Manufacturing and Inspection Equipment for Efficient Production of Large LCDs

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OVERVIEW: The range of applications for large LCDs is expanding from PCs to TVs and the international adoption of LCDs is being accelerated by the shift from analog to digital broadcasting and by their use as a replacement for CRTs. It is anticipated that the trend to larger LCD sizes for TVs will continue to be driven by innovations such as the adoption of LED backlights and 3D TV. Leading production lines already use very large mother glass substrates in the 9-m^2 range to achieve efficient production of LCDs at low-cost. As a leader in the field of tenth generation LCDs, Hitachi High-Technologies Corporation develops production, inspection, and other technologies and supplies a wide range of manufacturing equipment for LCDs capable of handling large glass sizes.

INTRODUCTION

THE market for LCDs (liquid crystal displays) continues to be characterized by rapidly falling prices and the use of LCDs in large-screen TVs (televisions). As LCD TVs become larger, it has become necessary for the production lines that manufacture them to adopt larger mother glass substrates and increase production speed both to increase screen size and reduce the production cost of panels. The most modern factories for producing large LCD panels typically operate production lines that use glass substrate sizes of 2,200 × 2,500 mm (eighth-generation) or 2,880 × 3,130 mm (tenth generation).

This article gives an overview of the manufacturing and inspection equipment used to achieve efficient production of large LCDs, particularly the exposure system used to manufacture color filters.

MANUFACTURING EQUIPMENT BEHIND ADVANCES IN LCDS

Mother glass substrates have grown in size because of the need to produce larger LCDs and achieve efficient production by producing multiple panels per substrate. The rapid progress made since 2000 has primarily been targeted at the manufacture of LCD TVs, with panels reaching sizes unimaginable in earlier times. The production equipment has also grown accordingly, increasing its size and weight, while technologies for processing large components with high precision and the problem of how to transport equipment to the production line and then reassemble and commission it so that this precision is maintained have become major issues.

The LCD production process can be broadly divided into the color filter process, array process, cell process, and module process, all four of which require efficient production machinery capable of handling even larger glass substrates. Hitachi High-Technologies Corporation offers a range of manufacturing and inspection equipment for large glass substrates that satisfies these market needs (see Fig. 1).

EXPOSURE SYSTEM FOR COLOR FILTERS

Evolution of Exposure System for Large Glass Substrates

In terms of area, the size of the latest tenth-generation mother glass substrates has grown by

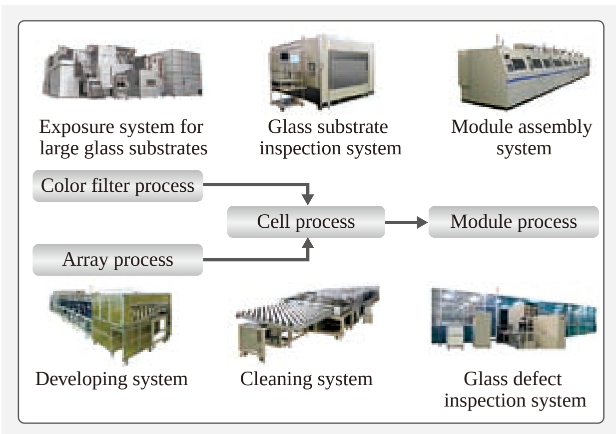


Fig. 1—Production Process and Equipment Range for LCDs.
TFT (thin film transistor) LCD (liquid crystal display) production consists of four processes, namely the color filter, array, cell, and module processes. Hitachi High-Technologies Corporation supplies manufacturing and inspection equipment for each of these processes.

a factor of more than 75 from the 300 × 400-mm first-generation substrates. However, the precision of color filter photolithography and the line cycle time have remained largely unchanged with each succeeding generation while high-speed processing and maintaining temperature and process uniformity over a wide area have become even more important.

Also, single-axis step exposure has been adopted in place of exposing the entire substrate at once to solve the problems caused by larger mask sizes, specifically higher cost and masks flexing under their own weight. For the fifth generation, Hitachi High-Technologies developed an industry-first XY step exposure system using proximity exposure. XY step exposure went on to become the industry standard in subsequent generations (see Fig. 2).

LE0300S Overview

In addition to faster control speed and the development of new features such as a high-intensity light source for exposure using the XY step method and a high-speed glass substrate transport mechanism to cope with the larger glass substrate size, the LE0300S exposure system for tenth-generation glass substrates also incorporates scaled-up versions of mechanisms used in previous models such as a pre-alignment technique, proximity gap control, and auto-alignment. The exposure system also helps improve yield and achieve efficient production with high quality through further features such as negative-pressure-type flexure compensation, various clean functions, and temperature control.

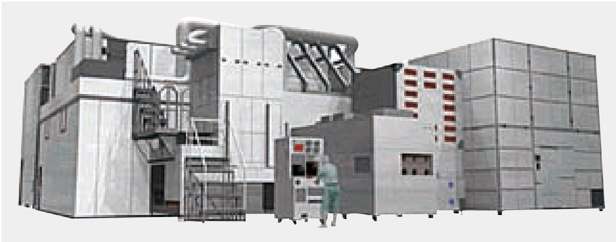


Fig. 3—LE0300S Exposure System for Large Glass Substrates.
A proximity exposure system that uses the XY step exposure method for tenth-generation LCDs is shown.

The product range also includes models designed for higher dimensional accuracy that incorporate a feedback function and a laser measuring unit for the first exposure used to form the black matrix (see Fig. 3).

Main Features of LE0300S

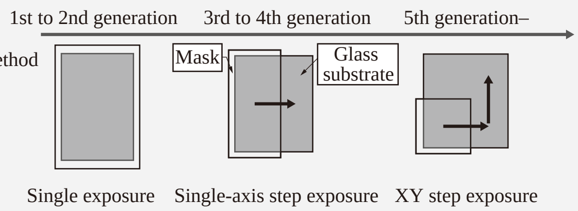
(1) High-speed, high-precision stage for large glass substrates

The large stage for tenth-generation substrates allows exposure to be performed over the entire extent of large glass substrates by providing high-speed and high-precision stepwise movement in both the X and Y directions.

		Mother glass substrate size (mm)	1st generation 300×400	2nd generation 400×500	3rd generation 550×650	4th generation 730×920	5th generation 1,100×1,300	6th generation 1,500×1,850	7th generation 1,950×2,250	8th generation 2,200×2,500	10th generation 2,880×3,130
		Time (year)	1988–	1993–	1996–	1999–	2002–	2004–	2005–	2006–	2009–
		Area relative to 1st generation	1	1.7	3	5.6	11.9	23.1	36.6	45.8	75.1
		Application	Notebook PC			Monitor			TV		
No. of panels per substrate	Standard panel	10.4 inch	2	4	6	16	35	66	110	126	216
		12.1 inch	1	2	6	9	25	49	77	96	154
		15 inch	1	2	4	6	16	30	42	63	99
		17 inch	—	1	2	6	12	25	40	48	80
	Wide panel	32 inch	—	—	—	2	3	8	12	18	24
		40 inch	—	—	—	1	2	4	8	8	18
		50 inch	—	—	—	—	1	2	3	6	8
		60 inch	—	—	—	—	—	2	2	3	8
		65 inch	—	—	—	—	—	2	2	3	6

(Aspect ratio is 4:3 for standard panels and 16:9 for wide panels)

Exposure method



PC: personal computer TV: television

Fig. 2—Evolution of Exposure Techniques and Larger Mother Glass Substrates.
Mother glass substrates are being made increasingly larger to produce larger LCD panels and improve production efficiency by increasing the number of panels per substrate. To keep pace with this increase in the size of mother glass substrates, exposure system have moved away from exposing the entire substrate at once toward use of XY step exposure.

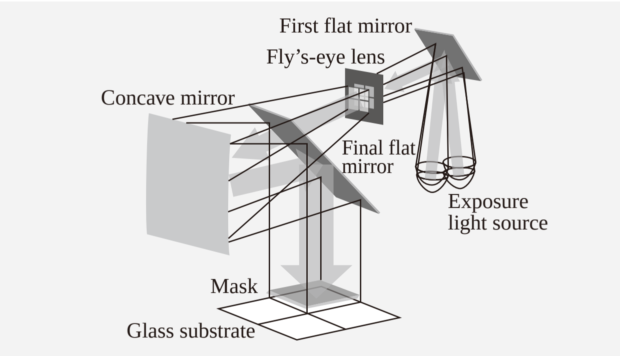


Fig. 4—Configuration of Exposure Projection System.
The light from the light source is reflected by the first flat mirror onto the fly's-eye lenses and then travels via the concave lens and final flat mirror to be projected onto the mask in the form of parallel rays.

(a) The number of steps can be set based on the size of the panels being produced.
(b) Although large enough to handle tenth-generation substrates, the stage has a split design to allow for transport and assembly.
(c) The split stage achieves both high precision and high speed thanks to the analysis-based design of each component in which simulation was used to predict and minimize deformation at the stage joints.

(2) Mask flatness

At 1,680 × 1,720 mm, the masks used for tenth-generation LCDs are 1.7 times larger than those for the eighth generation. The degree of pattern deformation is minimized to improve exposure accuracy by adopting negative-pressure-type flexure compensation in which a pressure differential between the upper and lower surfaces supports the mask so that it does not flex under its own weight. Also, the mask holder has been made lighter and its rigidity improved to achieve a level of flatness similar to that for eighth-generation masks.

(3) High-output exposure optics

The optical characteristics of the declination angle have been improved by lengthening the optical path in the optics. Changes to the exposure area are made easier by allowing the fly's-eye lenses to be switched in or out so that exposure can be performed efficiently based on the number of panels per substrate. A constant illumination control technique and a high-output light source using multiple lamps have also been adopted to handle the larger exposure area (see Fig. 4).

GLASS DEFECT INSPECTION SYSTEM

GK8000 Overview

LCD TVs are moving to 40-inch and larger sizes and it is anticipated that screens will become even larger in future. Meanwhile, the adoption of digital broadcasting means that TVs require higher resolution and better image quality and, as even very small flaws constitute a defect, preventing defects in the glass substrate and controlling foreign material in the production process are becoming increasingly important. In particular, along with the need for high-precision detection as glass substrates become larger and thinner there is also demand for faster inspection times. Hitachi High-Technologies offers a range of inspection products designed in response to these market needs including glass substrate defect inspection systems, glass substrate inspection systems, and in-line inspection systems.

Because of the need to inspect for and manage surface defects, internal bubbles, and other flaws in order to improve panel display quality and increase product yield for the liquid crystal glass substrates used to fabricate the TFTs (thin film transistors) in the array process, Hitachi High-Technologies developed the GK8000 glass defect inspection system to allow inspection of every substrate processed (see Fig. 5).

GK8000 Features

(1) Two different optical detection systems

(a) Defect detection optics

This optical detection system uses high-intensity laser light to find minute defects in the glass surface by detecting the tiny amount of diffraction

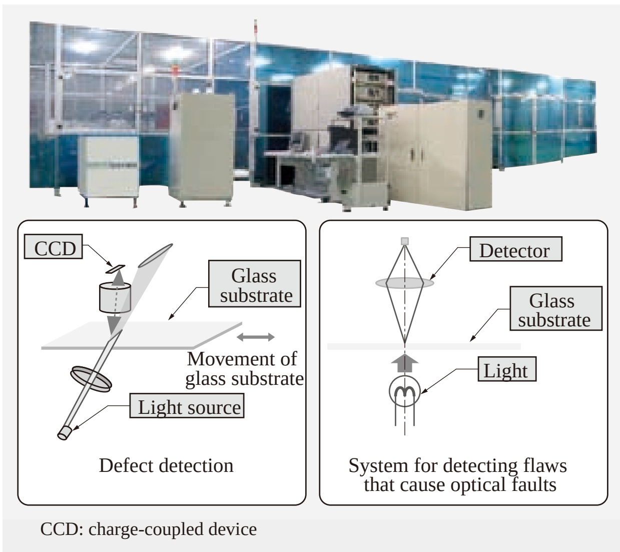


Fig. 5—GK8000 Glass Defect Inspection System and its Detection Mechanism.
A glass defect inspection system for eighth-generation LCDs is shown. The optical detection mechanisms include an optical system for detecting defects that affect the TFT circuits and a system for detecting flaws that affect the optics.

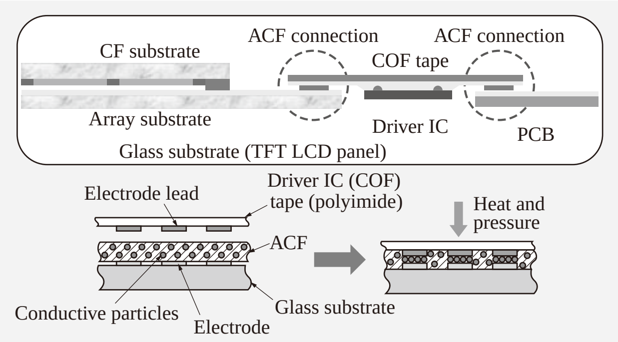


Fig. 6—Connection of Driver ICs to TFT LCD Panels.
ACF is used to connect the terminals of the LCD panel to the output pins of the driver IC. ACF is also used to connect the input pins of the driver IC to the PCB.

Fig. 7—AL/AB7000 Module Assembly System.
This module assembly system for the production of wide panels up to 57 inches in size is an integrated line able to perform all steps from driver IC to PCB mounting.

repeatability performance, being able to detect foreign material of 0.5 μm in size. The system also includes optics for selectively detecting upper side defects and an autofocus function that selectively detects upper surface flaws.

(b) Mechanism for detecting defects caused by optical flaws

This detection mechanism works in a similar way to a person visually inspecting a panel. The system uses the strength of light passing through the glass and the flaw size as criteria for judging pass or fail.

(2) High-speed operation

To ensure that all substrates are able to be inspected, it is important that the inspection is fast enough to keep pace with the production process. This is achieved in the following two ways.

(a) Use of a high-speed stage able to keep the large glass substrate stable while it is scanned at high speed

(b) Use of functions such as real time inspection in which fast data processing is achieved by using multiple CPUs (central processing units) for each optical system to ensure that the system has sufficient speed to inspect all eighth-generation substrates

AL/AB7000 SERIES MODULE ASSEMBLY SYSTEM

Overview of Module Process

In the module process, ACF (anisotropic conductive film) is used to electrically and mechanically connect the COF (chip on film) driver ICs (integrated circuits) to the LCD panel electrodes. ACF is also used to connect a PCB (printed circuit board) containing control, interface, and other circuits to the other COF electrodes. ACF is a film adhesive made from an insulating adhesive in which conductive particles with a diameter of several micrometers have been evenly dispersed.

After the ACF is applied to the LCD panel electrodes, the COFs are precisely aligned and then temporarily crimped in place and heated to prevent the ACF from peeling off or any shift in position. This is followed by a pressure bonding process in which heat and pressure are applied to harden the adhesive.

In the next process, ACF is used to connect the PCB to the other electrode of the COF. Next, the LCD module is completed by attaching additional components such as the backlight.

A micro wiring junction technique that uses ACF to mount the driver IC plays an important role in LCD module mounting (see Fig. 6).

AL/AB7000 Series Features

The features of the AL/AB7000 Series module assembly system for large LCD modules are listed below. The AL/AB7000 Series can handle production of wide panels up to 57 inches in size and Hitachi High-Technologies has supplied numerous systems to large panel manufacturers in Japan and elsewhere (see Fig. 7).

(1) Able to process large LCD panel sizes

The system provides a fully automated integrated line for production of wide panels up to 57 inches in size. The product range supports small, medium, and large panel sizes, including models for producing 47-, 37-, and 27-inch panels.

(2) Improved productivity

Because the same unit can mount both COG (chip on glass) and COF, the time taken to reconfigure for different products is significantly shortened. Similarly, long operating times are made possible by the "automatic exchange parts function" for COF/ACF tape and similar.

(3) Suitable for low-cost production

Material costs are significantly reduced by the adoption of a technique for high-speed sticking of segmented ACF.

CONCLUSIONS

This article has given an overview of the manufacturing and inspection equipment used for efficient production of large LCDs, particularly the exposure system used to manufacture color filters.

The LCD market continues to grow rapidly as prices fall. In this market, LCD panel manufacturers are earning a high return on investment and are undertaking mass production on eighth- and tenth-generation production lines able to produce low-cost panels. To improve productivity further, manufacturers are now planning the construction of the next generation of production lines which will use mother glass substrates that measure more than 3 m on each side. While this next generation of production lines will naturally require faster machinery with higher performance, it is also necessary to reduce total cost through measures such as modular machine configurations and the adoption of smaller equipment designed for lower production costs.

Hitachi High-Technologies Corporation intends to proceed with the development of technology for the next generation of process innovation as well as manufacturing and inspection equipment able to perform production with even greater efficiency, and to extend its range of equipment which utilizes technologies for the efficient production of large glass substrates into new fields such as organic EL (electroluminescence) and photovoltaic cells.

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