

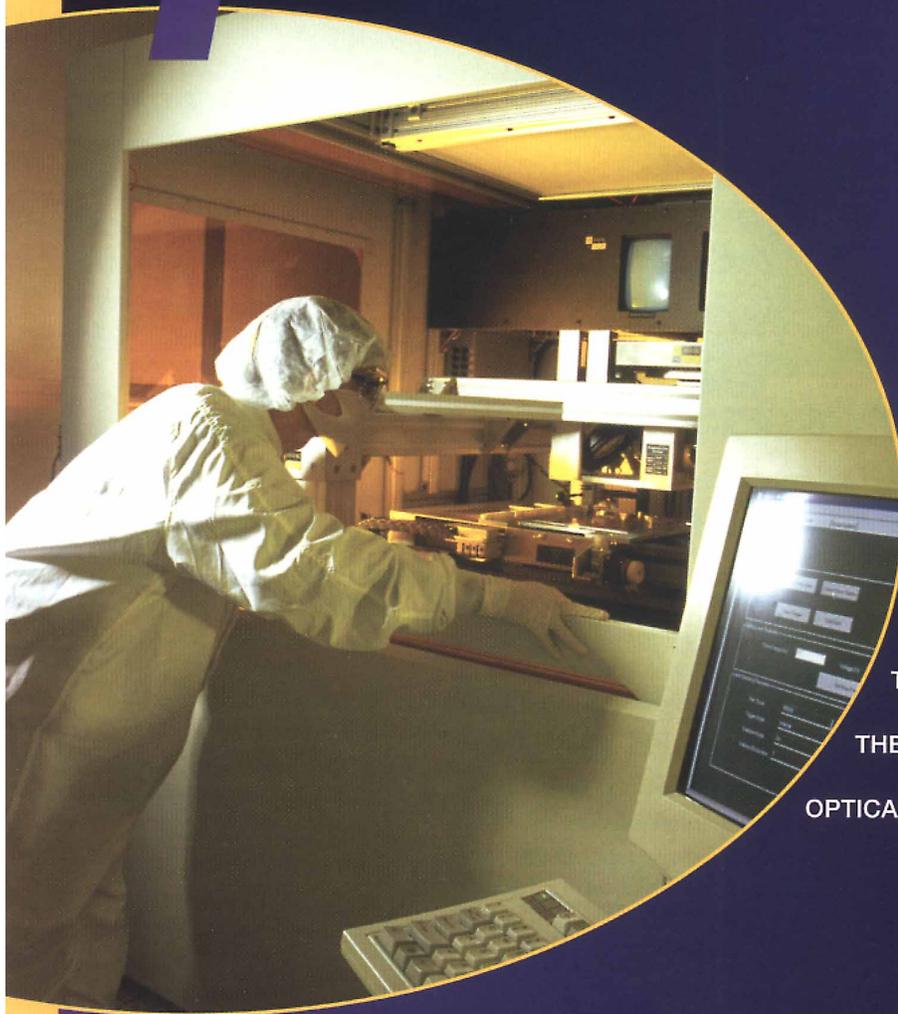
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# Microlithography WORLD<sup>®</sup>

Volume 11 • Number 3



LIFT-OFF LITHOGRAPHY

LARGE-AREA PATTERNING

THE LITHO EXPERT: LATITUDE

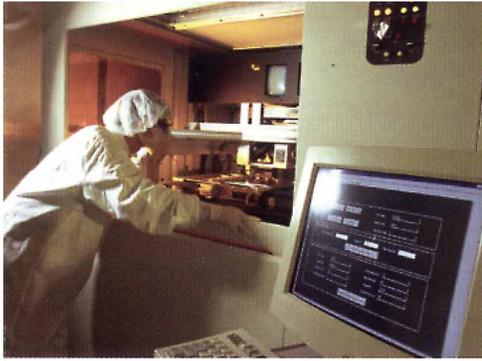
THE FUTURE OF THE CD-SEM

OPTICAL RETICLE WRITING

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## COVER

The Anvik HexScan large-area, dual-function, projection lithography and photoablation system is designed for high-resolution, high-throughput patterning for production of microelectronics, optoelectronics, and MEMS devices.  
*Photo courtesy of Anvik*

## COVER ARTICLE

# Large-area excimer laser lithography and photoablation systems

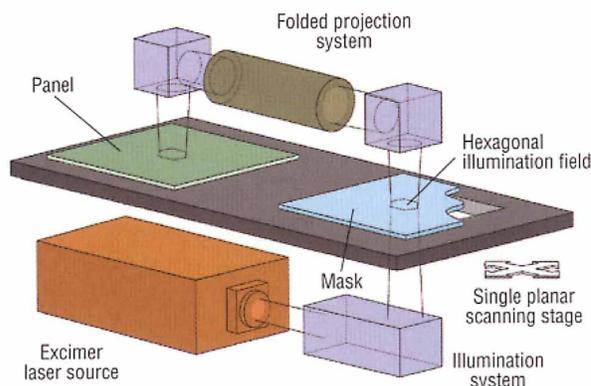
K. Jain, M. Zemel, M. Klosner, *Anvik Corp., Hawthorne, New York*

Many microelectronic, optoelectronic, and microsystem devices require large-area patterning with moderately high image resolution and precise alignment. A new class of projection lithography systems using excimer laser sources pattern photoresists as well as photoablate polymers for large-format products, with feature sizes from  $15\mu\text{m}$  to below  $1\mu\text{m}$  and substrate sizes from  $150\times 150\text{mm}$  to  $610\times 915\text{mm}$ .

Large-area lithography is an important requirement in the production of numerous microelectronic, optoelectronic, and microsystem devices. The lithography requirements for the fabrication of such large-format products are distinctly different from those of semiconductor ICs, and require a new class of projection lithography systems that provide both moderately high-resolution imaging and very large exposure area capability.

In the world of displays, patterning  $1\mu\text{m}$  features is considered "high resolution," but for ICs even  $0.25\mu\text{m}$  lithography barely qualifies as

(Left) The Anvik HexScan large-area, dual-function, projection lithography and photoablation system.

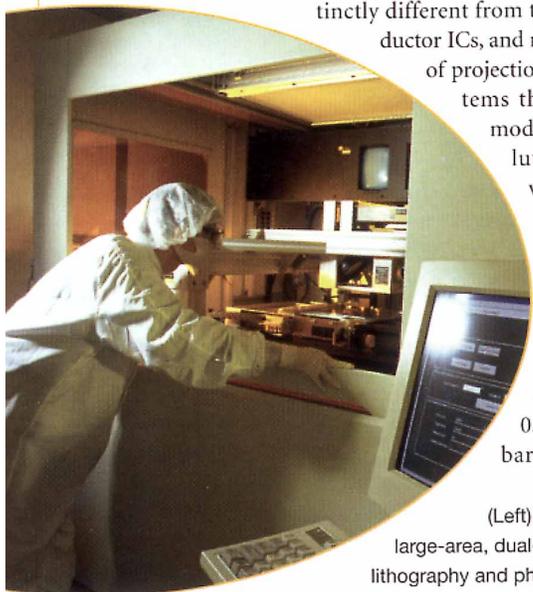


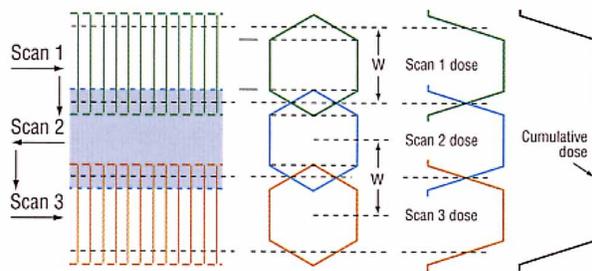
**FIGURE 1.** Illustration of large-area projection lithography technology, showing seamless scanning with a single-planar stage and hexagonal illumination beam.

leading edge. The highest-density flexible electronics and printed circuit boards are beginning to use  $\sim 20\mu\text{m}$  features on fields that are  $150\text{mm}$  and larger. Thus, although it is customary to focus on the minimum printable feature size when discussing resolution, it is equally important to consider the size of the substrate over which the resolution is being achieved.

Common IC exposure tools, including steppers, scanners, contact printers, and direct-writers, have various shortcomings, including limited substrate size capability, low throughput, prevalent stitching errors, high system cost, limited resolution, poor yield, mask life degradation, and insufficient power to drill multiple vias simultaneously. A new class of large-format exposure tools overcomes these limitations using a large-area laser projection lithography technology.

New products, such as flat panel displays and advanced chip packages, require advanced patterning, but conventional exposure tools are approaching the end of their capabilities. For example, advances in contact printers have enabled them to print  $\sim 25\mu\text{m}$  features, but they are unlikely to provide  $300\text{mm}$  substrate lithography capability at the  $5\mu\text{m}$  level, much less at





**FIGURE 2.** Seamless exposure is obtained by complementary overlap between adjacent hexagonal scans. The effective scan width is the scan-to-scan pitch, given by  $w = 1.5 l_h$ , where  $l_h$  is the hexagon side length.

1 $\mu$ m. Even more critically, they are unlikely ever to be able to meet the corresponding alignment requirements. Steppers, on the other hand, may satisfy the resolution and alignment considerations, but not the large substrate size requirement without problematic stitching between the segmented fields. The lithographic and economic challenges of large-format products are inherently different from those of ICs. The appropriate figure of merit would include large substrate capability, depth of focus, and alignment system flexibility, as well as resolution and cost of ownership.

We have developed a new class of projection lithography systems, called HexScan [5], that provide both high-throughput, high-resolution resist patterning and dielectric via drilling for fabrication of large-format, high-performance electronic products [1–3]. These results are achieved with a unique, hexagonal seamless scanning technique and a single-planar stage configuration. Different versions are attractive for high-volume, cost-effective production of micro-electronic products with feature sizes ranging from 15 $\mu$ m to below 1 $\mu$ m and substrate sizes ranging from 150 $\times$ 150mm to 610 $\times$ 915mm.

### Large-area laser projection

The core technology of the Anvik large-area laser projection systems is illustrated in Fig. 1. The panel and the mask are held on a single-planar,  $x$ - $y$  scanning stage. The illumination system comprises a UV excimer laser source and a beam-processing optical system. The exposure wavelength is selected based upon the application. The 351nm XeF excimer wavelength is ideally suited for conventional  $i$ -line resists, whereas the 248 and 193nm (KrF and ArF) wavelengths work for deep-UV lithography. For photoablation, the most commonly used excimer laser wavelength is 308nm (XeCl), although the others may be used. The laser radiation is processed and relayed by a beam delivery system that transforms it into a beam of hexagonal cross section that is typically 10–50mm in size (vertex-to-vertex) with a uniform intensity profile. The beam-processing system illuminates the mask from below as shown in Fig. 1.

The mask pattern within the illuminated hexagonal region is imaged onto the panel by a 1 $\times$ -magnification projection lens through

a folded image path. The projection lens, the illumination system, and all other optical components are stationary, as are all the light paths. The sole moving component is the single-planar stage, which is scanned in a serpentine fashion in the  $x$ - $y$  plane such that successive hexagonal scans partially overlap, as shown in Fig. 2. Since the time-integrated exposure dose delivered by each hexagonal scan has a trapezoidal profile, the complementary overlap between adjacent trapezoidal dose profiles in a cumulative exposure dose from all scans that is totally seamless and uniform across the entire panel.

Thus, this large-area lithography technology makes it possible to obtain the desired resolution by selecting a projection lens of a suitable numerical aperture, and to deliver that resolution over very large substrate areas efficiently by the technique of hexagonal seamless scanning. Another key advantage is its modular design — the main subsystems, including the illumination, imaging, and stage modules, are integrated in a mutually non-interfering manner. This unique feature permits not only choice of different user-specified system configurations, but also upgradability of the systems as products migrate from one generation to the next.

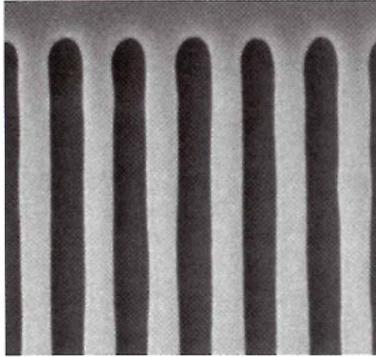
The overall specifications of one of our high-resolution systems, the 1 $\mu$ m-resolution HexScan 1010 SDE, appear in the table. The projection assembly in our systems is a unit-magnification, refractive imaging system designed for the specified resolution. For example, the HexScan 1010 SDE has an NA of 0.174, which provides 1 $\mu$ m resolution at the 248nm wavelength. Other system models have resolution specifications from 0.5–15 $\mu$ m, with corresponding NAs ranging from 0.35 (for  $\lambda = 248$ nm) to 0.0144 (for  $\lambda = 351$ nm). The projection lens field diameter ranges from 10–50mm.

The air-bearing  $x$ - $y$  scanning stage supports both the mask and substrate and is capable of scanning in either direction at speeds up to 500mm/sec. Its travel ranges are designed to meet the panel size specifications. The stage utilizes an optical encoder to provide position and velocity control, which is fully integrated with the system control software.

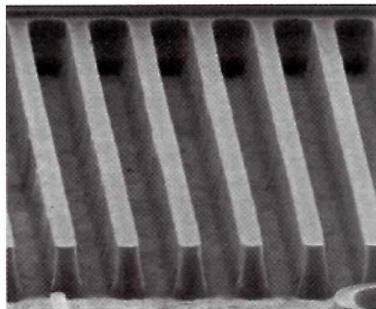
**Performance specifications for the HexScan 1010 SDE projection system**

Imaging technique	Seamless scanning projection
Resolution	1 $\mu$ m
Projection system	1:1 magnification refractive lens
Numerical aperture	0.174 ( $f/2.87$ )
Depth of focus	8 $\mu$ m
Panel exposure area	200 $\times$ 250mm
Exposure source	KrF excimer laser
Exposure wavelength	248.4nm, line-narrowed
Alignment precision	$\pm 0.25\mu$ m
Alignment system	Automatic
Panel & mask handling	Automatic
Exposure throughput	120 panels/hr

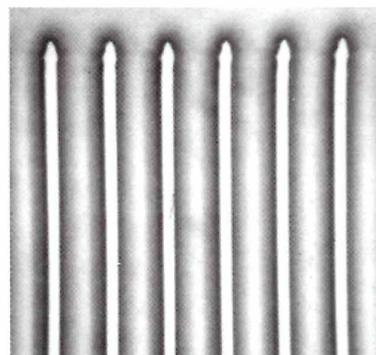
Finally, all of our systems incorporate a high-precision, automatic optical alignment system, consisting of an optical metrology system and an  $x$ - $y$ - $\theta$  fine positioning system. The HexScan 1010 SDE system, with its  $1\mu\text{m}$  resolution, has an alignment specification of  $\pm 0.25\mu\text{m}$ . Such capability is necessary for layer-to-layer alignment in multilayer circuits and for front-to-back alignment in microsystems and dual-sided panels.



**FIGURE 3.**  $1\mu\text{m}$  lines and spaces imaged on a large-area, deep-UV projection lithography system having a  $248\text{nm}$  KrF excimer laser source.



**FIGURE 4.** Results obtained on a large-area projection lithography system for printed circuits, showing  $10\mu\text{m}$  features in a  $13\mu\text{m}$ -thick resist.



**FIGURE 5.** Results obtained on a large-area projection photoablation system, showing  $8\mu\text{m}$ -wide,  $5.6\mu\text{m}$ -deep trenches ablated in a polymer.

### Patterning results

The Anvik large-area lithography technology has been demonstrated on several systems in use in commercial and military production of large format microelectronic and optoelectronic devices. Figure 3 presents results obtained on the HexScan 1010 SDE deep-UV lithography system: The SEM shows  $1\mu\text{m}$  lines and spaces patterned in a  $1\mu\text{m}$ -thick deep-UV photoresist. The system has an  $8\mu\text{m}$  depth of focus and can expose substrate sizes up to  $200\times 250\text{mm}$  at a rate of 120 panels/hr.

Imaging results showing  $10\mu\text{m}$  features, obtained in a  $13\mu\text{m}$ -thick liquid photoresist using the lower resolution HexScan 2100 SPE system, are presented in Fig. 4. This system is designed for patterning  $460\times 610\text{mm}$  circuit boards and its large depth of focus —  $560\mu\text{m}$  — minimizes substrate planarity requirements. Using standard resists, the exposure speed of the system is  $<20\text{sec/panel}$ .

These large-area projection lithography systems, due to their

excimer laser source, also function very effectively as photoablation tools. Excimer laser photoablation of polymers [4] is widely used in the production of multilayer circuits to form the interconnect vias and in the production of inkjet printheads to form the nozzles. Extensive work has been carried out on direct projection ablation using such a dual-function system in a wide variety of cured polymers, including polyimides, acrylics, polycarbonates, etc., for numerous applications in microelectronics and optoelectronics. As an example, Fig. 5 shows photoablation-patterning results obtained in the polymer DuPont Pyralin PI2611D using a HexScan 3030 SXE system that incorporates a  $308\text{nm}$  XeCl laser and provides a resolution of  $3\mu\text{m}$ .

### Conclusion

Large-area lithography is becoming an important process in the production of numerous microelectronic, optoelectronic, and microsystem devices. The lithography requirements for the fabrication of such large-format products are distinctly different from those of semiconductor ICs, and are ideally met by a new class of projection lithography systems that provide high-resolution imaging, large depths of focus, and very large exposure area capability. The systems can also function as dual-mode production tools, capable of patterning photoresists as well as photoablating polymers. ■

### References

1. K. Jain et al., *Proc. SPIE*, Vol. 3331, p. 197, 1998.
2. K. Jain, US Patent 5,285,236, issued Feb. 8, 1994, and US Pat. 4,924,257, issued May 8, 1990.
3. For a comprehensive overview of Anvik's large-area lithography systems, see [www.anvik.com](http://www.anvik.com).
4. W. Duley, *UV Lasers: Effects and Applications in Materials Science*, p. 148, Cambridge Univ. Press, 1996.
5. HexScan is a registered trademark of Anvik Corp.

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