

Scanning Projection Lithography for Large Area Substrates

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Biography

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Abstract

Intermediate resolution projection lithography tools are now available for the wide range of substrate sizes used in the manufacture of AMLCD, EL, FED, plasma displays, and MCMs. These systems provide optical resolution down to 4 microns, and accommodate substrate sizes up to 840 x 1025 mm. This paper outlines the basic design concepts of scanning projection systems, and reviews performance results for the newest tool in the series, the Model 340.

Introduction

Photolithography is an area of significant cost in the manufacture of flat panel displays (FPDs). Following the semiconductor manufacturing model, FPD lithography tools evolved from contact/proximity printing in the early stages to projection printing in the 1970s. The relatively low yields of contact printers quickly proved unacceptable for large scale production of displays. The main problem was rapid degradation of the mask, which frequently became contaminated with particles from the substrate it contacted. Proximity printers reduced but did not eliminate this problem.

Projection tool development followed two distinct paths: step and repeat, and one dimensional scanning projection. Step and repeat systems utilize small 5 inch or 6 inch reticles which are used to photocompose the circuitry on substrates (mother glass) containing one or more panels. This process of photocomposing requires

the utilization of several reticles printing small rectangular areas which are stitched together to complete the display. One dimensional scanning is accomplished with a slit-shaped exposure field which is scanned across the mask, and the pattern is transferred by the projection optics in a 1:1 manner onto the substrate

Step and repeat and one dimensional scanning operations are inherently expensive. Specifically, step and repeat systems require very precise X-Y stages which must have a range of travel equal to the X and Y dimensions of the substrate. This results in the need for laser interferometry in the positional control loop, which becomes increasingly costly when applied to long two-dimensional travels. Scanning projection in one dimension requires very sophisticated optics which must yield large field images free of distortion. Since the underlying covenant is to avoid stitching procedures, the exposure field has to be at least as long as the shorter dimension of the substrate. Scaling this type of tool to match the increasing size of substrates drives the cost to very high levels and makes exposure of large one meter panels virtually impossible. Convergence of these two technologies has produced step and scan tools which have been introduced recently. Their performance specifications are similar to those of tools based on one or the other parent technology, and since these tools retain some form of complex stage control and high end optics, no large cost advantages are immediately apparent.

Scanning Projection Lithography

An elegant way to avoid premature mask degradation, while maintaining a moderate level of capital expenditure is two dimensional scanning projection lithography. This technology has been described previously in recent papers ^(1 - 3). In

brief, a mask of the same size as the substrate is *continuously scanned* through the image plane of a non-inverting 1:1 projection system, which constantly projects a small fraction of the mask image onto an equally sized fraction of the substrate as shown on *Figure 1*. The substrate is mounted on the same stage as the mask, so that the mask image always falls onto the correct substrate location.

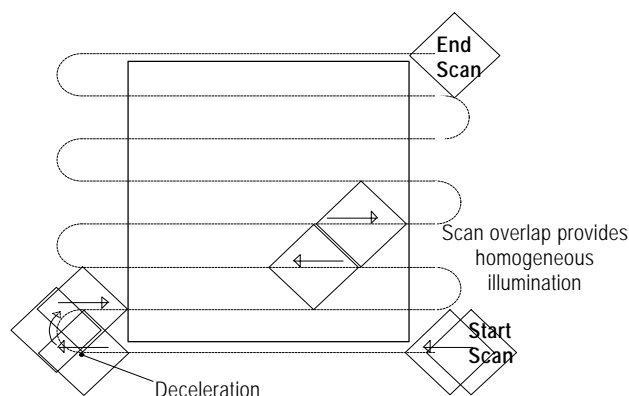


Figure 1

The mask and substrate are separated from each other by 250 mm, so that any mask damage during exposure is virtually eliminated. See *Figure 2*. The scanning operation will progressively expose the entire substrate, and is adjustable to any substrate size within the mechanical limits of the tool. The new Model 340 Scanning Exposure Tool described in this paper is targeted at fabs using generation 3 and 3.5 mother glass, providing the ability to expose substrates up to 650 by 830 mm.

Scanning Projection System

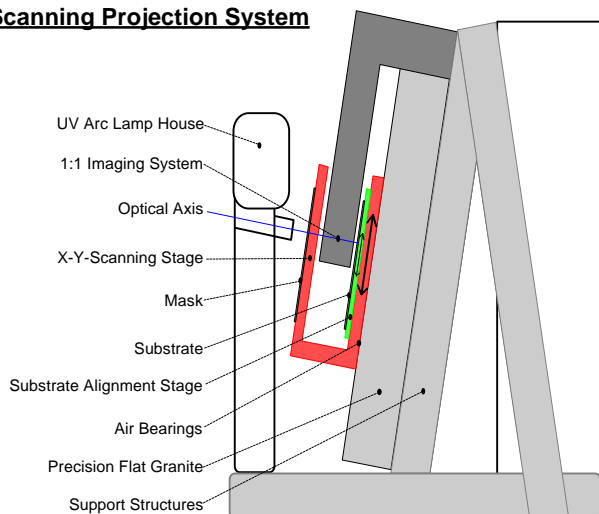


Figure 2

Intermediate Resolution

In the semiconductor industry, the high cost of excimer-laser-based step and repeat lithography tools caused several manufacturers to adopt a “mix-and-match” strategy, using high-throughput steppers for their non-critical layers. With this strategy, critical sub-micron levels are produced on excimer-based steppers, and the less critical levels are produced on a 1:1 lithography tool that employs a Dyson catadioptric lens system.

In the flat panel industry, step and repeat projection tools (with field stitching) are now the dominant force for manufacturing active matrix liquid crystal displays which require 1.5 micron resolution for critical transistor levels, but less resolution for traces and transparent electrodes ⁽⁴⁾. A similar mix of requirements exists in the fabrication of FEDs. The global market size for FPDs is expected to exceed \$22 billion by the year 2000 ⁽⁵⁾. This rapidly growing market includes AMLCD, EL, FED, and PDP technologies. The ensuing competitive pressures will create strong demand for cost effective manufacturing solutions. In lithography, intermediate resolution tools with large area capability can meet this demand.

The mix-and-match strategy applies to the manufacture of FPDs which have critical and non-critical levels of lithography. The non-critical levels can be economically fabricated using an intermediate resolution tool, such as a scanning projection system which is capable of resolution ≥ 4 microns and alignment accuracy of ± 2 microns. The resolution requirements for electroluminescent (EL) and plasma (PDP) displays are greater than 4 microns; therefore, intermediate resolution scanning projection can meet 100% of the requirements for patterning these devices. Scanning projection can also be used for the production of pixelated color filters that require resolutions greater than 4 microns.

Development

Several major advances were pursued during the Model 340 development program. In particular

the capability of scan exposing a 650 x 830 mm panel was addressed by increasing the size of the tool significantly as compared to its first generation predecessor, but keeping its foot print at a space saving 2.81 x 2.26 meters (9.2 x 7.4 feet). Throughput for the large area format was increased by adopting an enhanced version of a lens initially developed for the Model 350 (a one meter panel tool developed in conjunction with the USDC) and by increasing the maximum scan speed by 50% compared to the first generation tool. The new lens has two times the field size of the original. Its numerical aperture was also expanded to 0.15, in addition to being variable from 0.07 to 0.15. This variability of the numerical aperture of the projection lens allows the process engineer to optimize his process for depth of focus and resolution. Illumination intensity was also increased by utilizing a 2000 watt Hg arc source with variable partial coherence and zoom capability.

The illumination and projection lens systems are broad-band corrected. Filters are available for I, I+H, H+G, and G line to tailor the UV radiation to optimize the process for a wide variety of resist materials.

Due to its highly modular design, this tool can be easily configured for laser ablation, substrate compaction compensation, and automatic substrate loading from cassettes or conveyor systems.

Initial test data shows resolution in the 3 to 4 micron range with depth of focus $\geq \pm 15$ microns using 2.5 micron Shipley 1808 resist. Measured alignment accuracy: $\leq \pm 2$ microns. Throughput numbers for 550 x 650 mm substrates: total scan time using 150 mj/cm² resist is less than 27 seconds. When fitted with a dedicated pick and place substrate loading system, the throughput is expected to average 60 panels per hour @ 150 mj/cm².

Conclusion

An expanded line of scanning projection lithography tools is now available for stand alone use or integration into a mix-and-match environment. Its simple design brings the option of intermediate resolution at a moderate initial

capital expenditure to an industry faced with escalating costs and increasing competitive pressures. The trend toward increased availability of high quality large area masks will further reduce the cost of ownership of these tools⁽⁶⁾.

References

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Acknowledgments

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