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NEWSLETTER SERVICE

Lithography Review

Important Developments in Microlithography

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1. MAY AT A GLANCE:

The business outlook for equipment continues to improve. There is no question the bottom has passed. Everyone wants to know how quickly the upturn will arrive, and how high will it go.

Bill McLean of IC Insights spoke to this issue at the SEMI New England Breakfast on 5/22. Elizabeth Schumann from SEMI presented her outlook too. At this inflection point, history provides a better indication than data does.

Markets are moving in the right direction. Demand for electronic systems is recovering. Chip markets are recovering, but not enough to show sustained growth yet. Foundry utilization is near 80%. Equipment bookings were up significantly. The book-to-bill hit 1.20. In a business that is either boom or bust, we must be swinging back to boom. But this peak may only reach CY2001 levels. Time to adjust to a lower expectation.

Immersion Lithography created quite a buzz at SPIE in March. There are many details to work out. This idea is worth looking at, as I pointed out in my June issue last year.

Petersen Advanced Lithography has developed a novel image simulation tool, the ProLE™. This tool uses GRID computer architecture and custom software to parallel process image simulations. Already a 120-day computing job has been reduced to less than one day.

2. IMMERSION OPTICS?

If 193nm optics could be extended to the 45nm node using improved resists, reticles with ordinary pellicles, lenses with minimal CaF_2 and well controlled birefringence solutions, do you think people would be interested? You bet they would! But like most radical ideas, immersion lithography will be resisted before it is adopted.

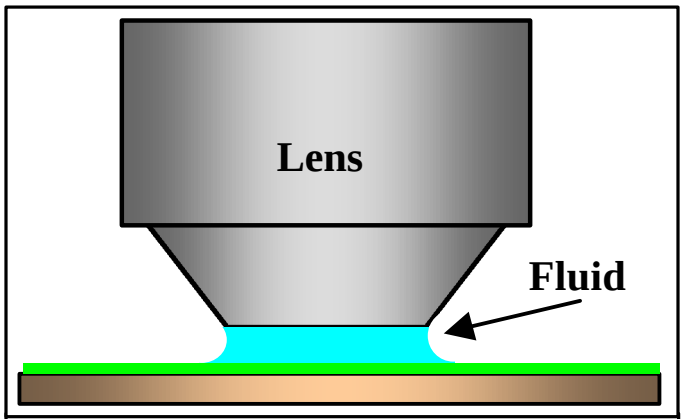

Figure 1: Immersion Imaging Concept
A high-index fluid fills the gap between the lens and the resist on a wafer

The concept is shown in figure 1. A high index fluid is used to fill the gap between the lens and the resist on a wafer. The numerical aperature can be increased up to approximately 1.3. The effective wavelength is shortened by about 1.5X. A

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193nm imaging system works like a 127nm wavelength system under such conditions, but without changing lasers or lens materials or pellicle materials, or phase shifting coating materials, or resists. This technique has been used in optical microscopes for many years. To my knowledge, until recently, it has not been tried in lithography.

Applying this technique to microlithography was first proposed at last year's EIPBN conference in June, by Michael Switkes and M. Rothchild from MIT Lincoln Labs. In my June 2001 issue of Lithography Review, I highlighted this paper as a novel idea to watch.

Since last June the MIT team has made significant progress. They have carefully defined the steps needed for a successful application of this technique. Their work has tested likely fluids for use at 193nm and 157nm. Most of the work has gone into finding clear fluids for 157nm. Water looks like a good fluid for 193nm. The relation between scanning speed and fluid viscosity has been tested. Suitable solutions have been identified and the parameter range narrowed. This work was presented at this year's SPIE meeting in March.

The MIT team has examined optical properties of several fluids for transparency, refractive index and optical defects. Useful solutions have been found. They intend to examine the uniformity of refractive index, particularly to look for local heating problems caused by laser exposure. Resist out-gassing during exposure could be a problem.

They have also studied a few key physical properties. A study of the relationship between fluid viscosity and the task of filling the gap showed that lower viscosity is better. For high speed scanning lower viscosity is also better. These physical properties have not been optimized, but basic feasibility has now been demonstrated.

Chemically compatible fluids have been found. But this will be an ongoing effort as resist systems are tested to find optimized systems.

The fluids selected are also compatible with present chemical safety requirements. The use of water with 193 systems strikes me as most attractive. Perfluorinated polyethers, such as Fomblin Z-25 vacuum pump oil have the right set of optical, mechanical and chemical properties for use at 157nm.

The MIT team modified an interference lithography system, since it was relatively simple to do so, and printed 30nm lines with 157nm light. While the resist pattern is quite rough looking, the feasibility of using immersion technology to extend the life of optical microlithography has clearly been demonstrated.

There are many unanswered questions to be explored. Optical studies continue in the search for more candidate fluids. The possibility of optical damage to fluids caused by laser exposure is being examined. The team plans to look at additional mechanical issues, for example, how do the choices of fluid and gap impact focus and stage motions. A refracting optical imaging system will be built and additional imaging tests will be run.

In the year since this idea was first presented, interest in immersion lithography has increased significantly. The potential benefit, namely using much of the present optical infrastructure to reach the 45nm node with 193nm light, is simply too attractive to ignore.

3. PARALLEL PROCESSING MACHINE:

Petersen Advanced Lithography has created a powerful computing product, the ProLE™, to speed up the modeling of OPC features in high numerical aperture imaging systems.

Imaging systems that use numerical apertures above 0.65NA and/or use phase shift masks (PSM) that have 3-dimensional surface topology on the mask surface require much more detailed modeling to properly predict the imaging effects of OPC (optical proximity correction) and PSM designs. The added detail increases modeling computation time significantly.

"Last year, in April, we were given an OPC optimization job that would take 120 days of computing time on one processor. This challenge forced us to look at parallel processing methods," John Petersen told me.

The ProLE uses a GRID processor architecture. A Master Computer runs custom software that breaks up the simulation work into smaller computational jobs. As these smaller jobs are made ready, the Master Computer posts a notice on the network. On the network can be 8, 16, 32, 64, 96 or even 128 individual processors that are

looking for jobs to process. As each individual processor finishes its smaller computational job, it posts the results back to the Master Computer. As computational results arrive, additional custom software on the Master Computer assembles the simulation result and displays it for the user on a simple graphic user interface.

John has 20 processors running in parallel on his network in Austin, Texas. This set of networked processors runs that original simulation in just 0.75-days now, a 160X improvement in computational speed. An 8-processor system was shown at this year's SPIE show in March. At that conference a paper describing the use of a 13-processor system was presented.

Petersen Advanced Lithography is now packaging the ProLE computing system as a product. "Our goal is to have the product look and work like one simple PROLITH workstation, with an improved user interface," John explained. The key is the custom "Job-Builder" software that organizes the parallel processing jobs, manages the network, and reassembles the jobs into one result for the user.

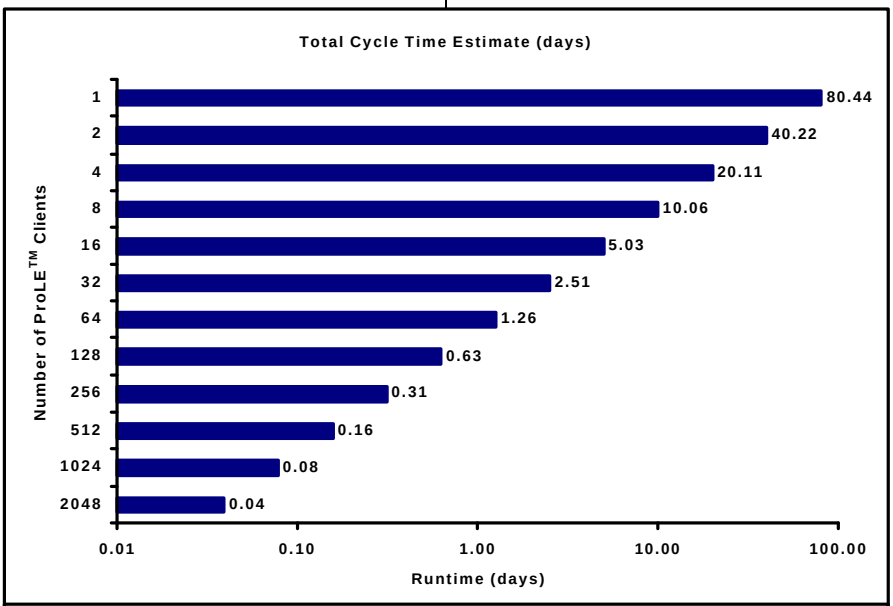

Figure 2: Processing time in days vs. number of processors working in parallel as a ProLE ™ System

Their initial model will use one rack of electronics for the Master Computer, an array of disc drives for data storage, and the network hardware. A second rack will hold all the individual processors. A low power "blade processor" board is being used to reduce power requirements and heat.

Each "blade processor" board runs its own PROLITH™ software from KLA-Tencor to do OPC simulations. Each processor also runs KLA-Tencor's ProDATA™ software for model calibration. Custom "Client" software on the Master Computer manages PROLITH and ProDATA license usage so that fees for this software are significantly reduced.

ProLE is expected to sell to major design and IC fabrication customers. Basically anyone working below 0.13-micron will need this kind of modeling capability, and this kind of massive parallel processing capability.

Petersen Advanced Lithography is working with a few leading users now, to settle final features. First systems should ship later this year.

4. SEMI'S NEW ENGLAND BREAKFAST:

"It's up from here, perhaps dramatically up," Bill McLean said as he launched Wednesday's presentation at the New England breakfast on 5/22.

Bill began by reviewing the economic events that led to the collapse of the IC equipment business. "A perfect storm," he called it. World GDP, Electronic System Sales, both turned down at once. In fact system sales dropped 10%, the first drop ever. This pushed IC sales down 32%. After some lag, equipment sales dropped 38%. Elizabeth Schumann showed details by quarter, for regions and for product groupings. In some cases bookings dropped nearly 8X in just 6 months. Bill has increased his volatility limits for equipment to +70% and –50% around a core growth rate of +14%.

Bill does see IC sales approaching saturation around 21% of electronic system sales. The systems business grows about 7% a year. As chip sales approach saturation, Bill is lowering the chip growth rate from 17% down to 14%, and speculated again that IC sales growth might move to 7% soon. In

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fact measured in dollars, IC sales appear to have been flat for the past decade.

Bill compared this cycle with the 1984-86 cycle. We are now seeing a "rolling bottom" he said. This should end soon.

Do you remember when this industry speculated that it might see a "soft landing?" Imagine! To his credit, Bill McLean said at that time that this business never had average years or soft landings. It is either boom or bust. As we come out of the bust phase, equipment business should move up dramatically Bill observed.

Both Bill and Elizabeth admit that the drivers that will grow primary IC demand are unclear at this time. Without good growth of IC demand, the current upsurge might be short lived as inventory levels are reset, but sustained growth is does not arrive. This is a concern on the minds of many.

Bill believes that as businesses see the economy growing, and their profits improve, business investment will return. A round of PC upgrades, driven by Windows XP is expected, he says. This will be the primary driver for growth. He also does not expect a repeat of the 97-98 double dip. "That was driven by world GDP, which fell in 98 due to the Asian money crisis in the last half of 97," Bill observed. He's not expecting a similar drop in world GDP next year. So he expects we will avoid a double dip this cycle.

It is clear that the "boom again" scenario is now an article of faith that history will repeat itself. A "rolling bottom" does not provide clear signals in the market data. I expect another dynamic will impact scanner bookings, creating at least a "virtual boom." A perceived shortage of advanced 193nm systems may lead to early and heavy buying of these systems. This kind of shortage mentality has often made normal growth look like a new boom in this business.

5. TRENDS IN THE NEWS:

157nm meeting: 140 participants met in Dallas the first week in May to review progress on 157nm lithography. In its press release, International Sematech says that 157nm progress has been excellent, and the technology should be ready ahead of other alternatives for features below 65nm. Annealing methods for 111-oriented CaF_2 crystals have now met specs for index uniformity and birefringence.

Similar work with crystals having a 100 orientation has really just begun. Researchers have determined that polishing and annealing methods will have to change for this orientation, so a new learning curve is needed. This may delay implementation of 157nm lenses by another 12 months, in my judgement.

Pellicles may be the final gating item. Progress has been very slow with thin organic pellicles, the type used at 193nm and longer wavelengths. Sematech has launched studies with several universities to understand the failure mechanisms at the molecular level. As an alternative several teams are working on hard pellicles. They are finding the kinds of problems that I'd expect. The glass becomes an active element in the reduction lens. So it must be a part of the lens design. The hard pellicle window needs to meet the same tolerances as any other element of the lens design. Thickness variations, sag, curvature, and bending due to mounting forces will all frustrate hard pellicle efforts. Unfortunately, to maintain the schedule for 2004 introduction of beta units, the choice of pellicles must be made now. Lens designs will need to incorporate the dimensions chosen for a hard mask. Lens design, fabrication and integration takes 18 to 24 months.

This meeting did not address resist issues. Good progress on resists was reported at SPIE. So, it now looks like pellicle and 100-oriented CaF_2 issues will be the gating technical problems that must be solved before 157nm gains widespread use.

JMAR reports that its X-ray program has been accelerated, and is on track for integration and testing by the end of this year. The company purchased SAL in South Burlington, Vermont last year. JMAR has since received DARPA funding to build a machine that uses JMAR's proprietary point source X-ray source. The product is aimed at volume production of military chips for high frequency circuits.

LSI Logic has joined the TSMC, STMicro, Philips consortium, based in Europe, to develop 90nm processes. This is the same group that Motorola joined recently (see the March issue of Lithography Review). Their goal is to develop this process capability for system-on-chip (SoC)

products. TSMC said it plans to introduce four logic and mixed-signal products using this 90nm technology within the next 18 months.

Brooks Automation completed its acquisition of PRI Automation on 5/15/02. The new company name is Brooks-PRI Automation, Inc. The deal was done as a tax-free swap of stock. Its trading symbol will be BRKS, listed on NASDAQ. The new company had $650 million of CY2001 sales, and becomes the 11th largest semiconductor equipment company in the world. According to a spokesperson for Brooks-PRI Automation, this new company is now nearly twice the size of its nearest competitor. Brooks-PRI builds material handling systems for tool interfaces, intra-bay, and inter-bay transport systems, and the software to manage material movement throughout the fab. Brooks has also built a significant position in fab related software. Last year the company obtained rights to distribute yield data management software from KLA-Tencor. Brooks-PRI continues to add to its fab related software capability.

Brooks-PRI Automation also announced on May 15th that the company has received its third patent, US #6,375,403, for its 300mm loadport technology. The patent covers details of opening, closing and accessing substrates from front opening unified pods (FOUP's) used for clean transport of 300mm wafers. This technology is available for licensing on a "commercially reasonable, non-discriminatory basis." By providing OEMs with the option to buy 300mm loadports from Brooks-PRI or to license this technology, the company is striving to foster compliance with 300mm standards.

6. BUSINESS OUTLOOK:

The future is always hard to discern at an inflection point in the business cycle. As Bill McLean observes, we are at a "rolling bottom." Experts remain divided about the future, some predicting a double dip as in 97-98 and others saying the good times will roll again. Let's look at this layer by layer in the marketplace.

World GDP appears to be on the upswing, led by the US economy. Productivity has jumped significantly. These trends will support a return to profits at most "old economy" companies.

These businesses will wait to see profits return before increasing capital outlays. This will delay an upturn in system sales to the second half of this year. Business investment in a new generation of PC's, driven by a switch to Windows XP, is the expected scenario. The normal Christmas buying cycle will be in sync with this timing. Finally, the long awaited investment in 2.5G and 3G cell phone infrastructure is expected to improve second half system demand. All these factors should sustain IC demand, avoiding a double dip.

Foundries have been the first to report the return of IC chip demand. Leading edge capability has been tight all year. Now overall capacity utilization is reported to be above 75%, headed towards the magic number of 80%. TSMC expects to pass 80% utilization this quarter. Chartered Semiconductor expects its Q2 sales to increase 40% sequentially. All three foundries have just raised their capital plans and purchases.

The increase in business for the Foundry segment also reflects an important shift of capacity expansion from the US to Asia. Several US based integrated device manufacturers (IDM's) are shifting to an "asset lite" strategy. Motorola and TI have made their new strategy clear in recent announcements. I suspect the same motivation is behind IBM's recent cutbacks. These companies believe that they can achieve better return on assets by building production capacity with the help of foundry operations. Only when faced with significant IC demand, perhaps IC shortages, will these US based companies build additional 300mm fabs. Even then new investment may be shared with partners in Asia, to get the best possible return on investment. This makes Intel's plans, now expected to be $5.5 billion, critical to the North American outlook.

Clearly, the resurgence of equipment demand is going to vary by region. Europe, China and Korea should be strong buyers in the next upturn. All three regions appear to be in a solid financial position. Japan appears to be sliding to the bottom of the pack. The "Big 5" lost about $4 billion last year. Major realignments and partnering deals are being negotiated now. This kind of environment does not support aggressive investment plans.

The impact of these favorable trends has now reached equipment companies. SEMI's book-to-bill

ratio jumped to an unexpected high of 1.20 in April. Bookings increased impressively, while shipments remained nearly flat. Morgan Stanley has revised its Capital Spending Forecast, increasing CY2002's forecast to $26 billion, up 10% from their January forecast. Morgan Stanley expects CY2003 to be up another 35%.

If the Morgan Stanley forecast is right, CY2003 will provide $35 billion in billings. As impressive as a 35% growth year sounds, the result will still fall significantly below CY2001's billings of $41 billion. A "great year" will be one whose billings come in at slightly more than half of the last peak of $60 billion.

Month	Billed	Booked	Ratio
April 01	1655	721	.44
May 01	1462	723	.49
June 01	1360	731	.54
July 01	1192	769	.65
Aug 01	1144	715	.62
Sept 01	961	614	.64
Oct 01	896	644	.72
Nov 01	817	589	.72
Dec 01	810	614	.76
Jan 02	806	655	.81
Feb 02	818	737	.90
Mar 02 final	798	836	1.05
April 02 prelim	822	982	1.20

[The SEMI book to bill ratio is a three month rolling average, issued once a month. The data is compiled by Arthur Andersen LLP using unaudited data supplied by North American firms for their global business.]

7. About the Author:

Lithography Review is written by Griff Resor. Griff has developed several important lithography tools. He's best known for creating the first commercially successful wafer stepper. He also founded and was CEO of MRS Technology, Inc., an international supplier of stitching-steppers used to make active-matrix flat panel displays. Griff received the SEMI award in 1992 for these contributions. He now provides business and technology consulting services to high tech firms helping them understand markets, select technologies, reset strategies, and manage better. He has a BS in Physics from Yale and an MBA from Harvard.

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