WVGA solutions for mobile multimedia convergence

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Abstract

Mobile phones are evolving into a platform for internet access. In order to display web pages in handsets, WVGA and around 3-inch displays are strongly recommended. Low power consumption, compactness and narrow boarder area are essential. The general requirements for WVGA solution and the design factors to reduce the power consumption and boarder area discussed.

1. Introduction

The rapid improvement of mobile communication speed has enabled e-mailing and internet access on mobile phones. Mobile phone is evolving rapidly into a powerful multimedia platform by the addition of full web browsing function to existing multimedia functions such as camera, mp3 player, mp4 player, game, video communication, and mobile broadcasting. Among various functions, web browsing seems to be the key driving force to use high-resolution and large screen that minimizes the screen scrolling and maximizes the readability of contents. The resolution of around WVGA (800X480) and the screen size of around 3 inches have been already applied in mobile phone recently.

The developments of high resolution AMLCDs have been reported and the required characteristics have been discussed [1,2]. We have dealt with the necessity of wide viewing angle liquid crystal mode to show superior images both in portrait view and in landscape view according to applications. In addition, the importance of high aperture ratio has been emphasized in wide viewing angle modes. In this paper, we will extend our discussion on the issues in achieving high resolution AMLCDs for mobile phones.

Table 1 suggests a roadmap of display performance for mobile applications. The resolution and the screen size will increase. The color saturation would be above 70%, while increasing the brightness. Even though the input function of mobile phones was mostly key pad type in the past, the full touch sensor type is becoming the main stream of multimedia converged mobile phones. Since all the changes in the specifications provoke the increase of power consumption in panels, the power consumption is getting an extremely critical factor. In addition, the thickness and the narrow boarder area of a panel become important not to increase the thickness and the width of handset caused by display. For the mobile TV and the mp4 player functions, response time is another important factor.

TABLE 1. Display technology roadmap for mobile multimedia convergence.

	2006	2008	2010	2012
Resolution	qVGA	hVGA ~WVGA	WVGA ~WSVGA	WSVGA~
Diagonal Size (inch)	~ 2.2	~3.5	~4.0	~4.5
Brightness (cd/m^2)	<200	400	450	>500
Color (NTSC1976)	60%	80%	90%	>100%
Input function	Key pad	Touch sensor	←	←

We have implemented very competitive WVGA AMLCDs. Low temperature poly-Si TFT is essential in achieving high performance in terms of power consumption, screen performance, and compactness.

2. Design Issues

1) High Brightness

One of most challenging issues is achieving high aperture ratio at high pixel density. Since the portion of opaque area in a pixel increases as the pixel density increases, the aperture ratio is highly dependent on the patterning capability and liquid crystal mode. We have installed a 4th generation LTPS TFT line equipped with high-resolution steppers and dry etching machines to minimize the degradation of aperture ratio. The aperture ratio is also affected by liquid crystal modes as shown in Fig.1. The vertical alignment (VA) mode is advantageous in achieving high aperture ratio in lower resolution than 250PPI, whereas IPS mode is much easier to get high aperture ratio above 250PPI.

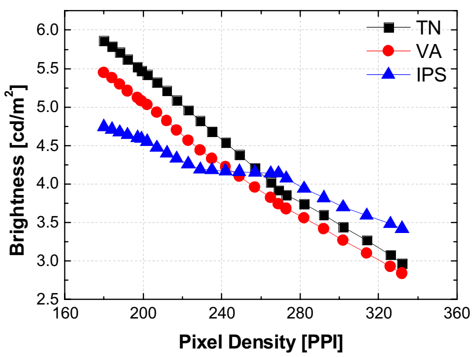


Fig.1 Aperture ratio variation vs. pixel density, for TN, VA, and IPS liquid crystal mode.

The off-state leakage current of pixel TFT is another issue to be considered in designing the pixel. The active channels of TFTs, having a conventional top-gate structure, are to be exposed to intense backlights. Since high leakage current can provoke flickering, vertical cross-talk, low contrast ratio, and image sticking, the leakage current should be suppressed. The surface luminance of LED backlight is calculated and summarized in Table 2, assuming the IPS mode, NTSC 85% of color saturation, and 300 PPI. The backlight intensity of above 5000cd/m^2 is required for the WVGA solution. The photo leakage currents are measured and shown in Fig. 2. The previous TFT structures are not acceptable without light blocking layer. The device structure is optimized to reduce the photo leakage current. Thinner active layer is helpful to reduce the photo leakage current. We have overcome the degradation of the device performance with ultra thin active layers.

2) Power Consumption

Power consumption is a big burden in increasing both display size and resolution in mobile phone. It increases seriously, since higher resolution requires more video signal transfer and processing at a higher frequency, in addition to the increase in the display itself. Therefore, it is a very important issue to reduce the power consumption of the display. Fig. 3 shows the comparisons of power consumption in the backlight units and the panels between qVGA and WVGA, and also between VA mode and IPS mode, with assumption of 400cd/m^2 of the brightness and NTSC 85% of the color saturation according to CIE1976. The increase in the backlight unit is caused by the decrease of aperture ratio and by the display area. Even though the power consumption can be saved continuously on behalf of the progress in the efficiency of LED light source, it is essential to find solutions for reducing the power consumption furthermore.

TABLE 2. The luminance of backlight vs. pixel density (simulation data).

LCM Surface Luminance (cd/m^2)	300	400	450	500
Backlight Luminance (cd/m^2)	4700	6200	7000	7800

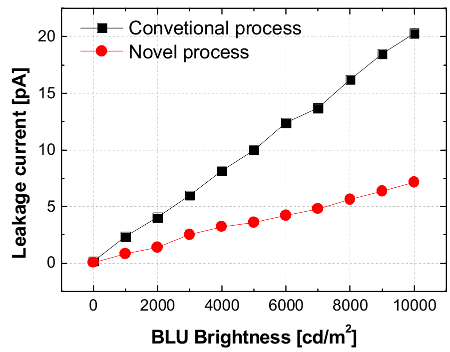


Fig. 2 Photo-leakage current of TFTs

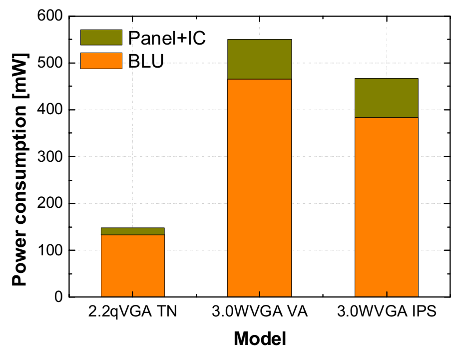


Fig. 3 The comparison of power consumption in different displays (400cd/m^2, NTSC85%)

A powerful approach is to control the intensity of backlight adaptively analyzing the contents of displays and sensing the illumination of ambient. Content-based adaptive brightness control (CABC) is the method to save power consumption by reducing the backlight intensity and adjusting the gamma curve when display contents consist of a lot of dark images. If we adjust the backlight intensity adaptively according to ambient brightness, so called, light-based adaptive brightness control (LABC) , it's possible to save more power in a dark environment. Table 3 suggests the feasibility of power saving effect for different situations and contents. Even though there are cases that users see mobile phones outdoor, many users may use mobile phone indoors. And also, if system developers adopt black graphic user interfaces, more power can be saved. ABC seems to render much of freedom to mobile phone designers.

Table 3. An example of power savings by the adaptive back light controlling method,

Pattern	Ambient	CABC [mW]	CABC+LABC [mW]
Still image (384mW)	Dark	315	94
	Indoor	315	173
	Outdoor	315	315
Black GUI (384mW)	Dark	230	69
	Indoor	230	127
	Outdoor	230	230

In implementing the function to control backlight intensity according to the ambient illumination, light intensity sensing is mandatory. Light sensing component has been located somewhere very close to display. However, the integration of light sensors on the panel can give more freedom for designing the compact systems. We have developed integrated photo-sensors with p-type LTPS TFTs. Since the structure of conventional top-gate poly-Si TFT is not adequate to absorb the light entering through liquid crystal layer, a new TFT structure has transparent gate electrode. Fig. 4 shows the photo current characteristics of the fabricated photo sensing devices according to the intensity of illumination. At low illumination conditions below a few hundred lux, the accuracy of sensor is poor due to thermal leakage current so that it's difficult to discriminate the light intensity. We have optimized the sensing device to eliminate thermal leakage current term. Fig. 5 shows the photo current of the new architecture according to the illumination intensity. The sensing resolution can has been improved at low light intensity regardless of ambient temperature.

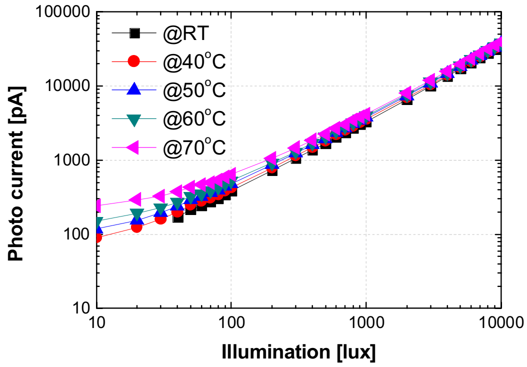


Fig. 4 Photo current of the sensing TFT according to the light intensity.

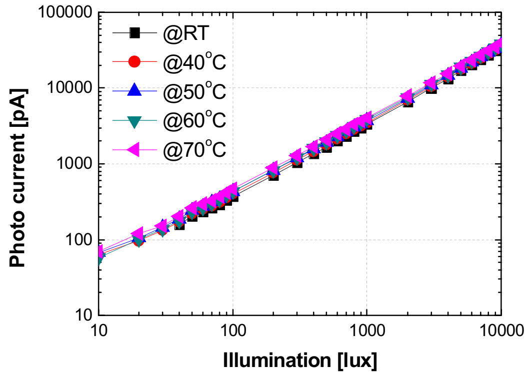
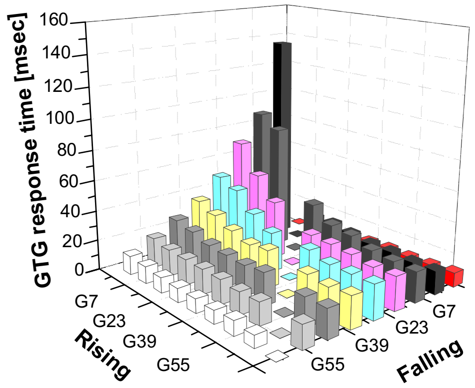


Fig. 5 Photo current behavior of the improved sensing structure.

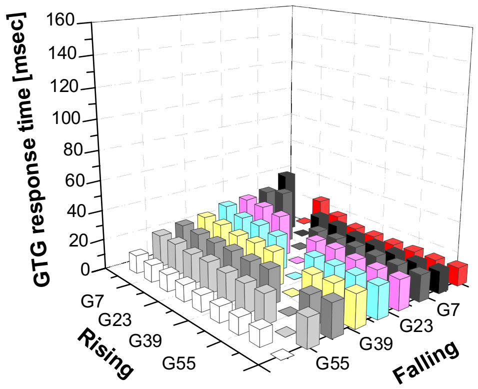
3) Response time

Even though the response time of display for moving pictures was not so critical for small-sized display as much as in large-sized displays, the fast response time may give additional values to end-users, as the applications for moving image are increasing in mobile handsets. The overdrive method is normally applied in large-sized LCDs for TV [3-4], and recently, double frame rate and scanning backlight technology are developed [5-6]. It is not cost effective to adopt the same technology with large-sized LCDs for small-sized LCDs. In addition, power consumption is another factor in using conventional response time enhancement technology. Therefore, the response time of small-sized LCDs is fully dependent on the liquid crystal mode.

Fig.6 (a) and (b) show gray-to-gray response time characteristics of VA mode and IPS mode, respectively. While the response time of IPS mode is very even all over gray levels, the response time of VA mode around low-middle gray level is very slow. Therefore, it can be concluded that IPS mode is adequate for moving pictures in small-sized LCDs.



(a)



(b)

Fig. 6 Gray-to Gray response time of (a) VA mode and (b) IPS mode.

3. Implementation of WVGA AMLCDs

WVGA AMLCDs have been implemented using p-type low temperature poly-Si TFT process. IPS mode is advantageous in all aspects, such as viewing angle, response time, and aperture ratio, for around 300 PPI and higher resolution. High contrast ratio and narrow boarder area have been achieved by the optimization of IPS mode and by the integrated circuits. P-type TFTs are sufficient to integrate the gate driver, the DC-DC converters for the integrated circuits, and the de-multiplexing switches for the reduction of data signal connections between a COG chip and pixel arrays.

The characteristics are shown in Table 4. We have fabricated various panels having different color gamut. In order to achieve high color gamut above NTSC 100% (CIE 1976), we have adopted RG-LED backlights. Only NTSC 63% color saturation is achievable with a white LED backlight, using the same color filters in both panels. Even though the RG LED backlight should be improved in terms of efficiency and thickness, it is a good solution for high color gamut.

Table 4. Characteristics of the fabricated Panel.

	3.0-in WVGA	Remark
Pixel format	480RGB x 800	
Pixel density [PPI]	313	
Pixel pitch [mm]	27.0 x 81.0	
Dimension [mm]	45.60 x 76.40	
Brightness [cd/m^2]	400	
Contrast Ratio	900:1	
Color Saturation [%]	85%	NTSC ratio
Viewing angle	160^o/160^o	CR>100

4. Summary

The LTPS TFT and IPS technology is a very competitive solution for the multimedia convergence of mobile handsets. High resolution, wide viewing angle, and high color saturation are strongly demanded. Power consumption is a big challenging issue in achieving the demanding performance. We have suggested and implemented various low power solutions. The highest aperture ratio has been obtained by the IPS mode for high pixel density. CABC and LABC scheme are very helpful to reduce the power consumption further more.

5. References

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