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Handling 300-mm Wafers

1997: Chip Market Grows,
Equipment Stays Even

UHV Pressure Control

New Negative-Tone Photoresists

Special Section: Flat Panel Displays

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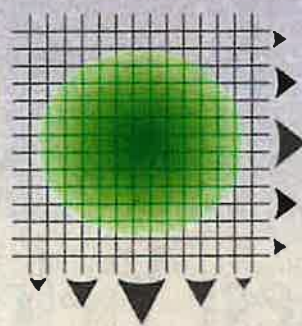
ROBOTICS

COVER ARTICLE

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Automation and control for 300-mm process tools

Mitchell A. Drew, Michael G. Hanssmann,
Dan Camporese



The 300-mm wafer presents new automation challenges. Larger wafers are heavier and require adjustments to wafer and cassette handlers, aligners, and box/pod handling systems. At the same time, large wafers increase the costs associated with scrap

and misprocessing, requiring improved reliability from both handling systems and process tools.

COVER PHOTO



Brooks Automation's batch wafer transfer arm loads and unloads 300-mm wafers from front-opening pod carriers into vacuum loadlock systems. Photo courtesy of Malcolm Hewitt.



Solid State Technology is celebrating its 40th anniversary this year. Our editorial staff is already hard at work preparing the May anniversary issue, to be packed with historical profiles and thought-provoking articles.

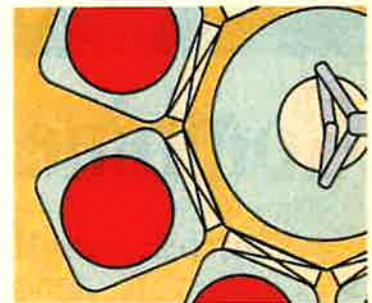
FEATURED

GASES/GAS HANDLING

67 Pressure control in a high vacuum multichamber system

Won Ick Jang, Jong Hyun Lee,
Jong Tae Baek

A new pressure control system for the transport chamber of a high vacuum multichamber system offers fast and precise operation for advanced semiconductor fabrication. It prevents back streaming of various contaminants from the process chambers, and cross-contamination between modules may be reduced by allowing wafers to be transferred at precisely controlled vacuum pressure.



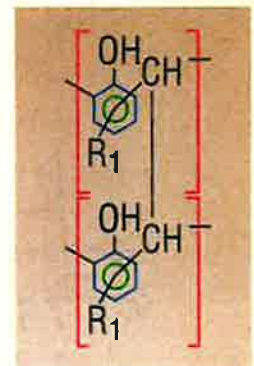
LITHOGRAPHY

EQUIPMENT FRONTIERS

79 New negative-tone photoresists avoid swelling and distortion

Gabi Gruetzner, Simone Fehlberg, Anja Voigt,
Bernd Loechel, Martina Rothe

A new series of negative-tone photoresist materials provides easy patterning, high resolution, protection for dry-etching while avoiding swelling and distortion. Steep edges and high aspect ratios of etched features can be achieved, making these photoresists ideal for lift-off techniques. Moreover, using a safe solvent such as ethyl lactate will allow the materials to meet increasingly stringent environmental requirements.



CONTINUED ON PAGE 5

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Electrostatic problems and ionization solutions in TFT-LCD production

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The liquid crystal display (LCD) has a multilayered structure combining insulating materials and electronic circuit devices. Since many LCD production methods involve friction, movement, and separation of materials, it is difficult to avoid static charge generation and the resulting problems of particle attraction and electrostatic discharge (ESD). This paper will describe the problems caused by static charge in LCD manufacturing and discuss control measures using ionization.

The LCD first appeared as the indicating device for watches and portable calculators in the 1970s. In recent years, it has been widely used for personal computers, video cameras, multimedia devices, portable televisions, video games, and other devices. The demand for a major improvement of picture quality from early displays is now being met by the thin-film transistor driven LCDs (TFT-LCDs).

Increased demand has resulted in a rapid expansion of existing manufacturing facilities in Japan and South Korea. The US Display Consortium is working to stimulate construction of new LCD facilities in the US. Meanwhile, demand for LCDs continues to exceed supply, particularly for the large-size displays used in personal computers and video monitors. Because TFT-LCD displays have relatively low yields compared to other electronic devices, increased production capacity will help meet demand, but costs will remain high.

Static electricity on the substrate of the LCD panel is a serious production hurdle. This substrate is glass, a good insulating material capable of both generating a high level of electrostatic charge and maintaining the charge for long periods of time. Problems caused by electrostatic charge are well known in the production of semiconductors, where contamination of product surfaces, product damage due to electrostatic discharge, and equipment operation problems can all result. The same sources of static charge, and resulting problems, occur in the production of LCDs. This "unseen contamination source" is frequently overlooked, however, and the problems caused by static charge are misunderstood.

Static charge generation

Whenever two surfaces in close contact are separated, one surface loses electrons and becomes positively charged, while the other surface gains electrons and becomes negatively charged. This phenomenon is known as triboelectric charging. While the net charge on the two surfaces together is still zero, two charged objects are formed when they are separated. If either of the two objects is conductive, it may contact ground and lose its charge. Once an object has become charged, it can also create, or "induce," charge on other nearby objects without actually touching them.

Once static charge has been created, it can also be directly transferred from one material to another by ESD. During the process of making LCDs, materials will become triboelectrically charged, will induce charges on other materials, and will cause damaging ESD events. Contamination and equipment malfunctions result [1, 2].

Static charge sources and effects

The structure of a typical TFT-LCD device is shown in Figure 1. TFT-LCD production is largely divided into two distinct areas. The array process creates the thin-film transistor driver system for the LCD and is very similar to a front-end semiconductor wafer process. The cell module assembly process, which is unique to

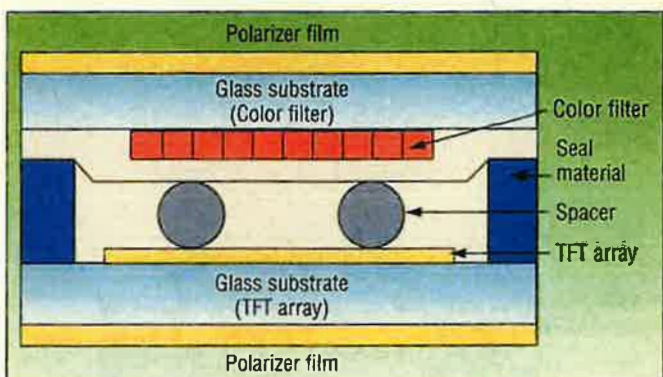


Figure 1. Structure of a TFT-LCD device.

Table 1. Methods of generating static charge in the LCD production process

Cause of static charge	Static potential (kV)	Charge generation method
Transfer by roller or belt	-1 to -2	Contact of different materials
Photoresist spinner	-2 to -3	
Rubbing process	-6 to > -10	
Seal printing	-0.2 to -3	
Deionized water rinse	-2	
Removal from vacuum chuck	-2 to -3	Separation of materials
Film removal (polarizer film or protection film)	-2	
Heating/cooling of hardener	-1 to -2	Thermal effects
Layers of glass substrate	-2 to -4	Pressure effects

LCD production, integrates all the components required for the finished display.

In the array process, static charge is often generated by the friction between photoresist coatings applied to the glass surface and deionized water spray rinses used for cleaning. In cell module assembly, static charge is generated by the pressure and separation of glass panels from vacuum chucks, the high-speed pads of rubbing treatments, and the laminating of plastic films. In general, any LCD production operation that involves friction and separation will generate static charge (Table 1).

In semiconductor production areas, the problems caused by static charge are well known. The problems caused in LCD production are similar. Despite cleanroom air filtration systems, particles are attracted to charged glass surfaces, causing defects. Both the product (LCD screens and TFT drivers) and the means to make the product (for example, robot handlers or photolithography reticles and photomasks) are vulnerable to damage from ESD. ESD events can create product damage like visible screen defects, vaporized metal lines, resistance changes, and oxide failures, and can also damage the fine metal lines of production items such as photomasks and reticles. Finally, ESD can interrupt the operation of the production equipment, causing errors to be made by microprocessor-based electronics and causing physical mishandling of the product [3] (Table 2).

Table 2. Problems caused by static charge in LCD production

Problem	Electrostatic phenomena
Random short circuits and point defects in TFT driver array	Contamination from particle attraction and bonding
Damage to polarizer film and driver transistors	ESD
Ink splashing during printing	Attraction and repulsion of charged materials
Nonuniform distribution of spacers	Movement due to electrostatic forces
Adhesion of glass substrates and unwanted movement	Attraction and movement of materials
Unwanted movement and contamination of polarizer film	Particle attraction and electrostatic forces

Measuring static charge during LCD production

Controlling static charge in LCD production requires an understanding of the mechanisms of charge generation, and their locations in the production process. Unless static charge control is included in production operations, lower yields and higher costs for all parts of the LCD production process will result.

The first steps in solving these static-related problems should be determining where the static charge is being generated, and what objects are becoming charged. The most common measuring method for static charge levels, particularly on large flat objects like glass panels, is the electric field strength meter (fieldmeter). The unit of charge measurement is coulombs, but the fieldmeter measures the electrostatic field produced by the charge in units of V/cm (V/in.). Since most fieldmeter measurements are made at a fixed distance of 2.54 cm (1 in.), the values in this paper are stated in V or kV.

In many situations during actual LCD production, it is difficult to obtain accurate measurements. LCD glass panels are commonly transferred by metal forks, robot arms, and rollers in the production equipment. Good engineering practice makes these items conductive and assures that they are well grounded. When these grounded materials are located near the charged glass panels, they will suppress the field from the charge, giving inaccurate, low measurements no matter how much charge is actually present [4].

Table 3. Variation of charge level during an LCD process

Location of glass panel	Static level (kV)
Before coating	0 to -1
After coating	+4
Prebaking	-3
After aligner	-0.5
On the robot fork	-0.2
Glass in the unloader cassette	-6

Electric field strength measurements are also difficult when other charged objects are present. Fieldmeters typically make measurements of the net electric field from an area 75 mm (3 in.) in dia. Nearby charged objects, whatever the polarity, will affect this measurement.

Since most LCD processes occur within production equipment, measurements are typically made at the load and unload stations. High electrostatic potentials are found on the glass substrates as well as their carrier cassettes. The polarity of static charges on the substrates often changes during processing, indicating that static charging is occurring within the production equipment.

Table 3 shows the actual measurement results obtained at a number of steps in the LCD photolithography process. The variation in static charge levels during the various steps is especially important. Due to the effects of field suppression and other polarity charges, measurements have likely understated the actual levels of static charge present on the glass panels.

Different values for the field due to static charge may be observed as the measurement location and other measurement conditions change. Fortunately, accurate measurements are not of primary importance. The most important measurement is the change in the static charge level (or field strength, or potential) that occurs due to movement, separation, friction, heating, or cooling throughout the entire LCD production process. By making measurements under a variety of conditions, it is possible to determine the

mechanism responsible for generating the high static charges, and to estimate the magnitude of the static charge that might be affecting the production process. Static charge levels in production are frequently higher than reported in this paper.

Static control measures using ionization

The generation and storage of static charge during LCD production occurs primarily on the glass panels themselves, although other objects may also be charged. Neutralizing static charge on an insulator like glass requires air or nitrogen gas ionization, particularly in cleanrooms.

Air ionization is recognized as the most effective means of neutralizing static charge on glass panels and is widely used in the LCD production process. High production speeds are required to achieve profitability, often meaning that ionizers must reduce the static potentials at any particular location in a very short period of time. To neutralize high levels of static charge in short periods of time, a high density of air ions must be supplied, and ionizers must be installed as close as possible to the charged glass panels.

Applications of ionizers

In LCD production, unlike semiconductor fabrication, there are no established levels at which problems caused by static charge can be prevented. Each situation must be analyzed to determine at what level the static disappears. The following examples illustrate the use of air ionization to solve static problems in both the array and cell module assembly processes of LCD production.

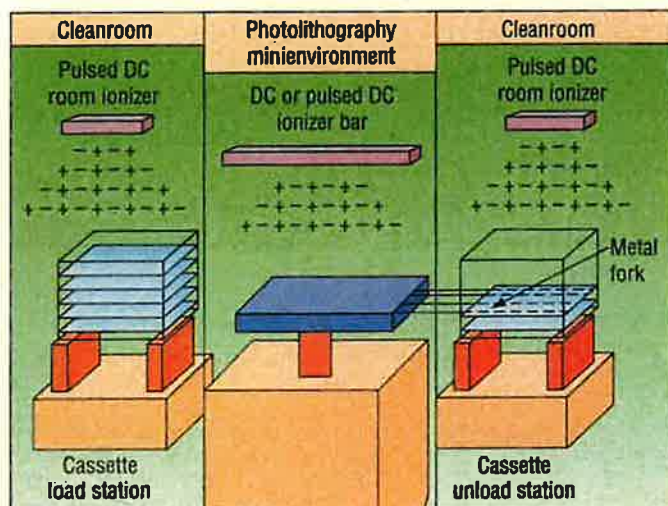


Figure 2. Typical LCD photolithography process.

Photolithography process. During the photolithography process, patterns required for the transistor driver array are created on the glass panels (Fig. 2). For precision, the glass panel is positioned and fixed on a metal stage by means of a vacuum chuck. This movement, and the high pressure between the stage and glass due to the vacuum, generate a high level of static charge (Table 4). Objects coming close to the glass surface cause ESD events, damaging the photoresist patterns.

A DC ionizer with the ability to separately adjust the positive and negative ion output levels was used for this application. The static charge on the glass panel appeared to be essentially monopolar and negative. To provide high production speeds and fast static decay times, the ionizer was adjusted for a high positive ion output. The level of negative ionization was much lower,

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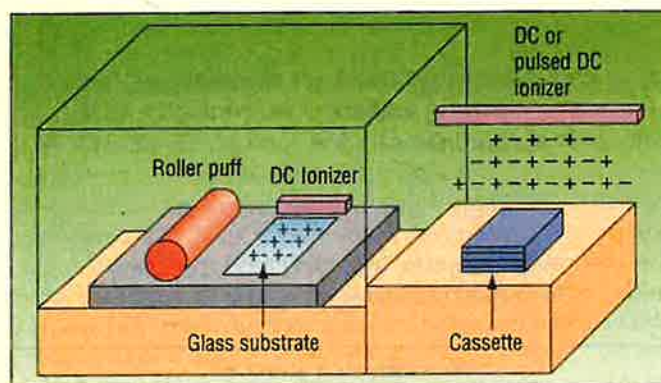
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Table 4. Variation of charge level during a photolithography process

Measurement location	Static level (kV)
Glass in the loader cassette	-3.8
Glass in the unloader cassette	-16.4
Glass in either cassette after ionization	<0.1

but sufficient to prevent recharging of the glass panel to the opposite polarity by the positive ionization. Results with ionization are also shown in Table 4.

Rubbing process. The rubbing process is unique to LCD production. A roller puff revolving at high speed rubs the glass substrate to form the "twisted nematic liquid crystal" that serves as a light valve (Fig. 3). The process generates a high level of static charge that subsequently causes damaging ESD events. The most serious ESD problems occur when the charged glass panel is lifted from the metal stage on which the rubbing process occurred.

**Figure 3.** Typical LCD rubbing process.**Table 5. Charge level reduction in a rubbing process**

Condition	Static level (kV)
Glass panel without ionization	> -10
Glass panel using ionization	< -2

Table 6. Charge level reduction in a seal-printing process

Condition	Static level (kV)
Glass panel without ionization	-3
Glass panel using ionization	-0.2

Ionizers used in the equipment during the rubbing process reduced the static charge level enough to prevent ESD events from occurring when the glass was lifted from the metal stage for transfer to the next production step. Measurements at two locations are summarized in Table 5.

Seal-printing process. Seal printing, also unique to LCD production, involves the application of an ink to the glass substrate using a roller printer. The pressure and movement of the roller on the glass creates a static charge, which causes the ink to move, creating a "splashing" defect on the pattern of the substrate.

Reducing static charge levels with air ionization eliminated this problem. Results are shown in Table 6.

Conclusion

Due to friction, separation, rubbing, and thermal effects, it is almost impossible to avoid generating static charge throughout the LCD production process. The result is product yield loss due to damaging ESD events, equipment malfunctions, and particle deposition on the LCD surface.

Measures available to eliminate static charge are restricted by the size and insulating properties of the glass substrates, limited humidity requirements of the production process, and cleanroom requirements for eliminating chemical and particle contamination. High humidity, chemical antistatic solutions, and carbon-loaded static dissipative materials are not available.

Under these restricted conditions, ionization is an effective and indispensable tool for solving electrostatic problems in LCD production. As with any other application of ionizers, the ionizer balance must be adjusted and controlled to levels suitable for each particular process. ■

Acknowledgment

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