Privacy LCD Technology for Cellular Phones

携帯電話向けプライバシー液晶技術

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Abstract

People increasingly need to access information on the move. Some information they wish to share with others, but some is confidential. Therefore a display technology is needed which allows users to easily select who can see information. In this paper we describe the development of new technologies for privacy LCDs and explain the factors controlling privacy strength and image quality. This development resulted in the commercialisation of Sharp's VeilView technology for cellular phones.

携帯機器の進化とともに公衆環境でさまざまな情報にアクセスする機会がますます増えている。その中には，他人に見せたい情報もあれば，見せたくない情報もある。そこで，他人に見せる・見せないを簡単に切替えられる表示技術が求められている。本稿ではプライバシーLCDの新技術の開発について述べるとともに，プライバシー保護のための遮蔽レベルと表示品質をいかに制御するかについて説明する。この開発の成果はベールビュー液晶技術としてシャープ製携帯電話に搭載されている。

Introduction

Over the last few years great progress has been made to improve the viewing angle of LCDs. Current Sharp LCDs can easily be seen from a wide range of directions. However in some situations this very wide angle visibility can be a disadvantage. More and more information is becoming available on mobile products, including bank details and other personal information. Therefore people need to be able to control who can see the information they are consulting, choosing between a wide viewing angle display to share information and a narrow viewing angle to keep information private.

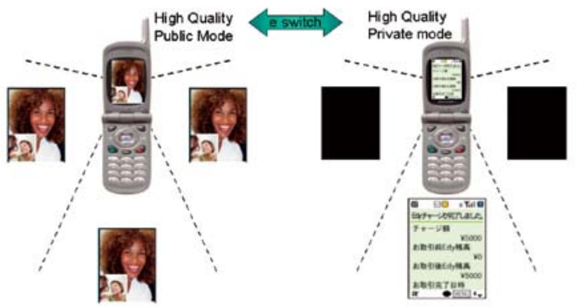

Fig. 1 Sharp concept for electrically switchable privacy LCD.

Add-on films based on micro-louvres [1] have already been used to give privacy on mobile displays. However these films are not switchable, they must be added and removed by hand and carried separately from the display when not in use. Therefore, in line with the company philosophy of developing unique products, Sharp has identified the need for privacy technology which can be easily switched on and off by users. This concept is illustrated in Fig. 1. Engineers in Mobile LCD Group and at Sharp Laboratories of Europe have worked in collaboration to develop new LCD technologies to realise this concept.

Cellular phones benefit from a switchable privacy function since they are often used in crowded places,

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for example on the street or public transport. However switchable privacy is useful on all mobile products, especially laptop PCs. Desktop monitors will also benefit from privacy technology and it is particularly needed for automatic teller machines (ATM).

1. Strong privacy technology

The advantage of micro-louvre films is the strong privacy achieved. Therefore, for applications where privacy is critical, a prototype for an electrically switchable micro-louvre has been made.

The structure of Sharp's switchable micro-louvre is shown in Fig. 2 Transparent polymer walls are formed between glass sheets. These walls are made of photopolymer (i.e. SU8 [2]) which can be patterned to give very high aspect ratio structures. The walls are typically 80μm high and 20μm wide. 10μm channels between the walls are filled with a mixture of liquid crystal and anisotropically absorbing black dye (Guest Host mixture). The dye molecules align with their absorption axes parallel to the liquid crystal director. If no voltage is applied to the micro-louvre layer the liquid crystal and dye molecules are aligned in the plane of the glass sheets, parallel to the transmission axis of the incident polariser of the LCD image panel. Therefore the dye molecules strongly absorb the light which would be transmitted by the incident polariser. As shown in Fig. 2a only the light which passes through the transparent walls of the louvre is transmitted by the louvre and the image panel. The aspect ratio of the louvre walls therefore restricts the angle at which an image is visible to ±30º from the on-axis direction. At larger angles the display appears black, giving a strong privacy function.

To produce a public, wide viewing angle, a voltage is applied across the guest host liquid crystal layer as shown in Fig. 2b. The liquid crystal and dye aligns with the field and therefore the dye no longer strongly absorbs light from the backlight. The measured transmission of the micro-louvre in both the private and public modes is shown in Fig. 3.

Fig. 3 shows that a narrow angle range private mode is achieved with very low transmission at angles greater than ±30º to the on-axis direction. The public mode does not have constant transmission as a function of angle. This is due to internal reflections in the micro-louver which can be predicted by optical modelling (Fig. 4). These reflections could be reduced by matching the refractive index of the polymer walls to the liquid crystal, giving a more uniform

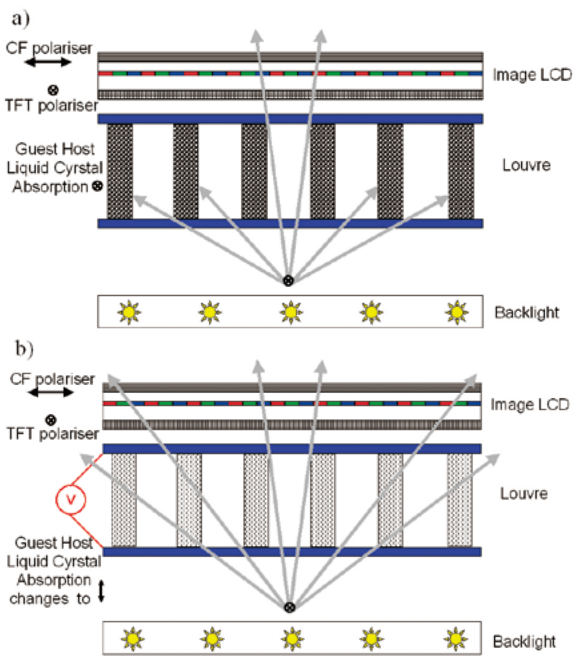

Fig. 2 Switchable micro-louvre
a) private mode - no voltage applied,
b) public mode - voltage applied.

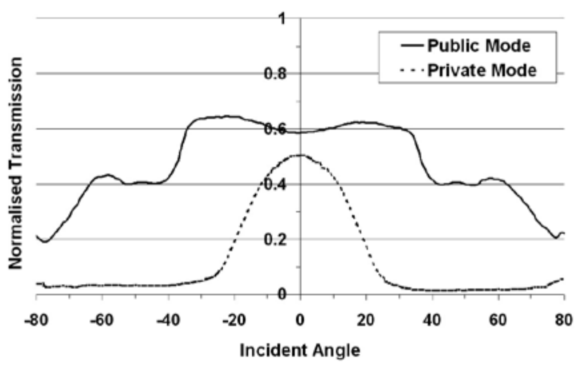

Fig. 3 Transmission as a function of angle for the public and private modes of the micro-louvre.

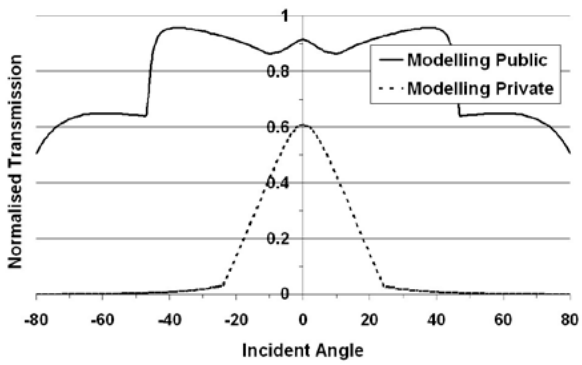

Fig. 4 Modelled transmission of the micro-louvre including the effect of internal reflections.

public mode.

Both the public and private modes of the switchable micro-louvre have reduced transmission in the on-axis direction. This is due to the finite order parameter of the dye which means that some light of all polarisations is absorbed. Since the highest feasible dye order parameter is approximately 0.8 this reduction in on-axis transmission cannot be completely avoided, though the loss can be reduced by minimising the width of the liquid crystal channels. A similar reduction in transmission occurs for fixed micro-louvre films.

2. Privacy technology for mass manufacture

While the switchable micro-louvre technology gives excellent privacy it is relatively complex to manufacture. For consumer products such as cellular phones cost is a critical factor. Therefore an alternative privacy technology has been developed using components that are compatible with mass manufacture. The technology uses the principle of blocking the light to side views, just as the switchable micro-louvre, however instead of the louvre a simple Electrically Controlled Birefringence (ECB) switch panel is used.

The ECB privacy technology is illustrated in Fig. 5. An additional liquid crystal switch panel and polariser are placed in front of the LCD image panel. The LCD switch panel is rubbed antiparallel, giving an untwisted planar alignment of the liquid crystal (ECB mode). The rubbing directions of the switch panel, the transmission axis of the additional polariser and the colour filter polariser of the LCD image panel are all set parallel. With no voltage applied to the switch panel the liquid crystal is oriented parallel to the two polarisers and so has almost no effect on transmitted light at any angle of incidence. This gives an excellent public mode.

When a small voltage is applied to the ECB switch panel the liquid crystal tilts out of the plane of the glass panel. The plane in which the liquid crystal tilts remains parallel to the polarisers, therefore light propagating near the on-axis direction of the display is not affected by the switch panel. However light propagating at a large angle to the on-axis direction has it's plane of polarisation rotated by the tilted liquid crystal layer. This light is then blocked by the additional polariser, giving a dark view to the sides.

The viewing angle range for both public and private modes is shown in Fig. 6 and the transmission in the horizontal direction is shown in Fig. 7. These figures show that in the private mode there is a minimum in transmission at one viewing angle, the angle at which the switch panel rotates the plane of polarisation by exactly 90º. This angle for maximum privacy is determined by the birefringence

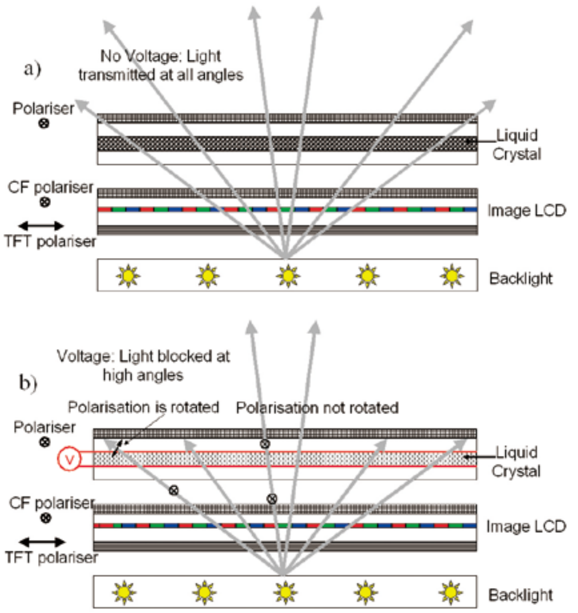

Fig. 5 ECB privacy display
a) public mode - no voltage applied,
b) private mode - voltage applied.

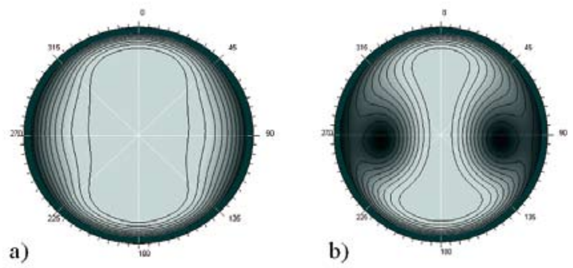

Fig. 6 Polar viewing angle range for ECB privacy display
a) public mode , b) private mode.

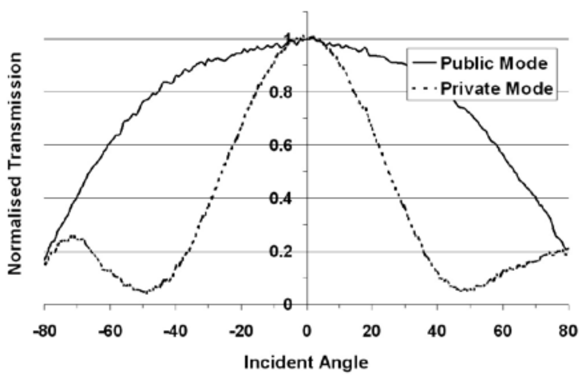

Fig. 7 Transmission in horizontal direction for ECB privacy display.

and thickness (Δnd) of the liquid crystal layer and can be set at time of manufacture.

Because the ECB privacy technology uses a simple switch panel, which does not require TFTs or duty driver ICs, the technology is straightforward to mass manufacture. However the ECB technology gives weaker privacy than the switchable micro-louvre technology. This can be seen by comparing the transmission at large angle in Figs. 3 and 7. The performance of the two technologies is summarised in Table 1.

Table 1 Summary of performance.

	Switchable micro-louvre	ECB privacy
Public mode image quality	Reduced brightness	Excellent
Private mode image quality	Reduced brightness	Excellent
Privacy	Strong	Weaker
Manufacture	Complex	Simple

3. Patterned masking images for improved privacy

The ECB privacy technology is attractive from a manufacturing point of view but its privacy is weaker than the micro-louvre based technology. Therefore a method of increasing the privacy strength without adding to complexity has been developed.

If an image is overlaid by a pattern of light and dark areas it is much harder to read than one which is overlaid with a uniform dark layer. This masking effect, illustrated in Fig. 8, is well known from the psychology of human vision [3].

The ECB privacy technology can produce a masking image by patterning the electrodes of the additional switch panel. Almost any masking image can be chosen by patterning the electrodes at manufacturing time. In addition the electrodes can be designed to give several different user selectable masking images from a single switch panel. Two masking images which can be user selected on a production Sharp privacy LCD are shown in Fig. 9.

4. Current and future VeilView products

Sharp is the first company to mass manufacture privacy LCDs, commercialising the technology under the name VeilView LCD. The first VeilView products are cellular phones, and for this highly cost sensitive application the

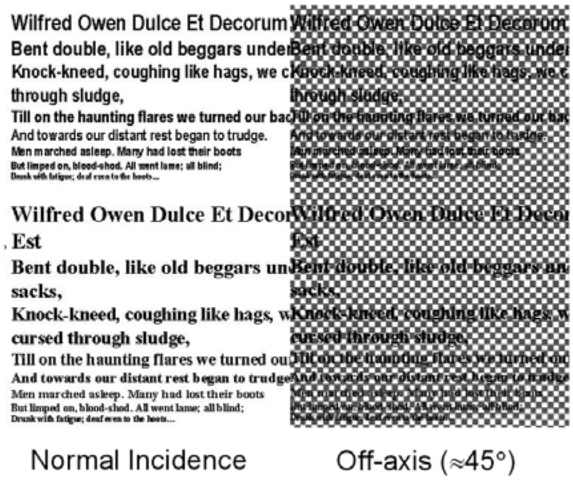

Fig. 8 Effectiveness of a patterned mask at obscuring an underlying image.

Fig. 9 Patterned masking images for production Viel View LCDs.

mass manufacture compatible ECB technology is the most attractive option. By combining ECB and patterned masking image technology good privacy for text has been achieved.

Several cellular phones with VeilView displays are already available in Japan. For NTT DoCoMo the SH851i (DOLCE), SH902i, SH902iS, SH902iSL (DOLCE SL) and for KDDI the W41S. Phone companies in the US and Europe are also evaluating Sharp VeilView displays.

Laptop displays are likely to be the next application for VeilView technology, enabling people to work on confidential documents in public places.

With the start of one segment TV broadcasting to cellular phones in Japan privacy is required for moving video images. This is a challenge because the human eye finds it easier to identify moving images than it does static images or text. Therefore Sharp is further developing the mass manufacture compatible VeilView technology to give privacy for moving images.

For the ATM application strong privacy is a key requirement, while cost of manufacture is lower priority. For this application the switchable micro-louvre technology has strong potential.

Conclusions

Sharp is the first company to mass manufacture privacy LCDs, meeting people's increasing need to access confidential information on the move. These LCDs allow users to easily switch between public and private modes, without the need to add or remove extra films. Two privacy technologies have been developed. One, switchable micro-louvres, gives excellent privacy but is relatively complex to manufacture. The other, ECB privacy, is straightforward to mass manufacture, but gives weaker privacy.

For the cost sensitive application of cellular phones the ECB VeilView technology has been commercialised. It has been combined with a patterned masking image to produce good privacy. The strong privacy of the switchable micro-louvres makes it suitable for the ATM application. Further development of privacy technology is ongoing to meet the challenge of TV on cellular phones.

Acknowledgements

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References

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