LCDs

Development of System-on-Glass (SOG) Display Technology

ASADA Hideki, SERA Kenji, KANEKO Setsuo

Abstract

The SOG-LCD is formed by integrating the LCD and driver LSI functions onto a glass substrate and it is expected to achieve optimum display device status for personal/mobile equipment in the broadband age. By focusing on the two major technical trends of image quality/function improvement and driver integration this paper is intended to introduce the latest SOG-LCD technology developed by the NEC Corporation and the NEC LCD Technologies, Ltd. This innovative technology is expected to evolve as one of the key support systems for the display devices of the Ubiquitous age.

Keywords

System- on-Glass (SOG), LCD, 3D display, built-in driver LSI, excimer laser annealing, crystal growth

1. Introduction

As rapid progress of the application of broadband has prepared environments for accommodating services such as photo and video mails and mobile digital TV on personal/mobile equipment, the display panels are required to offer higher resolution, narrower bezels and more compact modules than hitherto. The system-on-glass (SOG) liquid crystal display (LCD) using low-temperature poly-silicon thin film transistors (p-Si TFT) allows integration of the LCD panel and driver LSI. It can therefore meet all of the requirements of the display devices for personal/mobile equipment, including high resolution, narrow bezel and compactness. Consequently, the use of SOG-LCD is rapidly expanding in the display devices of cellular phones, smartphones, digital cameras, PDAs and portable media players.

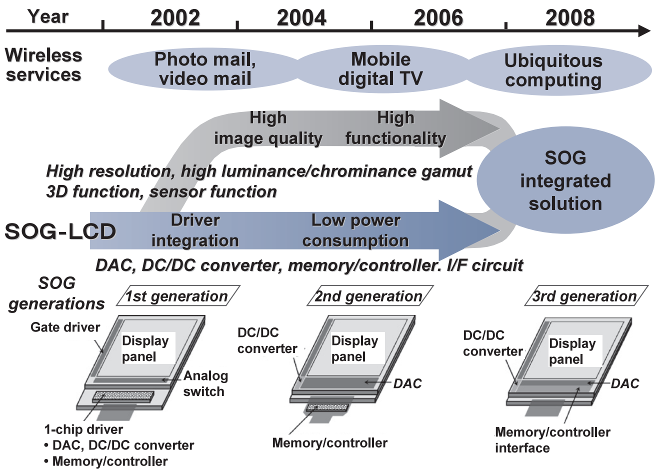


Fig. 1 Technological trends of SOG displays.

As a result of these environmental and market stimuli, we at NEC LCD Technologies, Ltd. have been developing and commercializing the SOG-LCD technology by following two major technological trends as shown in **Fig. 1**. Namely, 1) the technology for improving image quality and functionality, which specifically includes resolution improvement, luminance/chrominance improvement and 3D display technologies and 2) the technology for integrating the display control driver circuit/system onto a glass substrate for the display. In the future, we will integrate these two major technological trends into an SOG integrated solution device that can respond to the needs for display devices in the Ubiquitous age.

In this paper, we introduce the SOG display technology that has been developed by NEC Corporation and NEC LCD Technologies, Ltd., in the context of the two technological trends referred to above.

2. High Image Quality, High Functionality SOG Display Technology

2.1 High Luminance/Wide Color Gamut SOG-LCD

In order to respond to the need for improving the image quality of display devices used in PDA and video equipment, we developed a 4.1-inch SOG-LCD module and achieved indus-

Photo 1 High luminance/wide color gamut SOG-LCD.

try-leading qualities at the highest level for compact LCD panels. The module features a wide VGA (800 × 480 pixels) display capability, wide color reproduction gamut of 110% compared to NTSC, and high luminance of 400cd/m^2 **(Photo 1)**[1)].

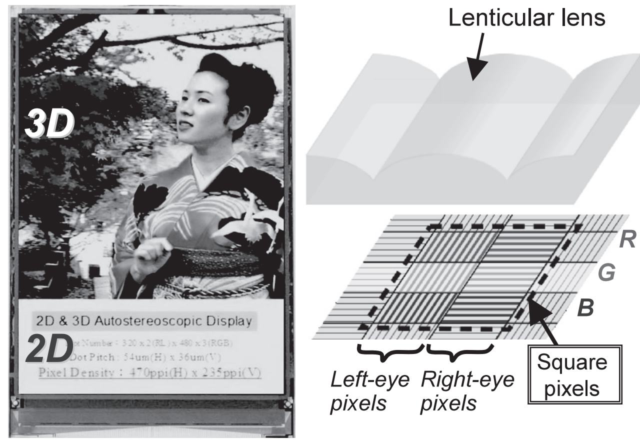
This SOG-LCD module is based on a high-transmittance SOG-LCD panel and incorporates an optimized backlight system and color filters in order to achieve compatibility between the wide color gamut of 110% compared to NTSC and high luminance of 400cd/m^2. As a result, it has succeeded in displaying pictures of a clarity and brightness that has not previously been achieved with any existing compact LCD panels.

In addition, the peripheral driver circuitry is formed from the same glass substrate as the LCD with a consequent reduction in the bezel size as well as in the number of component parts of the equipment required to accommodate the SOG-LCD module, thereby contributing to equipment size reduction and an improvement in the ease of incorporation.

2.2 High Resolution 2D/3D SOG-LCD

To meet the need to display video games, GPS (Global Positioning System) electronic maps and electronic merchandise catalogues more realistically, we also developed a 2.5-inch HVGA (320 × 480 pixels) SOG-LCD module with a 3D display capability that achieves the world's highest resolution[2)]. This 2D/3D SOG-LCD module combines a unique 3D display configuration that crosses previous barriers of 3D display resolution. It is called the HDDP (Horizontally Double-Density Pixels) and features a lenticular lens to achieve a 3D display with a resolution of 235ppi (pixels per inch) (**Fig. 2**).

The HDDP configuration is composed of the RGB color arrangement in horizontal stripes with the pixels doubling the horizontal resolution (470ppi) as shown in Fig. 2 (b). With this



(a) Display example (b) HDDP configuration

Fig. 2 High resolution 2D/3D SOG-LCD.

configuration, each square pixel consists of vertical oblong pixels for the left and right eyes.

While the resolution of the 3D display of traditional pixel configuration is halved from that of the 2D display, the HDDP configuration can display 3D images in the same 235-ppi resolution as 2D images. The reason for this is that, with the 2D display, the same image data is written in the two adjacent oblong pixels. While, with the 3D display, different image data, for the left and right eyes respectively, is written in the two adjacent oblong pixels. The 2D and 3D displays of this system can be switched over by means of software, and it is capable of allowing the mixed presence of 2D and 3D displays, for example displaying only part of a 3D display image in 2D.

The SOG-LCD module developed by combining the HDDP configuration with a lenticular lens has a thinner and simpler structure than the traditional 3D display systems and offers a brighter and more natural 3D display.

3. Driver Integrated SOG-LOG Technology

The generations of the SOG-LCD technology can be defined from the 1st to 3rd generations according to the integration level of the display control driver (Fig. 1). Most of the SOG-LCD modules that are widely disseminated in the compact LCD market have display sizes of 2 to 4 inches and integrate a gate driver and a de-multiplexer (switch) as a part of the data driver, and belong to the 1st-generation SOG-LCD technology.

In this section, we discuss the advanced, 2nd- and 3rd-generation SOG-LCD technology that has been developed by

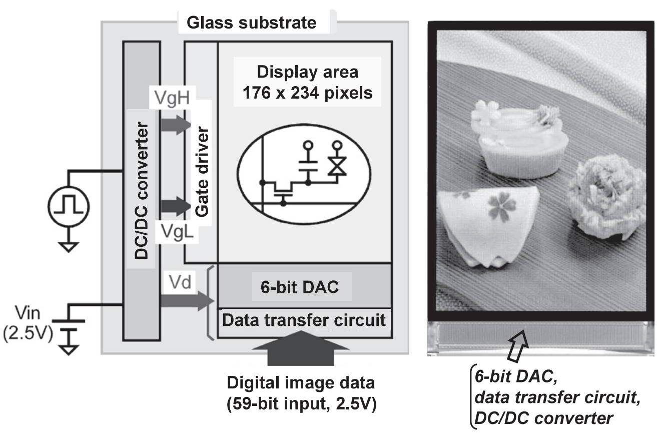
NEC Corporation and NEC LCD Technologies, Ltd.

3.1 Low Power, High-Integration SOG-LCD

In order to meet the need for reducing both the size and power consumption of personal/mobile equipment, we developed a 2.1-inch QCIF+ (176 × 234 pixels) SOG-LCD module with a low power consumption of 5mW (**Fig. 3**)[3]. This SOG-LCD module integrates all of the basic functions of the driver LSI including the gate driver, 6-bit DAC and power supply circuitry (DC/DC converter) and runs with a 2.5V single power supply. It attempts to reduce power consumption by introducing unique low-power-consumption architecture in the 6-bit DAC and power supply circuitry.

The 6-bit DAC is composed of a resistor-string type DAC (R-DAC) and a pre-charge buffer. This configuration can reduce the DC current supplied to the resistor string to a very low level because the power required to drive the data line from the resistor string needs only to be enough to correct the offset voltage of the pre-charge buffer. As a result, the power consumption of a 6-bit DAC has been almost halved compared with previous designs.

For the power supply circuitry, the voltage for the data driver that varies the current value according to the images is supplied from the regulator, and the negative voltage for the gate driver that does not vary the current value according to the images is supplied from the charge pump circuit. This architecture has actually achieved a high power supply efficiency of 73% for the SOG-LCD product.



(a) Block diagram (b) Display example

Fig. 3 Low power, high-integration SOG-LCD.

3.2 510K-bit SOG-DRAM

To implement a display with a built-in image frame memory that allows portable equipment to be fabricated in a compact and slim size and with low power consumption and cost, we developed a world-leading SOG image frame memory by integrating it on a glass substrate **(Photo 2)**[4]. Once a display with a built-in image frame memory is achieved, it can be connected directly to the processor built into a mobile equipment system. This facility not only reduces the size of and simplifies the installation of the display module but it also makes an external driver LSI completely unnecessary.

The developed SOG image frame memory is composed of a 510K-bit DRAM storing QCIF+ (176 × 240 pixels) image gray-scale data equivalent to 4,096 colors, and an image compression/decompression circuit based on a unique algorithm called SPC (Smart Pixel-data Codec). This system configuration makes it possible to reproduce a 262,000 color equivalent image from 4,096 color equivalent compressed gray-scale data in the memory. **Fig. 4** shows an actual reproduced image read out from the SOG image frame memory.

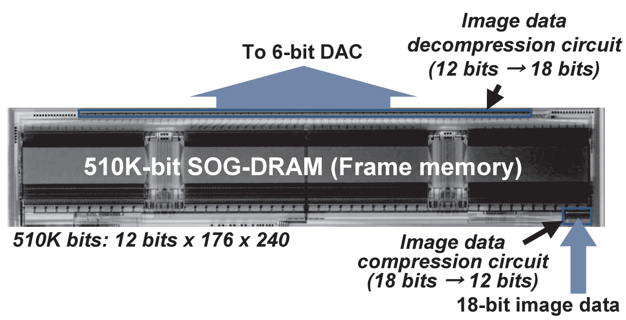


Photo 2 SOG image frame memory chip.

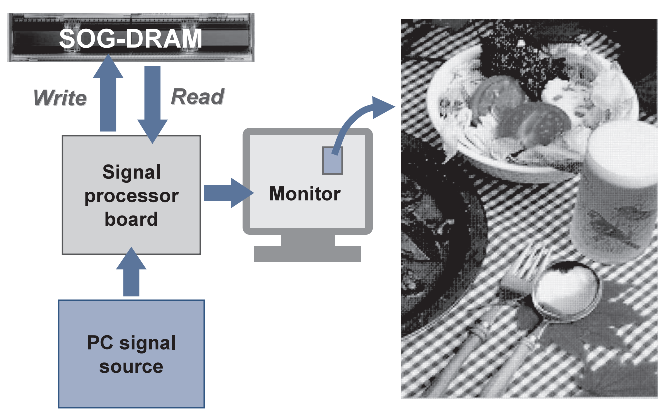


Fig. 4 Reproduced image read out from SOG-DRAM.

3.3 High Performance TFT Technology

In order to integrate advanced, large-scale functional circuits/systems such as the above described image frame memory and controller on a glass substrate, while at the same time ensuring that the area, circuit speeds and power consumption remain at practical levels, it is required to improve the p-Si TFT as well as to shrink the design rule. As part of the 3rd-generation SOG technology we developed a technique for significantly improving TFT performance by enlarging the crystalline grains of the p-Si thin film. The excimer laser annealing (ELA) technique is used for the crystallization of Si. We provided the laser beam with a unique, comb-shaped beam as shown in **Fig. 5** (a) and succeeded in obtaining continuous ribbon-shaped crystal grains with a width of 2μm[5]. These crystal grains were made possible by controlling the 2D thermal gradient during melt crystallization by means of the comb-shaped beam to reduce the sub-grain boundary that may be produced randomly. We fabricated TFTs using the position controlled crystalline grains actually obtained with this technique and achieved a high mobility of 677cm^2/Vs with the n-channel TFT and 230cm^2/Vs with the p-channel TFT (the mobility of conventional n-channel TFT is 100 to 150cm^2/Vs). This figure is high enough for the mobility of a TFT for use in the 3rd-generation SOG-LCD modules.

4. Conclusion

In the above, we introduced the SOG-LCD technology that has been developed by the NEC Corporation and NEC LCD Technologies, Ltd., in the context of the two major technological trends of image quality/function improvement and driver integration. NEC LCD Technologies, Ltd. is planning to start marketing SOG-LCDs in FY2006 and to sequentially introduce the SOG-LCD technology in their new products as reported herein. It is expected that the SOG-LCD technology will evolve further as one of the key technologies for the display devices of the Ubiquitous age.

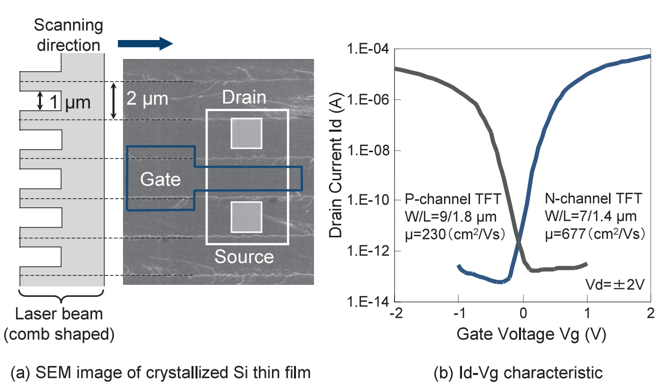


Fig. 5 Si thin film obtained with continuous crystal growth, and transistor characteristics.

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