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The Next Wave of Innovation
ASML’s Ultra-k™ portfolio of hardware, software and mask solutions enables extended performance in the challenging era of low k1 lithography. Ultra-k includes products such as LithoCruiser™ for process optimization, LumenShaper™ for customized illumination, and DoseMapper™ for optimal CD control. These and other designed-in technologies make high-volume, low k1 manufacturing a reality.

Rally to the next node with a partner that’s committed to technology leadership. Extend production resolution and increase process latitude with today’s most advanced low k1 solutions.

Test drive ASML’s Ultra-k simulators at www.asml.com/ultra-k1
The Next Wave of Innovation

by Mark Bigelow

As the IC industry continues to drive a "Protons Forever" strategy for manufacturing with aggressive design rules, a steady stream of lithography innovation is needed to ensure high yield for high volume manufacturing, as well as for specialized applications. This issue of Images profiles a number of innovative new products and technologies designed to extend your lithography capabilities well into the sub-100-nm domain.

The feature article showcases the TWINSCAN XT:1250, a streamlined evolution of the revolutionary TWINSCAN platform. The XT:1250 extends lithography down to the 65-nm node through the power of two stages, our Ultra-k, portfolio and fab friendly design.

Several other articles discuss emerging innovations including immersion, 157 nm and optical maskless. Recently, much attention has been given to immersion technology. ASML’s progress in immersion has been rapid, and the future for this evolutionary technology looks bright. 157-nm technology updates are provided in two articles. The first presents the performance of a recently shipped MS VII to IMEC, and the second, from our partners at Carl Zeiss, describes progress in lens materials and manufacturing. An update on ASML’s joint venture with Micron to develop optical maskless technology and bring this from concept to market is also provided.

Additionally our Special Applications group describes adaptive lithography innovations for addressing the unique and varied requirements of MEMS manufacturing.

In this issue we also introduce a new business group, ASML Optics—an extreme precision optical foundry—and its first commercial products, PerfectWave metrology standards. ASML Optics offers optical technology capabilities beyond the bounds of lithography, to the semiconductor and optical manufacturing communities.

Finally, articles on our Demo Labs and Customized Productivity Improvement (CPI) packages illustrate our collaborative efforts to improve your value of ownership.

As you ride the next wave of innovation you will be supported by ASML. We are actively committed to developing products and technologies that contribute to your success.
ASML Updates Market on Innovations and Operations

Positive Immersion Program Results Revealed

November 13, 2003 – ASML, in a meeting with investors and financial analysts, highlighted several of the company’s operational and technological developments. ASML reviewed its updated technology roadmap in response to future imaging challenges as the demand for “shrink” (smaller features) continues.

ASML presented the early successes achieved by the company in its immersion lithography program. Capabilities and customer benefits of ASML’s recently launched TWINSCAN XT:1250 system were detailed. Europe’s largest independent R&D center IMEC presented a synopsis of its 157-nm project, conducted on the ASML Micrascan VII. Maskless lithography technology was explained and the market opportunity explored. From a business infrastructure perspective, ASML reviewed accomplishments from cost-cutting measures in operations and suppliers’ improvements in cost and flexibility.

ASML’s New Generation TWINSCAN™ System Patterns for the 65-nm Node

October 21, 2003 – ASML introduced the new generation of its TWINSCAN platform—TWINSCAN XT:1250—a 0.85 NA, 193-nm volume production lithography scanner that extends imaging to the 65-nm node on both 200-mm and 300-mm wafers. ASML has already booked several customer orders for the XT:1250 with initial deliveries scheduled for the second quarter of 2004.

A Very Flat Piece of Glass Enables Atomic-Level Precision in Optics Technology

October 27, 2003 – To the casual observer, it looks like a round piece of glass in a metal holder, a bit larger than a hockey puck. However, the new PerfectWave metrology standard from ASML Optics enables reliable measurement of dimensions approaching the atomic scale.

Producers of semiconductors, nanotechnology devices, advanced optics and other technologies are constantly shrinking the features of their products to manufacture smaller, faster ICs. Today’s silicon chips have features as small as 90 nanometers, and 50 nanometer features are just a few years away. The lenses used to print these features have to be smoothed and shaped to even smaller tolerances. Engineers and scientists are finding that traditional measurement systems (based on interferometer techniques) are unable to keep up with advancing technology.

ASML’s new PerfectWave metrology standard helps solve this problem, because it is almost incomprehensibly flat—variation is just 1 nanometer across its 4-inch diameter. This consistency provides a new “gold standard” for calibration of advanced interferometer measurement systems, enabling a 5x increase in their accuracy.

Micronic Laser Systems and ASML Intend Joint Venture for Optical Maskless Lithography

July 18, 2003 – Micronic Laser Systems and ASML announced that the two companies have signed a memorandum of understanding to form a joint venture company (JVC) that will focus on the optical maskless lithography market for semiconductor manufacturing.

ASML MaskTools and Nanya Enter Into Software and Technology Licensing Agreement

June 11, 2003 – ASML MaskTools announced that Nanya Technology Corporation of Taiwan has licensed its proprietary software and intellectual property for deployment in Nanya’s advanced semiconductor production facilities. The capabilities provided by ASML MaskTools will enable Nanya to improve imaging performance in its next-generation process technologies.

For complete information regarding these press announcements, please refer to the press section of www.asml.com.
Immersion Lithography

by Christian Wagner, Jan Mulkens, Peter Jenkins and Harry Sewell

Immersion lithography has the potential to extend ArF technology below the 60-nm node. During the last six months, significant progress has been made in immersion tool and process development. This article introduces immersion optics and provides a status overview of ASML’s program and first production immersion tool.

Immersion Principle

Using an immersion fluid between the wafer and the lens has two benefits. First, it allows lens designs with numerical apertures (NA) significantly larger than 1.0, therefore allowing improved resolution. Second, it enhances depth of focus (DOF) for a given NA. Both the NA and the DOF potential are roughly in the order of the refractive index n of the immersion fluid.

Higher NA

To demonstrate the NA and resolution potential, we start by using the well-known Rayleigh formula for dense lines and spaces. Here we link the $k_1$-factor, the wavelength $\lambda$, and the numerical aperture of the lens NA, to resolution for dense lines:

$$\text{resolution} = k_1 \frac{\lambda}{(n \sin \theta)} = k_1 \frac{\lambda}{\text{NA}}.$$  

$\sin \theta$ is the angle of the diffracted ray in the medium between the wafer and the lens. The maximum angle of diffracted light that can be captured by a lens is given by:

$$\text{NA} = n \sin \theta$$

For ArF lithography, we can use water as an immersion fluid with $n = 1.44$. Water enables lens designs with numerical apertures of up to 1.35 (taking into account such practical limitations as lens size and cost) compared to “dry” lenses where the NA is practically limited to below 0.95. While adding fluid makes the lens designer’s life easier, lenses above 1.1 NA present their own special requirements, such as the use of strong aspheres and advanced manufacturing technology.
It is important to note that adding liquid will not change the resolution of an existing lens. The resolution is determined physically by the aperture stop of the lens. Even though rays with angles larger than the corresponding dry NA might enter the lens, the rays would be clipped at the aperture stop. Using Snell’s law, adding the water gives $\sin \theta_{\text{wet}} = \sin \theta_{\text{dry}} / n$. Filling this back into equation (2), we get $NA_{\text{wet}} = n \sin \theta_{\text{wet}} = n (1/n \sin \theta_{\text{dry}}) = \sin \theta_{\text{dry}} = NA_{\text{dry}}$. So, adding an immersion fluid to an existing lens will not increase the NA (see Fig. 1, page 3).

**Enhanced DOF**

Besides the potential to build lenses with an NA significantly higher than 1.0, the DOF is enlarged with respect to a “dry” lens by approximately the refractive index:

$$DOF = k_2 \frac{\lambda}{[2n (1 - \cos \Theta)]} \approx k_2 \frac{n \lambda}{NA^2}.$$  

The first steps in immersion testing were done with a readjusted Starlith 1150 lens, modified to be water compatible. As discussed above, the NA or resolution did not change by adding water, however, DOF was enhanced by a factor of $n$ or, as can be seen in Figure 2 (page 3), by roughly 150 nm (the table assumes a $k_2$ of 1.0). Due to this DOF improvement, immersion is expected to be of major interest for DOF-critical applications, such as contact holes.

Immersion has the potential to extend ArF to below 60 nm with > 1.0-NA lenses.

For 157 nm, perfluoropolyether material is being studied as an immersion fluid. With immersion, 157 nm can be extended to < 40 nm, taking into account the lower $k_1$ factors being supported in this timeframe.

**ASML’s Program**

The primary challenges of immersion technology include the following:

- building and testing of an immersion lens (“under water” lens metrology at Zeiss)
- liquid supply in the scanner
- liquid containment during scanning and at wafer edge
- exclusion of detrimental effects of liquid on imaging (heating, bubbles, mechanical effects like vibrations, etc.)
- photoresist compatibility

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**Technology Leadership**

- Extends ArF technology below the 60-nm node
- Allows lens designs with larger numerical apertures and enhances depth of focus for a given NA
- Dual-stage TWINSCAN ideally suited for immersion adaptation

**Figure 3**

*Immersion ArF Interferometer, with an effective NA of 0.75*

**Figure 4**

*100-nm lines obtained with 2s exposure immersed with distilled water, Tarf-5068 resist with TOK Top Coat*
ASML research efforts are focused on bringing water between the lens and the wafer. In principle, there are two basic design choices: submerging the whole wafer stage into water (the “bathtub” or “swimming pool” solution) or confining the water to the imaging region only (the “showerhead” solution). ASML is currently fine-tuning a design which will prevent bubble formation and confine water at the wafer edge.

We are integrating an immersion test machine (AT:1150i) at our headquarters in the Netherlands. This test rig shows the benefits of immersion on DOF and, therefore, CDU performance (see Fig. 5).

Concurrently, the first Starlith 1150 immersion lens has been adjusted and measured at Zeiss using an immersion version of the well-known Zeiss aerial image (VOPA) and wavefront (PMI) metrology.

Photoresists also needed to be optimized for immersion usage. For the ArF feasibility immersion program, ASML tested resist fluid compatibility on a test bench at our Wilton facility. Post-soak experiments were done using an ArF 0.75-NA Micrascan system. Although a few incompatible photoresist fluid combinations were found, most photoresists proved to be water compatible. For 157-nm lithography, good resist fluid combinations still need to be found (see Figs. 3 and 4).

**XT:1250i**

The first ASML immersion tool will be the recently announced XT:1250i scheduled to ship in 2004. The XT:1250i leverages the success of the TWINSCAN platform and provides a unique competitive advantage for immersion due to its dual-stage design. Dual stages enable “dry” metrology and “wet” exposure. Measuring in air—rather than in fluid—is more accurate and minimizes the potential for error.

Furthermore, the TWINSCAN platform’s dual stages enable the immersion hardware to be implemented without redesigning the metrology sensors. As an adaptable technology to a proven imaging system, immersion on the XT:1250i extends the performance of optical lithography.

**Acknowledgement:**
The authors would like to thank the immersion projects at ASML Veldhoven and ASML Wilton.

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**Figure 5**

90-nm Dense Lines

Immersion: DOF 0.9 µm

- F-0.5
- F-0.4
- F-0.3
- F-0.2
- F-0.1
- F0.0
- F0.1
- F0.2
- F0.3
- F0.4

Dry: DOF 0.4 µm

- F-0.2
- F-0.1
- F0.0
- F0.1
- F0.2
The move to 300-mm lithography required new thinking and revolutionary technology. Aggressive imaging, overlay and throughput requirements demanded a different approach. ASML responded with TWINSCAN dual-stage lithography. Since its introduction in July 2000, TWINSCAN has become the platform of choice for 300-mm lithography. Over 100 systems are currently installed and operational worldwide.

ASML’s commitment to technology leadership and to our customers’ value of ownership means continuous evolutionary improvement to the platform. Our engineering and design teams surveyed customer requirements around the world. Based on their findings, we began to develop a tool that would continue to set the standard for technological advancement while being more fab friendly, including compatibility with existing 200-mm fabs. The result is the TWINSCAN XT:1250, a smaller, faster, more cost-efficient 0.85 NA, 193-nm scanner that extends TWINSCAN to the 65-nm node.

### The Power of Two

ASML’s unique dual-stage approach is the reason behind the success of the TWINSCAN platform. Performing detailed metrology on one stage while the second stage is patterning provides multiple benefits to our customers.

The XT:1250 incorporates 6-axis laser interferometry coupled with a level sensor for off-line measurement and mapping of the surface of each wafer while in the metrology position prior to exposure. Premapping and playback of field leveling information during imaging provides fast and optimum calibration of wafer leveling and scan field tilt on a field-by-field basis. Off-line measurement provides detailed field-by-field wafer topography information without affecting overall system throughput. Focus depth control of the lens is in the order of 55 nm across the entire wafer. Customers can be confident that either stage will provide the identical performance they demand of an advanced lithography tool. Additionally, continuous improvement in reduction of lens aberrations from Carl Zeiss, our optics partner, coupled with industry leading metrology results in superior imaging quality (see Fig. 1).

Furthermore, during the TWINSCAN metrology step, up to 16 SPM marker pairs can be measured for fine alignment of 300-mm wafers without any productivity loss, resulting in excellent overlay adjustments. In fact, the overlay specifications of the XT:1250 are half of those of single-stage systems (see Fig. 2).
Dual stages allow imaging to occur at full scan speed. TWINSCAN Step & Scan systems do not slow down the wafer stage scan speed to achieve specified imaging performance. The bottom line is that the TWINSCAN platform delivers the highest raw throughput and batch productivity of any tool under both test and actual customer wafer conditions. The result for customers is higher yield at higher throughput.

For 300-mm production, a 40 W ArF laser with variable frequency control, in combination with the high optical transmission of the complete illumination system, provides a production throughput of over 114 wafers per hour (30 mJ/cm² exposure dose, 16 x 32-mm field size, 125 shots). For 200-mm production, a 20 W ArF laser contributes to a production of over 150 wafers per hour (30 mJ/cm² exposure dose, 16 x 32-mm field size, 58 shots) (see Fig.3).

**Room to Shrink**

The XT:1250 features Ultra-k₁, a hardware and software portfolio that enables imaging at extreme resolutions. This package of proprietary products gives chipmakers the ability to continue to shrink circuit features, ensures high die yields and maximizes bottom-line return. The Ultra-k₁ portfolio dramatically improves process latitude, depth of focus and critical dimension (CD) control. The end result is a tool imaging 70-nm dense lines and spaces, and 85-nm contact holes half pitch today, critical to customers’ 65-nm node development.

Specific illumination modes are designed to provide customized illumination for specific process layers at full productivity, enabling larger process windows for increased yield at low k₁ values. LithoGuide optimizes imaging performance through aberration monitoring provided by ILIAS on-board interferometry. DoseMapper compensates for external sources of non-uniformity and provides intra-field dose correction and critical dimension analysis. DoseMapper also allows correction of CD variations over the entire wafer resulting in better CD uniformity.

**Fab Friendly**

To continue providing chipmakers with the industry’s highest value of ownership, ASML reduced the TWINSCAN XT:1250 footprint by 25 percent, placing components from the original system into redesigned, compact support modules located in the sub-fab. Additionally, all TWINSCAN systems benefit from up to 50% reduction in specified installation facility requirements. Each of these improvements serves to reduce customers’ cost of ownership.
In addition, the XT:1250, like all TWINSCAN systems, incorporates many fab automation and integration technologies. Image Streaming increases productivity by reducing the image-to-image overhead by speeding up the metrology of multiple images with an identical pupil fill (identical DOE, NA and sigma setting). Lot Streaming allows a continuous flow of wafers, reticles and recipes to be processed from a queue, minimizing lost time between lots. SECS interface enables the integration into a factory automation system, thus delivering increased equipment productivity and efficiency. Several other options can be added for further integration and efficiency gains. These include: Integrated Reticle Inspection System (IRIS), Automated Reticle Transport (ART), RF/IR Tag Readers and Integrated Reticle Library (IRL).

**Value of Ownership**

- Dual stages separate metrology and exposure, which enables improved imaging, better overlay and greater productivity, resulting in more good die per day
- Ultra-\(k_1\) portfolio of hardware, software and mask solutions provides bigger process windows today and smaller design rules tomorrow
- Smaller fab footprint and reduced facilities decrease cost of ownership and provide greater customer flexibility

**Figure 3**
Greater throughput across range of die sizes (22% on average)
Breaking the 0.30 $k_1$ Barrier with CPL Technology

ASML has broken the 0.30 $k_1$ barrier and is extending the limits of optical lithography. The SEM images below show the initial results from an AT:1200B using ASML MaskTools’ advanced RET, CPL Technology. These results demonstrate resolution capabilities at 0.29 $k_1$ for both lines and contacts. The CPL contacts were created utilizing ASML MaskTools’ newest innovation: Interference Mapping (patent pending). This technique optimizes the specific OPC design used for each pitch, eliminating forbidden pitches and any phase conflicts. CPL Contacts with Interference Mapping were presented at SPIE Photomask 2003 in September. Further results will be presented along with CPL Technology and Interference Mapping details in February 2004 at SPIE’s Microlithography Symposium.

CPL Contacts using Interference Mapping

TWINSCAN AT:1200 ArF, 0.85 NA QUASAR illumination

- $k_1 = 0.29$
- 65-nm contacts
- 130-nm pitch
- $k_1 = 0.33$
- 75-nm contacts
- 150-nm pitch
- $k_1 = 0.35$
- 80-nm contacts
- 160-nm pitch

80-nm CPL Contacts (160-nm pitch)

TWINSCAN AT:1200 ArF, 0.85 NA QUASAR illumination, 160-nm resist thickness, through exposure

$k_1 = 0.35$, DOF = 0.35µm, EL = 15%

45-nm CPL Dense Lines (130-nm pitch)

TWINSCAN AT:1200 ArF, 0.85 NA C-Quad illumination, 170-nm resist thickness, through exposure

$k_1 = 0.29$, DOF = 0.6µm, EL = 9%
Economic Justification

Ever-increasing mask costs pose a significant problem for designs that are produced in low volumes (up to 20-200 wafers) such as ASICs. Maskless Lithography (ML) is the ultimate solution to the mask cost problem. Virtually all ML concepts use electron beams and suffer from inherent throughput limitations and from lack of process commonality with optical lithography. Therefore ASML is planning to make available Optical Maskless Lithography (OML) in cooperation with Micronic Laser Systems, A.B. of Sweden, building on their experience in optical mask writing.

A detailed economic analysis incorporating mask cost data, a realistic mix of mask-based and maskless lithography (10-14 critical layers exposed maskless), and maskless throughput and wafer processing cost has been performed (see Fig. 1). This analysis shows that OML is economical for surprisingly high wafer volumes per design (up to 200 wafers for 130-nm, 600 for 90-nm and 2000 for 65-nm technology). Foundry mask usage data indicates that over 75% of the designs can be printed with OML more economically, resulting in major savings on the mask bill. It is interesting to note that the corresponding wafer volume is only about 3% of the total wafer volume exposed, meaning that the additional maskless scanners barely off-load capacity from the existing mask-based lithography cluster.

Meanwhile, time-to-market is key to the commercial success of the electronic end-product and is therefore a key parameter for the realization of custom logic IC designs in such products. Next to the design time of the IC, the time needed to release a design for production and the waiting time for the leading-edge masks used for the first layers contribute to the time-to-market of the IC design. In addition, leading-edge masks frequently need “respins” to correct for design errors only discovered after first silicon, adding to time-to-market. About 61% of all ASIC designs are not “first time right” for a range of reasons. Functional logic errors and analog signal errors are the most common, leading to respins of one or more masks (source: Synopsis). OML completely eliminates the waiting time for the mask and subsequent mask respins and thus significantly reduces design time-to-market.

SLM Technology

At the heart of the OML scanner is the Spatial Light Modulator, a Micro-Electro-Mechanical-System (MEMS) device with millions of tilting micro-mirrors, which are imaged to represent individual sub-resolution pixels on the semiconductor wafer with > 200x reduction optics (to be compared to 4x for ASML mask-based scanners). The individual mirrors can be tilt-adjusted to represent white, black and intermediate gray value pixels, enabling the imaging of design features at arbitrary offsets from the pixel grid (see Fig. 2). By tilting beyond the angle corresponding to black or zero transmission, negative-phase intensity pixels can also be obtained as with attenuated Phase Shift Masks (att-PSM). For the currently used square SLM mirror shape, this negative-phase intensity is 4.7% at maximum. Innovative mirror shapes, or the use of piston-type mirrors, can enable negative-phase intensities up to 100%, similar to alternating Phase Shift Masks (alt-PSM).

![Figure 1](Projected mask-set cost for each technology node (customer data))

- $4,000,000
- $3,500,000
- $3,000,000
- $2,500,000
- $2,000,000
- $1,500,000
- $1,000,000
- $500,000
- $0

Technology Node

- 0.18 µm
- 0.13 µm
- 0.09 µm
- 0.065 µm
OPC Transparency and RET

For OML to be able to replace leading-edge masks, which are the most expensive and have the longest and least predictable delivery times, all Resolution Enhancement Techniques (RET) must be available. Unlike e-beam based alternatives, OML uses the same optical and resist technology as conventional scanners, enabling advances in conventional lithography to be easily adapted to OML. Furthermore, OML does not suffer from inherent throughput limitations from multi-beam coulomb interactions.

The goal is to have the maskless scanner accept the mask GDSII design files including OPC (e.g., scatter bars, serifs and hammerheads) and perform imaging that is equivalent to the corresponding mask-based scanner. To enable this, all non-conventional illumination modes (e.g., dipole, QUASAR and customized illumination) will be made available. Imaging transparency between mask-based and maskless scanners will lower the difficulty in starting manufacturing with OML. Transitioning to mask-based production will only be done once a significant production volume has been reached. Moreover, the soft mask has more flexibility than a conventional mask, in principle enabling more flexible OPC schemes: attenuation and gray level can be varied per pixel, whereas these quantities are fixed for a standard att-PSM (see Fig. 3, page 12).

Conclusion

OML enables a low-volume production roadmap for ASML complementary to the ASML mask-based high-volume production roadmap. OML eliminates mask costs, reduces time-to-market of new designs, lowers the risk of new design introductions, and allows for easy transfer between mask-based and maskless lithography. Unlike e-beam-based alternatives, OML does not have inherent throughput limitations. OML leverages the optical lithography roadmap in which the lithography community has invested so much.
Figure 3

Example of a maskless OPC scheme exploiting per-pixel programmable gray-levels, preventing line-end shortening and line widening in a separated T-shaped design feature.
157-nm Lithography takes a step forward with the shipping of Micrascan VII. The first full-field 157-nm exposure system was completed at ASML Wilton and has been shipped to and accepted by IMEC to support its 157-nm processing development needs. More systems are available; one has been shipped to another customer and is now being installed. The systems represent significant progress in 157-nm technology development.

157-nm Technology Development

157 nm is the next wavelength after 193 nm for semiconductor production lithography. We are exploring all the current technologies developed at 193-nm wavelength for implementation at 157 nm so that optical lithography can be extended a farther node on the semiconductor industry roadmap. The Micrascan VII pushes 157-nm engineering development for calcium fluoride material improvement; optics design; optical element surface figuring; purging and contamination control on optical surfaces, pellicles and reticles; ultraviolet oxygen cleaning of reticles; 157-nm excimer (fluorine) lasers and 157-nm photoresists. Many of these developments are being used in the building of the 157-nm preproduction systems in the TwinSCAN series (see Fig.1).

Calcium Fluoride

The requirements of Micrascan VII have prompted increases in the supply and quality improvements of calcium fluoride for use as an optical material at 157-nm wavelength. The initial results in terms of optical quality from suppliers, although encouraging, indicated that significant improvement was required. Cooperation between Schott, Zeiss and ASML Optics has yielded progressive and significant improvements in quality to a point where calcium fluoride supply is not a problem. The main parameters are homogeneity of refractive index and birefringence. Calcium fluoride has a level of intrinsic birefringence that can be eliminated with suitable optical design, but stress birefringence is a major issue because it occurs less predictably. Careful furnace design with improvements in
the crystal-growing process and engineered annealing cycles for
the crystal boules have markedly reduced stress birefringence
levels (see Fig. 2, page 13).

Early samples barely met the stress birefringence requirements
of the Micrascan VII, but there have been improvements. Figure
2 shows that within-specification material for the more exacting
157-nm TWINSCAN production system is now available.

Optical Design

Optical design for the 157-nm wavelength is a challenge.
The design options are limited by the availability of suitable
optical materials. Calcium fluoride is currently the only suitable
option available in the required quantity. This narrows the design
possibilities to either a catadioptric design or an ultra-narrow
bandwidth. This latter option presents severe problems because
laser technology has not progressed far enough to be able to
provide the < 0.1 picometer bandwidth currently required for
refractive optics. Further, as numerical apertures continue to
increase, an even narrower bandwidth will be required.

Using ultra-narrow bandwidth lasers with refractive optics is a
very difficult option. Alternatively, the Micrascan VII optics design,
which involves both reflective and refractive optical elements and
uses a beam splitter and polarized light, has proven successful. The
confirmation of the beam-splitter type of optical design at 157 nm
has now significantly reduced the risks associated with catadioptric
optics design for production systems. Many of the optical design
problems have been resolved. ASML Optics executed the
design and fabrication of the Micrascan VII optics. Zeiss, which
is responsible for the manufacturing of the TWINSCAN production
system optics, has significantly benefited from this technology
development. Zeiss has designed the optical system in close
collaboration with ASML Optics and has begun to manufacture the
improved optics design for the production systems. ASML Optics
is supporting Zeiss by manufacturing over 50% of the optical
components in the production system optics.

Optical Fabrication

In step with calcium fluoride stress-birefringence improvements,
optics manufacturing has progressed, prompted by Micrascan
VII requirements. The surface finish on optical materials clearly
demonstrates continued improvements. Improvement in surface
finish of over an order of magnitude is shown to have been
achieved (see Figs. 3a and 3b).

With improvements in the quality of the available calcium fluoride
and with the use of the polishing techniques now available to
make the optical elements, a significant enhancement of optical
performance in areas such as image flare will result. Image flare
in the TWINSCAN-based production systems is significantly lower
than in the Micrascan VII prototypes.

Reticle and Pellicle System

System design requirements have pushed a number of areas
associated with the reticle system. At the 157-nm wavelength,
control of reticle contamination and of purge become very important
because of the increased propensity of hydrocarbons and silicones
to polymerize under the influence of 157-nm photons. Polymerized
hydrocarbons cause significant light loss, but this situation is
potentially reversible with suitably engineered purging. The 157-nm
reticle management system development, which was begun on the
Micrascan VII, stores reticles in ultra-low-hydrocarbon and silicone-
free nitrogen. The reticle library has to be purged to keep reticles
free of contamination.

Figure 3a
Typical surface finish on Micrascan VII polished
calcium fluoride elements

Figure 3b
Typical improved surface finish on calcium fluoride elements for
the 157-nm TWINSCAN systems (surface polished at
ASML Optics)
For the first time, ultraviolet oxygen cleaners have been incorporated into the reticle system to ensure that reticles can be kept free of contamination and to remove any polymerized hydrocarbon deposition.

Special pellicle technology has been developed to protect the masking surface from particulate contamination while allowing continuous purging with ultra-pure nitrogen. Currently, use of hard pellicles made of fluorinated quartz is the preferred approach, but research to develop soft pellicles made of thin-film fluoropolymers continues. The Micrascan VII was engineered to accommodate soft or hard pellicles or no pellicle. This approach has been continued for the TWINSCAN 157-nm system. Tests of hard pellicles indicate that they do not have any adverse effects on critical-dimension performance, and the system has been designed to provide in-situ compensation for pellicle-induced distortion. Overlay effects have been reduced to less than 1 nm.

**Critical-Dimension Performance**

The Micrascan VII has conventional 0.75-NA optics that are specified at 100-nm L/S and 70-nm isolated lines. Critical dimension control of better than 12 nm (3σ) has been demonstrated (see Fig. 4).

The improvements seen in 157-nm resist systems are undeniable. Resist transparency has increased and has now reached a point where reasonable profiles are available with steep sidewalls and minimal resist loss. Figure 5 shows resist profiles from one of the new, higher-transparency 157-nm resists.

The system was designed to print in the 70–100 nm range, but the printing capability has been pushed to 40 nm using phase-shift masks for process development work.

Further improvement in 157-nm lithography technology is expected because of the use of Micrascan VII tools, particularly in resist and processing.

**Future for 157-nm Lithography**

The imaging performance of 157-nm systems is aimed ultimately at the 45-nm node. As usual, technology development is moving on two fronts: extending existing wavelengths and processes and developing new wavelengths and processes. 157-nm technology is being developed to follow 193-nm-wavelength technology. Dry 157-nm technology is running in parallel with the development of immersion 193-nm technology. Immersion 157-nm lithography opportunities are being investigated and look encouraging. 157-nm lithographic technology has made a significant step forward with the delivery of the first ASML Micrascan VII full-field 157-nm scanners.
157-nm optics

Projection and Illumination Optics for High-NA 157-nm Scanners

by Dr. Martin Brunotte of Carl Zeiss

The first Starlith 157-nm lenses (157 nm, NA ≥ 0.85) for the TWINSCAN platform are fully in fabrication phase. Key specifications and applications are set. Over the last year the quality of CaF$_2$ has been significantly improved. Handling of polarization and managing straylight are the key issues in this new catadioptric lens design.

System and Technology Overview

Carl Zeiss SMT AG is building the projection lens for ASML’s first 157-nm production tool. With the highest numerical aperture (NA = 0.85) in the market, the system is specified for a resolution of 65 nm at a field size of 26 x 33 mm. For the first time a catadioptric design was the only possible choice for the projection optics to compensate for the chromatic aberrations, because of the relatively large laser bandwidth (1.2 pm) and only one optical material (CaF$_2$) being available.

Significant advances have been realized in the development of 157-nm optical-lithography exposure systems as well as in the associated technology infrastructure. The key technical issues included purging and contamination control, calcium fluoride (CaF$_2$) birefringence and purity issues, coating robustness and developing a pellicle solution. Those issues, considered by many as roadblocks to 157-nm lithography, have now been resolved.

In September 2003 the first Aerial Image Measurement System (AIMS) for 157-nm optical lithography was delivered to International SEMATECH (ISMT), Austin, TX. As indispensable tools for the global semiconductor industry, Carl Zeiss SMT’s AIMS systems emulate the wafer printing characteristics of photomasks during optical lithography and are broadly used for the development, quality control, repair verification and defect classification of photomasks.

Fabrication Status at Carl Zeiss SMT

The production of the high-NA 157-nm optical system consisting of illuminator and projection lens is running at full speed. In September the first illuminator was shipped to ASML. Figure 1 shows the final assembly steps of the relay lens before shipment. The organic contamination levels of the first illuminator have proven to be well within specification, demonstrating extremely high purity standards during fabrication. The integration of the first illuminator at ASML is ongoing and the following illumination systems are about to be finished.

For the projection lens, three sets are currently being fabricated. The finished lens elements show excellent results for surface figure and microroughness. They reach the challenging surface specifications, which are necessary to keep wavefront aberrations and straylight to levels supporting 65-nm imaging.

System Performance Expectations

Thanks to new annealing procedures, CaF$_2$ material is now available with levels of [111] stress birefringence far better than 1 nm/cm, and a refractive index homogeneity that reaches

![Figure 1](https://example.com/figure1.jpg)

*Relay lens on illuminator shortly before shipment in Sept. 2003*
the performance specifications set for both [111] and [100] orientations. Nevertheless, growth yield improvement in CaF$_2$ material and additional investments will be necessary to reduce the costs and have sufficient material quantity available for the volume production of 157-nm exposure systems.

Intrinsic birefringence, which has been confirmed at 11 nm/cm for 157 nm, can be efficiently compensated for in the lens design by combining and clocking lens elements of [111] and [100] crystal orientations, yielding a residual level of less than 0.3 nm/cm in addition to that introduced by stress birefringence. The lens design has been further optimized to minimize the total CaF$_2$ content as well as the amount of [100]-oriented material, due to its higher-stress birefringence and lower-yield growth, thereby improving both the high-NA imaging contrast loss performance and the cost of the lens.

With respect to short range material defects such as striae, which predominantly cause straylight, CaF$_2$ has also undergone significant improvement. Figure 2 shows that the straylight has decreased by more than a factor of 2 between the first Micrscan VII lens and the first Starlith 157-nm lens. Further substantial improvement of straylight is expected for later 157-nm lenses. This progress gives confidence that the challenging specs on system level can be reached.

Considering the improved material quality and the actual surface quality of the finished lens elements, the imaging capabilities of the tool, for example contrast for 65-nm dense lines, can be estimated. Figure 3 shows a comparison between contrast of the TWINSCAN 157-nm system and of an high-NA 193-nm system. Although the TWINSCAN 157-nm system has more contrast loss due to straylight, wavefront and polarization, it shows less contrast loss due to polarization effects in wafer plane (vector effect) and chromatic aberrations (laser). Therefore the total relative contrast loss for both systems is comparable. However, due to the smaller wavelength, the 157-nm system starts with a significantly larger ideal contrast, thereby resulting in a substantially larger remaining contrast than high-NA 193-nm systems. The advantage of the smaller wavelength for imaging becomes obvious.

**Conclusion**

In all technological issues, 157 nm has made rapid progress during the last year. The basis for commercial usage will be completed in 2004. With further improvement in optical material and technology the 157-nm lens will carry imaging down to 55 nm. An even higher NA or 157-nm immersion will print features down to 45 nm or smaller. So 157-nm lithography will close the gap between 193-nm lithography and EUVL in the resolution range between 65 nm and 45 nm.

**Figure 2**
*Impact of CaF$_2$ quality on Imaging Performance of 70-nm dense lines (blue bars) and 70-nm isolated lines (yellow bars)*

**Figure 3**
*Comparison of contrast for 65-nm dense lines (binary mask, sigma = 0.75–0.95) and for $n_{\text{resist}} = 1.7$ between the TWINSCAN 157-nm system and a high-NA 193-nm system*
Micro-Electro-Mechanical Systems (MEMS) and Microsystem Technology processes find an ever-growing acceptance in the marketplace. Some MEMS devices have already become everyday items (inkjet printer heads, accelerometers for car air bag launch, pressure sensors). Others are on the verge of becoming commercially viable (lab on chip/biochip, RF MEMS for wireless applications, optical MEMS for fiber-based optical communication applications, gyroscopes for automotive applications such as roll-over sensing).

The biggest challenge in commercializing these devices is finding optimum volume manufacturing processes that reduce costs to acceptable levels for broader market penetration. Many of the larger- and medium-sized Integrated Device Manufacturers (IDMs) have started to integrate part of MEMS processing into their existing fab portfolio. This can be accomplished either by dedicating a particular fab for MEMS processing or by adopting the design of a MEMS device to allow standard processing in a CMOS fab, for example. Either approach makes use of an existing equipment set. However, in many cases the tool set has to be modified/upgraded to provide the appropriate processing characteristics for this new family of MEMS devices.

ASML Special Applications has developed many options and/or upgrade kits for existing ASML steppers to enable this special capability.

3DAlign

This modification allows for highly accurate alignment to targets on the backside of the wafer for imaging on the frontside of the wafer, thus enabling true front-to-backside alignment (FTBA). The simplicity of 3DAlign technology (with only two alignment targets and the same through-the-lens (TTL) technology as for frontside alignment and imaging) allows for a range of innovative alignment schemes where front- and back-side alignment can be used in a mixed mode. This upgrade is the substantially increases performance over previously available FTBA techniques. 3DAlign technology applies the benefits of ASML’s proven TTL alignment technology and phase contrast alignment targets (see Fig. 1).

3DMetrology

This option enables High Aspect Ratio Micro-machining (HARM), by aligning to targets in deeply recessed trenches. This means that the same alignment targets can be used for creating very high topography structures as for imaging on top of these structures. This particular situation can also occur when two substrates have been bonded together, and alignment to the lower substrate is required while imaging the upper substrate. In a similar manner, highly accurate alignment measurements can be performed using only two alignment targets on bonded wafer stacks without the limits of many targets (EGA), site-by-site or box-in-box methods. 3DMetrology is also based on proven TTL alignment technology, combined with a smart approach to maintaining alignment beam perpendicularly (see Fig. 2).

2DStitching

ASML’s superb alignment and low distortion enable the user to image devices that exceed the image field size of a single exposure shot. Therefore larger devices can be successfully imaged on ASML steppers. Capitalizing on the technology development that ASML Special Applications experienced for Thin Film Heads technology, where head-to-head alignment of separate exposure fields must be in the order of less than (a few) tens of nm, this
upgrade provides detailed knowledge on the stitching performance of a specific machine. This enables the users to optimize device design and machine performance to get the best from both ends. The stage accuracy of ASML’s exposure tools, together with the low-distortion lenses, the basis of this option (see Fig. 3).

Wafer Size/Material Flexibility

The sizes of substrates used in MEMS processing are quite often 6" round or smaller. ASML steppers provide solutions to processing not only 6" wafers but also 5", 4", 3" and 2" for selected stepper families. Besides size, MEMS substrates are often not made of standard material (Si), but of a variety of materials (glass, quartz, ceramic) and their thickness varies from below 100 microns to more than 2 mm (especially for bonded or sandwiched substrates). For many of these non-standard substrates, solutions have been developed and tested successfully.

Processing Expertise

Besides the above-mentioned hardware modifications, ASML Special Applications has also developed applications expertise for many of the MEMS unique challenges such as thick resist imaging (e.g., SU8 material), high aspect ratio lithography, and i-line imaging of other thick photosensitive materials (e.g., polyimides).

All of these capabilities can be provided on ASML’s stepper platform, thus taking advantage of the high productivity and performance of the whole stepper product portfolio. This in turn enables our customer to produce innovative MEMS devices at a lower cost basis, which is one of the key requirements for more successful MEMS devices.
Demonstration Labs Showcase ASML Tools and Commitment to Customers

by David Witko

The technology industry has been particularly hard-hit during the recent economic downturn. While our customers’ technology investments have been marked with an especially high level of scrutiny and evaluation, ASML Demo Labs have proven invaluable to both existing and potential new customers in making their investment decisions. In demonstration of our unwavering commitment to customers, we have continued to furnish our Demo Labs with the very latest ASML exposure tools and support equipment—even in these less-than-favorable economic times.

Before the Demo Labs were established in 1994, customers would visit the production facilities at ASML and test a tool on the production line. However, the need for dedicated demo facilities became clear, as a demonstration on a production-line tool is less likely to offer a potential customer a “true-to-fab” experience. In short, production line needs and demonstration needs are quite different. In response, we established two sales-focused lithography showrooms, showcasing not only ASML equipment but also the type of long-term positive experience a customer can expect to have with ASML.

Offering Customers a True-to-Fab Experience

Despite the current economical climate, the activity level at our two Demonstration Labs is in anything but a downturn. Demo activity is clearly up, signaling that first-time ASML customers and return customers alike are taking advantage of facilities and services that offer more than a simple opportunity to “try before you buy.” Intended to offer customers a wholly customizable demonstration experience true to the conditions presented in their own fabs, the Demo Labs play a vital role throughout the whole term of a customer’s relationship with ASML—from initial pre-purchase testing to evaluation of upgrade options and development of new lithography techniques.

Located in Veldhoven, the Netherlands and Tempe, Arizona, the two Demo Labs are stocked with the very newest ASML exposure tools. Offering the very same high levels of technical expertise and concern for customers, the Tempe facility performs 200-mm wafer-size demonstrations while all 300-mm demonstrations are currently performed at the Veldhoven facility.

The 3200 square-foot Demo Lab in Tempe houses ASML’s most advanced 200-mm exposure tools: the KrF wavelength PAS 5500/850 and the ArF wavelength PAS 5500/1150. The 2200 square-foot Veldhoven facility boasts the industry-leading 300-mm ArF exposure tool, the TWINSCAN AT:1200. Both facilities have also invested heavily in the finest support equipment from such companies as Hitachi, KLA-Tencor, FSI and TEL to ensure that a customer’s experience in the demo lab is indicative of the total litho experience he will have in his own facility using ASML tools.
More Than a Test-Drive

Given the nature of ASML’s business as a capital equipment manufacturer, the Demo Labs are the only locations within ASML where equipment is kept in a stable, controlled environment for an extended period of time. These stable environs have multiple benefits to customers beyond traditional “test-driving.” They also provide an internal testing ground wherein ASML can regularly produce data that substantiates its performance claims as well as a true-to-life environment where development engineers can test new hardware and software features on a tool to generate quantifiable data.

No longer is adherence to ATP specs the only requirement customers make of the equipment they purchase. Now customers assume that tools will meet published specs and want to know how a tool will perform in their own facility, under their own conditions and when they try to push the tool well beyond its intended specifications. Such work in the very low $k_1$ area of lithography requires painstaking attention to tool setup, processing control and metrology. Our Demo Lab facilities offer customers (be they internal or external to ASML) and industry partners the ideal environment to investigate and substantiate ASML’s tool performance.

Technical Partnering with ASML – A Positive Experience

As Demo Lab engineers are often some of the first technical contacts a prospective customer will make with ASML, their responsiveness and flexibility to customer requests is extremely important. Detailed preparations for the visit and thorough follow-up ensure that the demo includes precisely the tests and procedures requested by the customer. In this manner, the demo engineers often sustain a supportive interaction with the customer over many weeks or months, supplementing the support and care offered by the customer’s Account Team.

Certainly the Demo Labs, stocked with leading-edge ASML tools, illustrate a financial investment on the part of ASML in providing a valuable opportunity to its customers. But ASML’s non-financial investment—the thorough preparation, expert execution of the demo, follow-up and attentive care to the quality of the customer’s entire demo experience—is equally significant.

Customers leave the Demo Labs with two levels of reassurance regarding ASML and machine performance. First, they leave with verifiable, demonstrated evidence of ASML’s adherence to specifications and extendibility beyond. Second, they leave with a positive experience of ASML’s dedication and flexibility in all circumstances surrounding the demonstration, a significant positive indicator for the future of their technical partnering with ASML.
Customized Productivity Improvement (CPI)

By Henk Niesing and Francie Lamers

As fabs become more complex and process windows narrow, it becomes more difficult to reach optimal manufacturing conditions. At the same time, technology continues to change; new process transfers and different process techniques can limit the production efficiency of your installed base considerably. ASML now offers an efficient solution for optimizing your litho-cell Overall Equipment Efficiency (OEE), and therefore your litho-cell productivity performance (see Fig. 1). This solution is called CPI: Customized Productivity Improvement.

CPI: Customized Productivity Improvement

CPI is a modular approach combining your specific productivity requirements and in-house process engineering capabilities with our ASML productivity specialists, expertise and proven best known means and methods. CPI comprises three consecutive steps that build up from a productivity bottleneck analysis to full implementation of the recommended solutions.

Benefits of CPI

- CPI enables you to achieve realistic improvements based on your specific installed base, configuration, in-house capabilities and process requirements.
- It allows you to tap into ASML’s knowledge database in order to benchmark your performance with the best-in-class.
- There is a strong focus on on-site knowledge and best known methods transfer.
- The payback period is quick through immediate increased productivity.
- CPI projects are carried out by ASML’s productivity specialists and based on proven means and methods.

CPI – Step 1

In the first phase of a CPI project, our ASML productivity specialists, in close cooperation with your process engineers, begin an analysis to determine the current status of your litho-cell performance and prepare an OEE-cubes plot of your fab based on data from randomly selected systems. We perform a benchmark study of your current fab performance, identify a realistic productivity improvement target that can be gained through the CPI and introduce the general OEE methodology (see Fig. 2).

CPI – Step 2

The second phase of the CPI includes a detailed (on-site) analysis that results in a quantitative breakdown of each OEE cube into its unique components for a transparent monetary impact assessment of each issue. The analysis also results in the identification of critical process and tool inefficiencies and a recommendation of solutions ranging from easy-to-implement modifications to more significant structural improvements to tackle your productivity bottlenecks (see Fig. 3).

Figure 1

OEE Cubes Model

- Rate Efficiency Losses
- Quality Efficiency Losses
- Overall Equipment Efficiency (OEE)
- Standby Time
- Engineering Time
- Scheduled Down Time
- Unscheduled Down Time

Figure 1

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CPI – Step 3

If required, the implementation and evaluation can be carried out by ASML application engineers. This will be done in close cooperation with the customer’s engineering staff to safeguard effective knowledge transfer of ASML’s best known methods with careful attention to the implementation of solutions chosen, on-site best known methods and knowledge transfer to your process engineering staff and on-product evaluation to validate realized improvements.

Conclusion

Customized Productivity Improvement is a proven method of improving the litho-cell productivity performance in both 200-mm and 300-mm fabs, helping ASML’s customers to increase their installed-base performance and, therefore, reducing manufacturing costs.

Additional products to enhance your overall litho-cell performance, decrease current rework rates, or prepare you for your next technology node are Customized Overlay Improvement (COI) and Customized Imaging Improvement (CII).

Please contact your local ASML representative for more information.

Value of Ownership

• Achieve realistic improvements based on the specifics of your fab and processing requirements
• Multi-phase analysis, customized recommendations, on-site implementation and knowledge transfer, on-product evaluation

Figure 2
Example phase 1: Performance benchmark study

Figure 3
Rate efficiency loss breakdown and idle time
Bringing Design-to-Image Solutions to Broader Markets

In an effort to expand the utilization of its extreme precision optical manufacturing capacity, the ASML Optics group has recently extended the offering of its optical capabilities from lithography to include all semiconductor equipment and optical manufacturing market applications. Using the foundry business model, ASML Optics is committed to providing extreme precision optics to meet industry requirements in a timely and cost efficient manner.

There are only a handful of optical manufacturing operations in the world that have similar extreme precision capabilities. This provides ASML Optics with a unique capability to offer for the semiconductor industry and the broader high technology optical manufacturing sector. Expert resources in optical design, optical manufacturing, systems engineering, test and metrology allow ASML Optics to offer complete Design-to-Image solutions across a broad range of application requirements.

These capabilities include all forms of opto-mechanical designs using large diameter refractive and reflective aspheric optics to flats, windows and more conventional spherical lenses and mirrors for both prototype and volume production requirements. The grinding and polishing operations include the most state-of-the-art computer controlled optical polishing and final surface finishing, diamond point turning and magnetorheological polishing. A full range of optical coating expertise and capacity extends from the infrared to the ultraviolet, including expertise at 193-nm and 157-nm wavelengths, which is of particular interest for next-generation semiconductor inspection and measurement equipment (see Fig. 1).

ASML Optics also has a depth of experience in complete systems engineering design and manufacturing, which includes mechanical design, systems integration including sensor and control mechanisms and the necessary software for providing completely integrated optical systems. To manufacture with extreme precision you must be able to measure with extreme precision, and to this end the metrology competency of ASML Optics is world-class. In fact, the National Institute of Standards and Technology called on the expertise of ASML Optics to provide them with their special interferometer tooling for calibrating and certifying industry standards.

Advancing Lithography – Extending Expertise to the Extremes

In the extreme-precision world of lithography, many in the industry may not be aware of ASML Optics’ behind-the-scenes contributions to recent advances progressing 157-nm technology. ASML recently shipped the industry’s first full-field 157-nm Micrascan VII to IMEC in Belgium and has shipped the second system to a research facility in North America. All of the projection optics in these advanced systems were fabricated to very exacting tolerances by the team at ASML Optics (see Fig. 2).

The ASML Optics team is participating with Carl Zeiss in the design, select component manufacturing and assembly of the future 157-nm TWINSCAN product offering, due to customers in 2004 (see “Projection and Illumination Optics for High-NA 157-nm Scanners” in this issue of Images). And for those customers considering a maskless future, it may be interesting to know that ASML Optics is under contract for design studies for Optical Maskless Lithography. This is a new technology development that ASML is exploring in a joint venture with Micronic of Sweden (see “Optical Maskless Lithography” in this issue of Images).

For ASML’s EUV Alpha program, ASML Optics is an active partner with Carl Zeiss developing manufacturing and metrology processes. In a recent paper presented at SPIE Optical Science
and Technology Symposium in San Diego, Louis Marchetti, an engineer for ASML Optics, reported on results of recent EUV optic fabrication. Based on two sets of recently completed 10x Schwarzschild optics, Marchetti outlined the fabrication process and discussed the challenges of metrology due to the particular form factor and exacting tolerances placed on the optics. The results concluded that the figure and mid-spatial surface errors were significantly reduced as compared to a set of 10x optics fabricated in 1999. The reported results showed a surface figure accuracy of 0.64-nm rms for the primary optic, and 0.32-nm rms for the secondary mirror, which is well within the design specification for these optics (see Fig. 3, page 26).

PerfectWave Metrology – Improving the Accuracy of Interferometers

Perhaps the most impressive capability unveiled at SPIE's San Diego exhibition was ASML Optics' PerfectWave Metrology Calibration Flat that extends optic accuracy beyond Lambda/100, far greater than the current commercially available standard of Lambda/20 (@ Lambda = 632 nm).

The common method for verifying an interferometer's performance involves calibrating it relative to a known standard, the accuracy of which becomes a limiting factor. PerfectWave Metrology dramatically extends those limits with standards fabricated to the extreme precision level of 1nm rms (Lambda/632 rms), bringing a new dimension of accuracy to optical metrology. The PerfectWave Calibration Flat is currently available in 4” and 6” models. PerfectWave Metrology spherical radius standards will also be available soon in R0.75 and R3.0 models.

As the applications of optics and the semiconductor industry expand into the realm of nanotechnology, the PerfectWave calibration standards will ensure that the interferometer rulers being used to measure nanometers are accurately calibrated, and that a nanometer is indeed a nanometer (see Fig.4, page 26).
Extreme Precision Optical Foundry - Open for Business

With all these achievements in lithography it might be hard to believe ASML Optics has the capacity for additional outside work, but in fact ASML Optics is open for business. The initial commercial efforts to offer extreme precision optical foundry capacity are being well received with an increasing level of interest from a range of customers including those in semiconductor manufacturing as well as broader commercial markets in optical manufacturing.

For more information about ASML Optics extreme precision optical foundry and the PerfectWave calibration standards, please feel free to contact the authors.
ASML’s dual-stage TWINSCAN™ scanners outperform single-stage systems. Single stages have to measure during exposure, increasing out-of-focus conditions at high speeds, forcing compromise between focus control and throughput.

There is no compromise with TWINSCAN. Dual stages enable complete wafer mapping without throughput penalty to deliver accurate focus determination before exposure. Every height change in the wafer is anticipated during imaging and all die are printed at optimum focus. The prize: more good die per day.

Rally your lithography team online at www.asml.com/twinscan