Applications of Maskless Lithography for the Production of Large Area Substrates Using the SF-100 ELITE

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Executive Summary

Processing solutions using the SF-100 ELITE for fabrication of large area substrates, such as photovoltaic devices and flat panel displays, are presented. These solutions include unique processes, such as substrate numbering, where a solution is provided that fits easily into existing lithography processes. Also, the SF-100 ELITE can be used to offload non-critical processes from expensive substrate steppers, increasing the capacity of the steppers without major capital investment. Processes here include edge bead removal, interconnect fabrication, and contact hole processing.

The main advantages of using the SF-100 ELITE for these processes include:

- Maskless processing to reduce overall costs and provide flexibility,
- Scalable automation which results in lower capital costs,
- Proven design provides reliable solutions,
- Flexibility to vary pixel size using the standard optics, and
- Open system design provides easy integration with robotics for cassette to cassette processing.

Introduction

Large, rectangular substrates are often used in the fabrication of modern photovoltaic devices and flat panel displays. In order to make these devices cost effectively, thin film processes used in semiconductor manufacturing are often employed. These processes typically transfer well, however, due to the size and shape of the larger substrates, thin film processing equipment for these applications are often very expensive.

One method for reducing manufacturing costs in these areas is to use more cost effective equipment for less critical process steps. Examples of this mix and match strategy in the area of photolithography are discussed below. Since the cost of a stepper used in the fabrication of large rectangular substrates can be well over $5MM US, the use of a more cost effective maskless lithography system for specific process steps can save the user significant capital investment and reduce operational costs drastically.

The SF-100 ELITE Maskless Lithography System

The SF-100 ELITE is an elegantly simple, easy to use micro patterning system. Through it's unique patented design, the system allows users to fabricate microdevices quickly and easily.

Smart Filter Technology provides the means for easy and efficient optical processing utilizing the SF-100 ELITE. This technique utilizes reflective microoptoelectromechanical (MOEM*)* elements to spatially modulate light such that light can be controlled on the several micron sized regime, simultaneously over a 14mm x11mm field of view. Each SF-100 ELITE system includes a Smart Filter subassembly that incorporates all of the hardware and control software needed to produce these images in real time.

Figure 1 shows a schematic of the SF-100 ELITE. Designs are drawn using conventional engineering design or drawing programs. These designs are then transferred to SF-100 ELITE host computer for use on the system. The computer is a standard personal computer that provides dual video output, one to the computer monitor and the other to the Smart Filter subassembly. The Smart Filter then modulates the appropriate MOEM elements which are used to produce the pattern.

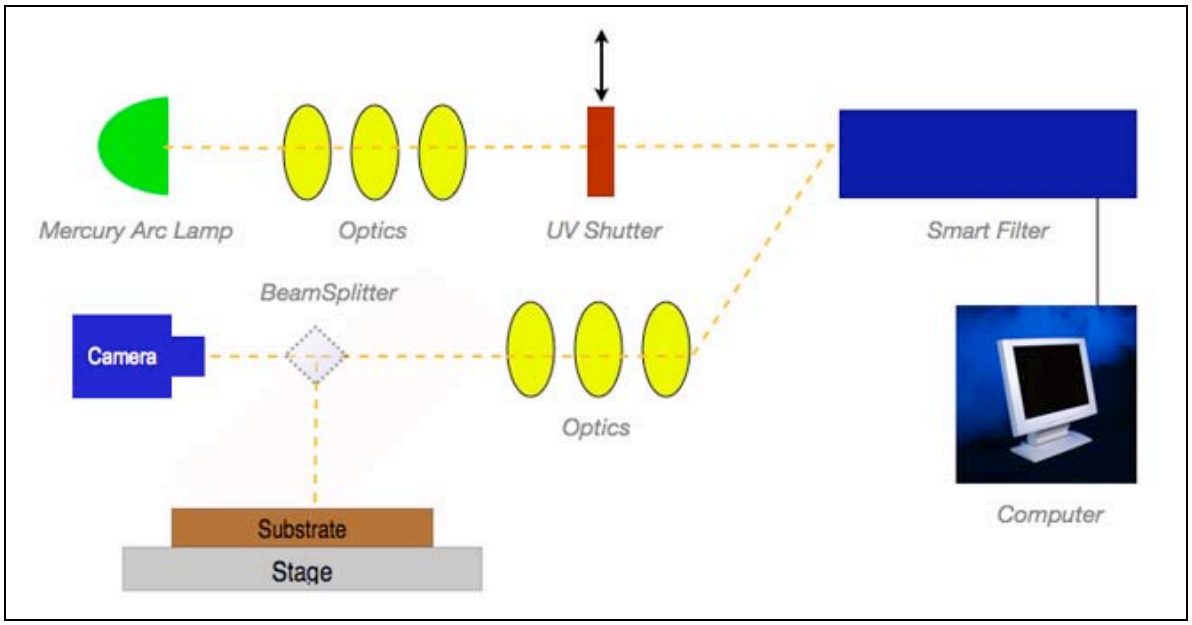

Figure 1-A Schematic Representation of an SF-100 ELITE Maskless Lithography System

A mercury arc lamp is the source of optical energy for the SF-100 ELITE. Since g-line (435 nm), h-line (405 nm), and i-line (365 nm) energies are transmitted to the substrate surface, many standard optical materials are compatible with the SF-100 ELITE. Light

energy passes from the lamp to the Smart Filter subassembly through a variety of optical components needed to provide collimated and uniform energy over the entire exposure area. The light reflects off of the Smart Filter assembly to provide the optical pattern. After passing through additional optical components, the pattern is projected onto the substrate. The SF-100 ELITE includes an alignment fixture for mounting of the substrate. This allows the substrate to be moved in three dimensions, providing alignment in two, coplanar dimensions and the capability to produce three dimensional structures by aligning the substrate in a third dimension perpendicular to the two coplanar dimensions. An inline camera is used for feature registration .

A UV filter shutter is included in the light path to provide for image to substrate alignment. This filter is normally located in the optical path allowing for viewing of the image on the substrate. By filtering all UV energy, the substrate can be aligned to the projected image without exposing the substrate. After the substrate has been placed in the appropriate position, the filter is removed from the light path through computer controlled actuation of the filter. All of the energy from the mercury arc lamp is then projected onto the substrate, facilitating exposure of the substrate. The length of time that the filter is removed from the light path is a user provided setting in the software.

A complete SF-100 ELITE system is shown below in Figure 2.

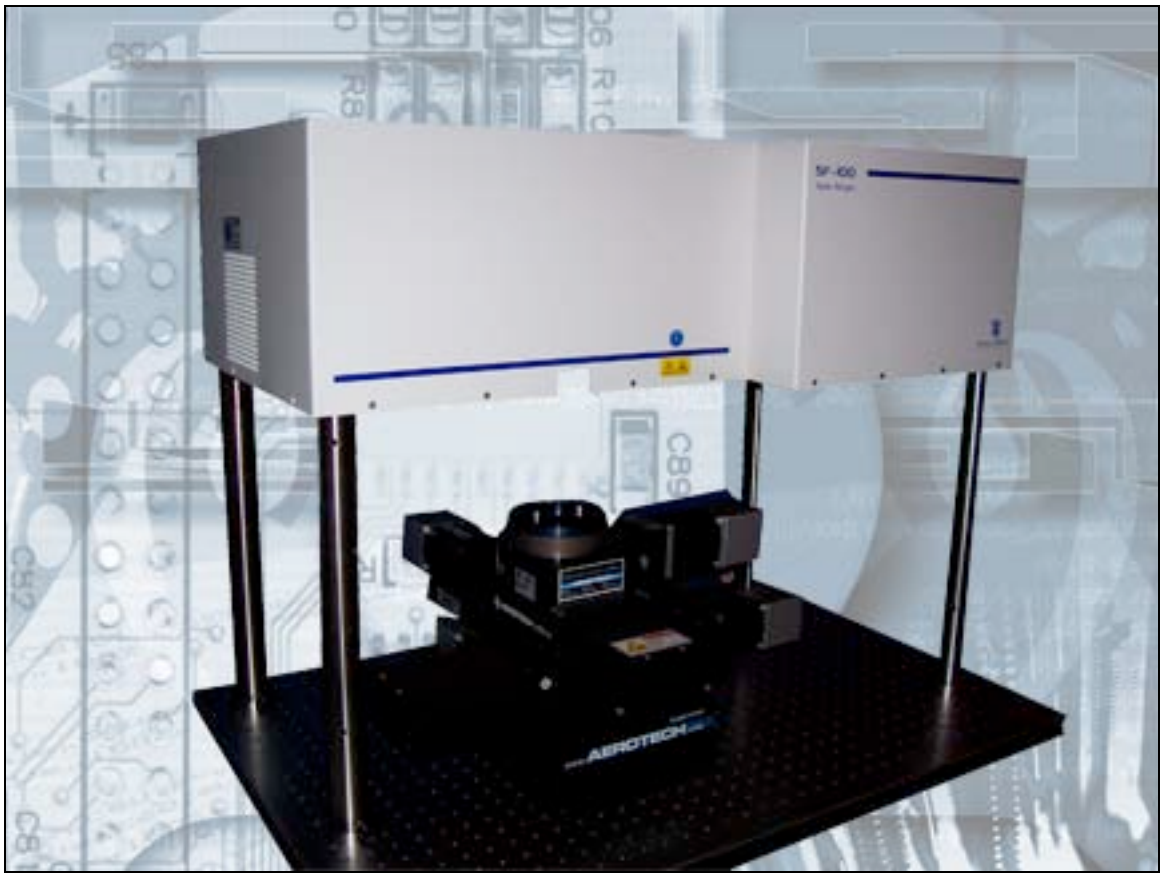

Figure 2-An SF-100 ELITE Maskless Lithography System

Incorporation of this system into a large area substrate production facility often requires automated loading due to the large, fragile nature of the substrates. This is easily accomplished through the integration of the SF-100 ELITE with a commercial atmospheric robotic substrate handler. Combining this robot with a simple mechanical aligner, substrates can be repeatably and automatically removed from a cassette and placed on the XY stage for exposure. After completion of the exposure step, the robot returns the processed substrate to the cassette and repeats the load/unload sequence for the remainder of the substrates in the cassette.

Applications of the SF-100 ELITE

A number of value added applications have been developed for the SF-100 ELITE, in the areas of photovoltaic and flat panel fabrication. These include substrate identification, edge bead removal, and other non-critical processes.

Substrate Identification

Laser identification systems are often used to serialize individual plates. The process flow for this marking process requires 3 steps:

- Coating the substrate with a protective layer of photoresist,
- Laser marking the substrate, and
- Stripping of the protective layer of photoresist.

The protective layer of photoresist is required due to the redeposition of substrate material that is removed during the laser machining of the identification on each plate.

Replacing laser inscriptions with a photoresist lithography process requires only a single additional process step to an existing lithography process. Since the SF-100 ELITE provides g-, h-, and i-line energies at the substrate, the labeling exposure from this piece of equipment can be dropped into a standard photolithography process before any photoresist exposure step. Through this integration, the numbers are exposed into the photoresist and then later imparted into the substrate through a subsequent etch or deposition step. The numbers are thus integrated into the device using existing equipment and processes and the potential for device contamination from the laser redeposition is eliminated.

Examples of identifiers produced with this method are shown below in Figure 3.

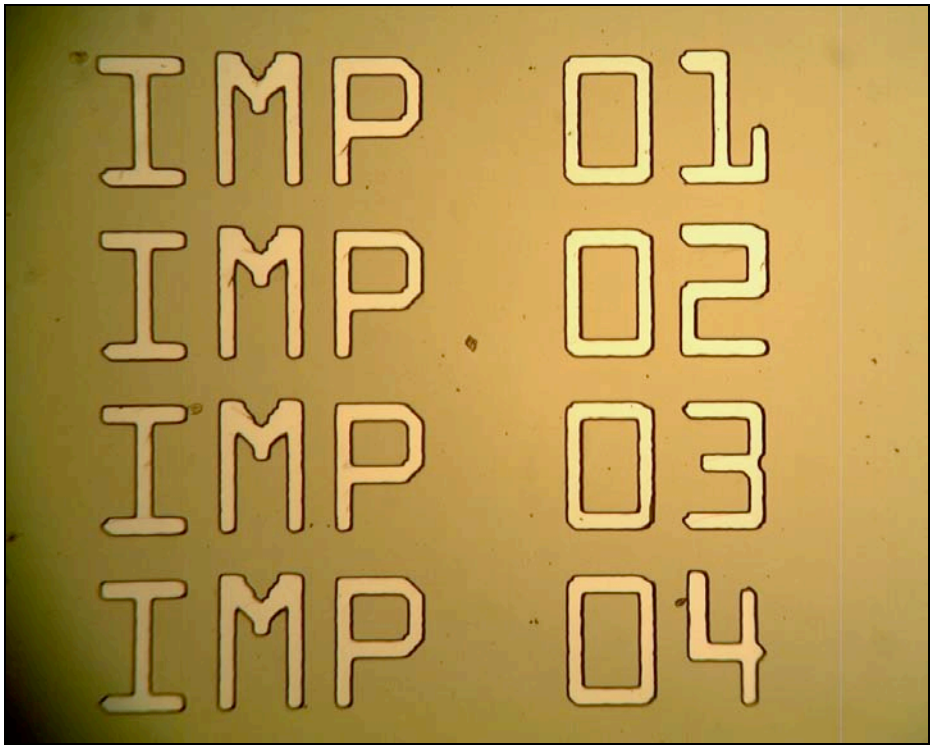

Figure 3-Individual Panel Identification Exposed on the SF-100 ELITE

The markers shown in Figure 3 are fully compatible with SEMI standards M12 and M13. Additionally, they are automatically indexed to prevent mis-marking and repeat numbering. Through variation of the pixel size, they can be scaled as needed for identification using either an automated camera or the human eye. The pre-number string is fully user configurable, so information on the company, processing line, or any other critical data can be included in the substrate marking. Finally, the font can be varied as required by the user through a simple software setting and even bar codes can be implemented.

Edge Bead Removal

When processing round substrates, such as silicon wafers, photoresist edge beads are easily removed on the coating track during resist spinning. This removal is required to reduce particulate contamination and expose the edge for electrical or environmental reasons. The inline edge bead removal is not available when processing square substrates. Hence, photoresist exposure is often used to remove positive photoresist from the edge of rectangular substrates.

Using a stepper to remove the edge photoresist is a very expensive process. Additionally, the size of the edge bead to be removed is controlled through either the fixed size of the

exposure field of the stepper or the use of a mask specifically made to provide the edge profile, limiting user flexibility and increasing processing costs.

Maskless lithography on the SF-100 ELITE provides a more cost effective and controllable method for doing this process. Exposures are still needed to remove unwanted photoresist edge beads, however, the maskless process provides a number of advantages over the stepper process, including:

- Easy variation of the size of the edge bead. This can be varied on an individual design basis, without the need to fabricate expensive photomasks.
- Using the SF-100 ELITE for this process frees up valuable time on the more expensive stepper, thereby increasing it's capacity with minimal cost.
- Through the implementation of greyscale processing, which is standard on the SF-100 ELITE, the photoresist thickness profile can be contoured specifically for each device design. This capability is provided as standard on the SF-100 ELITE and does not require photomasks.

Other Processes for the SF-100 ELITE

Since the SF-100 ELITE is compatible with most standard photoresist materials, the system can also be used to pattern less critical FEOL processes, which require large minimum features. Through variation of the system's pixel size, the system can be set up for patterning of many different features, such as large contact pads, interconnects, or via type processes. All are easily handled by the software, so the user can take full advantage of the system's automated capabilities and ease of use.

Summary

In summary, the SF-100 ELITE provides a cost effective, simply reliable maskless exposure system for the fabrication of photovoltaic and flat panel devices. The system can be used in a mix and match approach to offload work from expensive steppers and other high end processing equipment, so customers can maximize their investment capital to produce low cost devices.

For more information on the SF-100 ELITE or Intelligent Micro Patterning LLC, please go to www.intelligentmp.com