straight inter-digital electrodes structures. In 1998, a new electrode with a zigzag structure, named the Super IPS (S-IPS), which improved viewing angle characteristic further, was introduced [4-7]. Quite recently, LCD-TV sets consist of a new driving method and cell structure by which much-improved motion picture qualities and bright images have been obtained [8,9].

2. PROGRESS of IPS-TFT-LCDs

2.1 History and trends

Figure 1 shows history in TFT-LCD products and technology trends. From this figure, we see a tight relationship between innovations and new product markets.

In the early 90's, active R&D for overcoming problems of limited viewing angle characteristics in TFT-LCDs was conducted. After several innovations were made, a new market of desktop monitor TFT-LCDs, using the WVA technology, appeared. This market has been rapidly growing in late 90's. Next innovation is made for originating TFT-LCDs showing high motion pictures. In the last two years, the LCD-TV market has been opened. [10]. But large size digital TV required higher performance compared with conventional S-IPS TFT technology with high motion pictures.

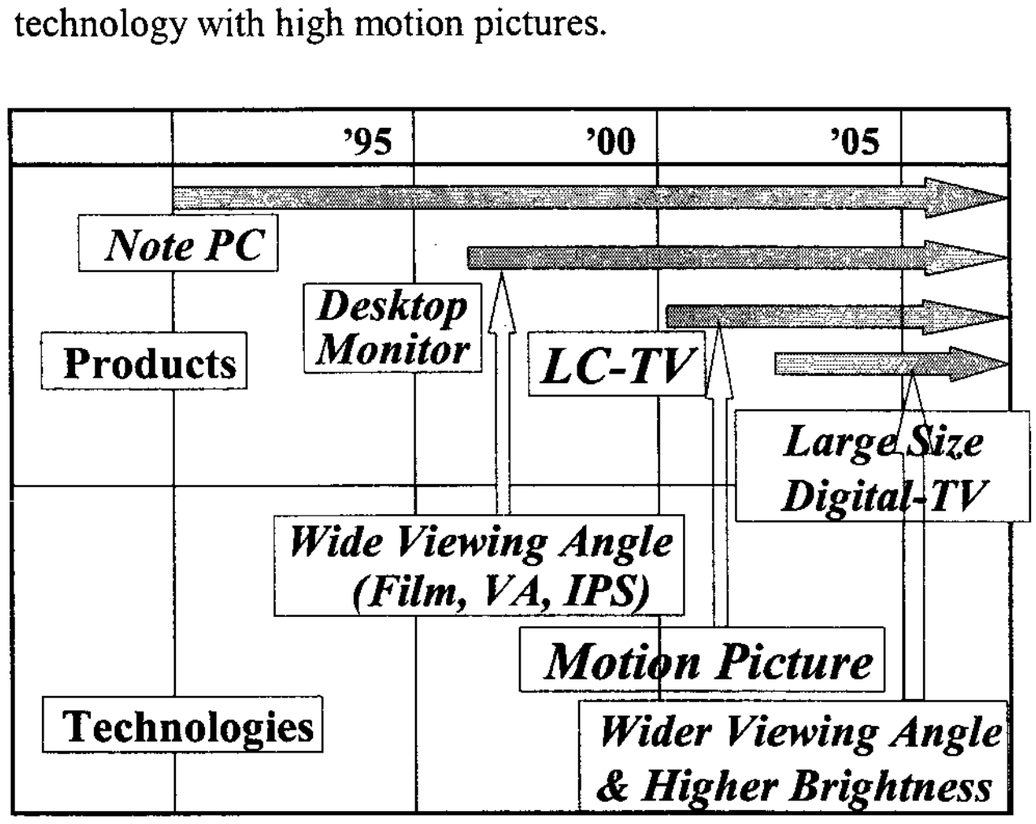

Figure 1 History and relationship between products and technologies in TFT LCDs

2.2 Viewing angle characteristics

There are many definitions for quantitative expression for the degree of the width of viewing angle characteristics. The followings are one categorization. All of the definitions are expressing the maximum angle.

(a)Without gray scale inversion with a certain number of gray levels

(b) Without γ characteristic change

(c) With a higher contrast ratio than a certain value of the contrast ratio

(d) Within a certain color shift

(e) Within a certain brightness variation

Although the first IPS product, which consists of normal and straight inter-digital electrodes structures, shows much wider viewing angle characteristics than those of the conventional TN mode, but some weak angles remained : Gray scale inversion (definition (a)) and lowering of contrast ratio (definition (b)) appeared in the oblique directions of 45, 135 degree with respect to the horizontal axis. This weakness was completely suppressed by introducing the S-IPS technology (zigzag electrode structures) [4-7]. The S-IPS shows color shift free characteristics (according to the definition (c)) too (in Figure 2).

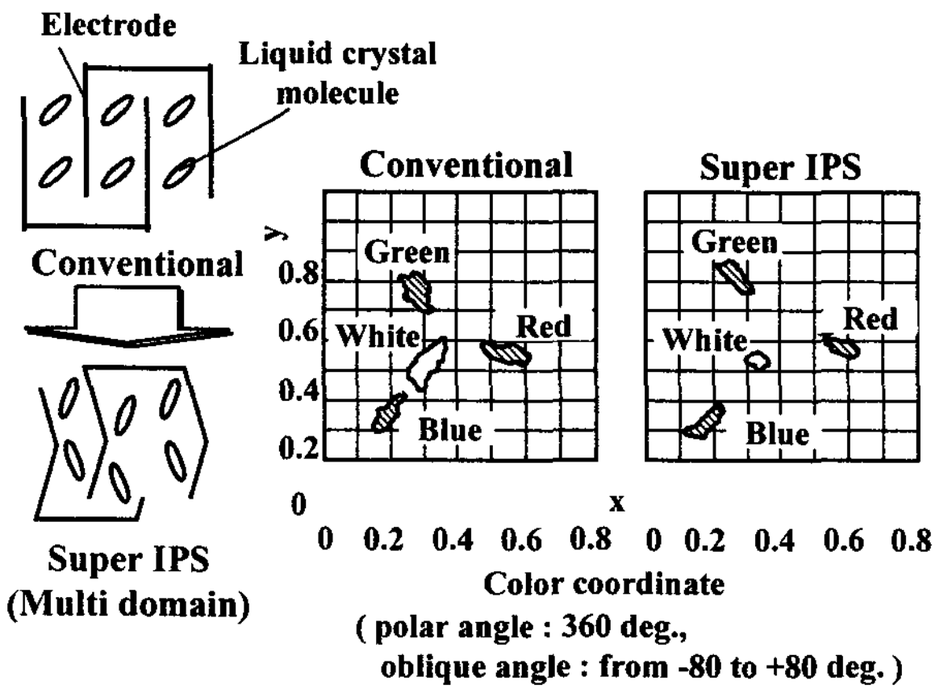

Figure 2 Electrode structure and color shift range of the super-IPS mode.

But large size display for digital TV requires wider viewing angle and higher contrast ratio compared with S-IPS technology. For this we introduced new polarizer to improve viewing angle and contrast ratio.(in Figure 3)

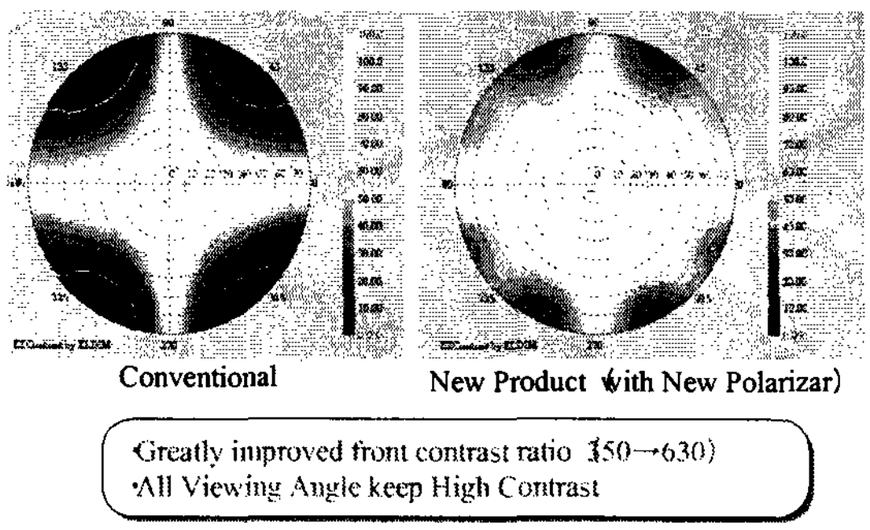

Figure 3 New technology improve the viewing angle

2.3 Motion picture quality

The response time of the liquid crystal switching, i.e. alignment change after applying or removing the electric field, is one of the important factors affecting the motion picture quality. Before the report by Kurita in 1998-2000 [11-13], in most of the cases the only factor of the response time above was discussed as a direct factor affecting to motion picture quality. One target was the time of 16ms, which is corresponding to the one frame period with a frame frequency of 60Hz. Kurita showed the fact that there still remain blurred images in LCDs even when the response time became zero second. He proposed the mechanism with comparison of impulse type and holding type display principles.

Based on the Kurita's proposal, Yamamoto established a new apparatus and architectures with which a degree of blurred width can be quantitatively evaluated [14,15]. One conclusion was that both of the response time of the liquid crystal switching and the frame frequency of scanning affected motion picture quality as shown in Figure 4. The vertical axis shows switching time, while horizontal axis shows frame frequency. As shown in the two regions in Figure 4, motion picture quality depends on both of these two factors.

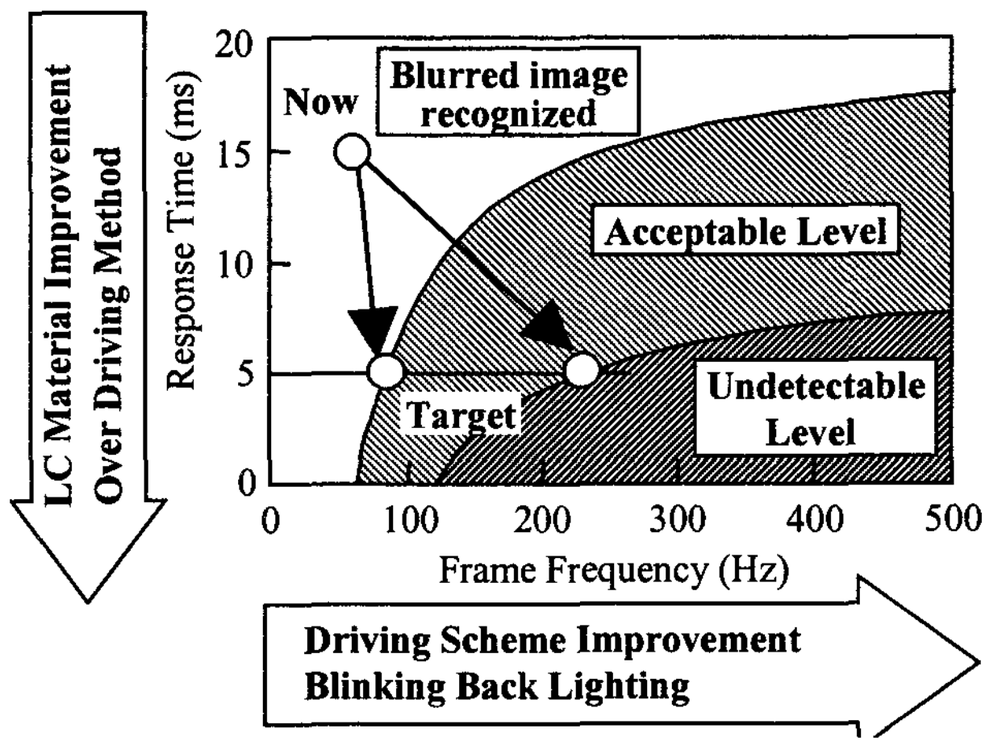

Figure 4 Targets for fast-response LCDs

Many efforts have been made to reduce the viscosity of the liquid crystal mixture for IPS applications [16]. However, it is difficult to reach to the requirement only with the renewal of liquid crystal mixtures. For switching time improvement, a new driving scheme, such as over driving method, is also effective [8,17]. Combination with new liquid crystal mixture and a new driving method is an effective way. Since the IPS mode shows relatively constant switching time characteristic between gray levels [18], over driving design is easier compared with other WVA technologies.

Instead of increasing the frame frequency, there are several effective methods: Blinking-back light system affects as an increase of the frequency. One drawback of the blinking back light system was supposed to be a decrease of the brightness of

the image or increase of the power consumption of the backlight. Hirakata et al. [9] found the fact that in the blinking back light system the power efficiency becomes higher if the current of the lamp tubes is set to be higher. The black image insertion has the same effect. The super impulse system consists of these two methods [8,9]. Now current product is using the black image insertion only, but moving picture image is improved compared with current product without the black image insertion.

2.4 High Brightness

For TV application, brightness enhancement is one of the most important items for IPS-LCDs in addition to the suppression of blurred images. For example , brightness of conventional LCD monitor is sufficient of 200 cd/m^2 but TV's requires higher brightness, target specification is to clear 500 cd/m^2 Several proposals have been made to increasing the aperture ratio while keeping the other image quality of the IPS mode; fringe field switching [19], finger on plane [20], transparent inter-digital electrodes [21],[22]. Quite recently, Hitachi has developed the advanced super IPS (AS-IPS) technology [23], with a new design and production technique by which the aperture ratio of the IPS pixel was enlarged 30% in relation to conventional IPS panels. (in Figure 5) This technology is applied to commercial large size digital LCD-TVs.

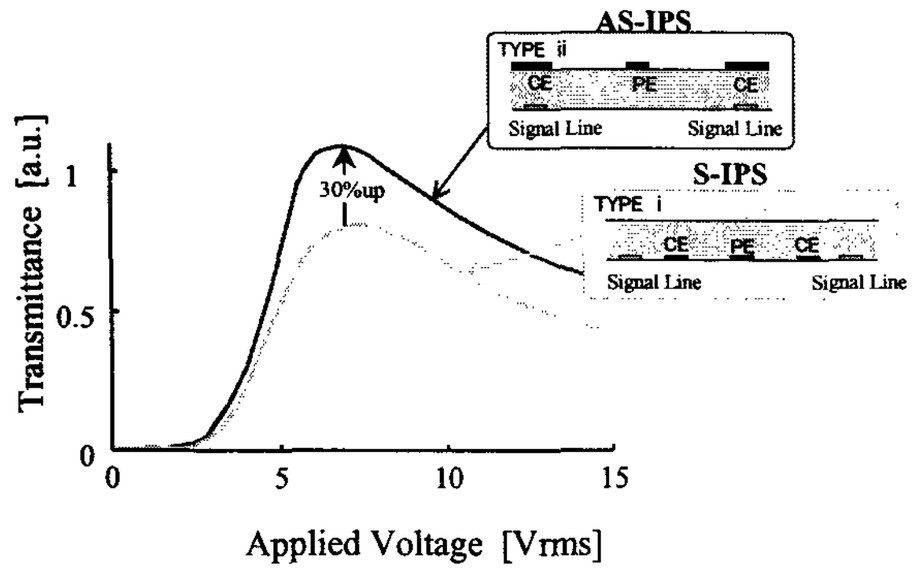

Figure 5 AS-IPS realizes a higher

2.5 Color reproductivity

In TFT-LCDs, some differences in colors are inevitably seen between monitors even when the same data are used. Furthermore, one panel shows color shift on luminance (color tracking) although the gray scale must be seen as an achromatic color. The case of the TN mode is shown in Figure 2 It is technically hard to control precisely the colors in TN-TFT-LCDs, because this feature is due to the intrinsic nature of liquid crystal optical properties.

The color tracking can be suppressed by using the IPS mode. However, the shift length is still large if we compared it with the limit of perception of 0.01. The authentic color IPS, a newly designed IPS mode, was developed to suppress the color tracking within the limit of perception [24].

For TV's, a color gamut range is based on EBU 100%, this means color gamut range of 72%-NTSC color reproduction. This was achieved.

3. CONCLUSION

Recent progress of the in-plane switching TFT-LCD technologies was reviewed.

(1) Viewing angle dependency of color was completely suppressed.

(2) Motion picture quality has been highly improved.

(3) The display with AS-IPS technology has higher brightness to satisfy for large size digital TVs, since AS-IPS technology can enlarge the aperture ratio.

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