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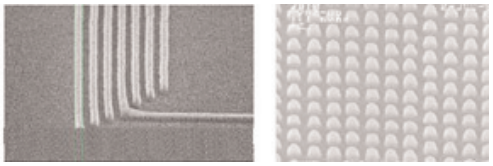
Will Nanotech Preserve Moore's Law?

Within 10 years, the entire semiconductor industry will rely on nanotechnology," says Mike Roco, the head of the United States' National Nanotechnology Initiative. Those are bold words. As we noted in our May 2002 article, "Will Nanotech Save Silicon Valley?" the technology used in the semiconductor industry needs a complete overhaul. Today's chipmakers such as **Intel** [INTC] and **AMD** [AMD] make Pentium and Athlon computer chips using a process called photolithography: patterning and etching chips using light sources. But this is running into some serious problems.

Traditional photolithography uses light shined over a mask to burn patterns into silicon wafers. Chipmakers can currently use photolithography to make feature sizes in the .13 micron to .18 micron range, and they are about to debut products from new 90nm production lines. But they need to get smaller to ensure the continuation of Moore's Law, which states that computing processing power (and, more specifically, the number of transistors on a chip) doubles every 18 months. Intel's first chip, the 4004, had 2000 transistors when it was released in 1971. Today's chips have 100 million. Ultimately Moore's Law will hit a brick wall as the lithography techniques used today become limited by the wavelength of light. So begins the hunt for new methods of sub-90nm scale lithography.

Nanoimprint Lithography

According to the 2002 International Technology Roadmap for Semiconductors, the production of sub-65nm electronic devices will require post-optical lithography solutions. The leading candidate is extreme ultraviolet (EUV) lithography, which will become a reality towards the end of this decade when it will be used in the mass production of chips. San Diego-based **Cymer Inc.** [CYMI] is the front runner in this field. But beyond EUV, the big chip makers have no formal strategy of their own other than investing in small start-ups, as **Motorola** [MOT] is doing with Molecular Imprints.



50nm lines and 60nm pillars made using Step-Flash NIL

Courtesy of Molecular Imprints

But Moore's Law may have another savior. Nanoimprint lithography (NIL). Originally pioneered by Princeton professor of Engineering Stephen Chou, nanoimprint lithography is a waffle-iron method of production. Here's how it works. "Everyone is familiar with newspapers or even how a stamp works," says Chris Keimel, one of the behind-the-scenes geniuses at Chou's lab. "A stamp has features etched into it, you put ink on it and press it on paper to transfer a pattern. Granted with newspapers you're transferring ink, but instead of ink, you create a mold using nanoimprint lithography. You press that mold into soft material, think playdough, which you then need to harden. Instead of putting the playdough in the oven, you use UV light or heat to cure it and you can get structures with as low as 10nm precision."

One of the keys to NIL is the polymer. "There are no out of shop polymers," says Chou. "You have to do your own mix. Our polymers were selected from over 500 recipes. We found the 'Coca-Cola' recipe for polymers."

This self-professed "Coca-Cola" polymer recipe is a key asset in Professor Chou's startup company NanoNex. The Monmouth Junction, New Jersey-based, 10 person firm sells three models of the nanoimprinting machines together with the masks, polymers, and processes for companies wanting to make nano-devices, optical components (such as his other company NanoOpto) or even biological devices like nanofluidic structures. But NanoNex has competition. A handful of companies worldwide have embraced Chou's general idea, modified it, and now are going head to head with him in certain industries. One of those is Austin Texas-based Molecular Imprints (*see Companies to Watch, January 2003*).

Nanoimprint Mod Squad

Molecular Imprints has already garnered solid financial backing from the likes of Motorola, **Lam Research** [LRCX], **KLA-Tencor** [KLAC] and venture investors Draper Fisher Jurvetson, Alloy Ventures,

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and Huntington Ventures. The company has developed a variation on Chou's technology called Step and Flash Imprint Lithography (S-FIL). Molecular Imprints' technique has some key advantages over Chou's. Molecular Imprints doesn't use high temperature, like Chou's method of curing using a high powered heat lamp, or high pressures. For applications in biotechnology or the medical arena, it's not possible to use high temperatures, because the materials will fry, and high pressures can fracture fragile substrates like glass. Instead, step and flash imprint lithography operates at room temperature and low pressure. It dispenses a polymer on each imprint field rather than coating the whole wafer, which is expensive.

"We're starting to see the other players drift in our direction", says CEO Norm Schumaker. In fact, NanoNex has a brand new thermal imprint technology called LAN (laser assisted or light assisted nanoimprinting). "We use a laser beam or high power lamp at the nanoscale which melts polymer quickly without heating mask," says Chou. This process is more precise than conventional thermal technology.

Molecular Imprints claims price is also on its side, boasting that its tool is 10 times cheaper than projection lithography tools. "We don't have the sophisticated optical systems that big silicon currently uses," says Schumaker. "That takes 40% out of cost of the tool. We've eliminated the need for elaborate automation for factory control. And with our process, we can do one wafer per hour, rather than the day long process it takes now." By comparison, Chou claims to be able to process 30 8" wafers per hour.

Technology aside, Molecular Imprints also has a business lead here. Besides $12 million in blue chip funding, its 33 person team has already produced and sold a $1.5 million Imprio 100 model imprinting machine to Motorola.

European Gems

There are two other European companies in this business I want to bring to your attention. Swedish firm **Obducat AB** [OBDU.B] and the Austria-based EV Group. Patrick Lundstrom, CEO of Obducat, says simplicity is his company's chief asset. "If we look at the competitors, they use two different types of equipment, one for imprinting, one for alignment. We built in an optical microscope for alignment into one piece of equipment."

Distinguishing competitive advantages is often a game of "he said/she said," but for Obducat, sales do the talking. Obducat has sold more than 25 nanoimprint lithography machines since the second half of 2001. About half of its anticipated $7 million in FY2003 revenues will come from NIL machines, the other half from sales of specialized SEMs.

GE Plastics [GE] already has a joint development agreement with Obducat for advancing the polymers used in nanoimprinting and, while the specific name is officially undisclosed, one of the world's largest semiconductor makers has been its most active customer to date. My guess: Intel.

Austria's EV Group, founded in 1980, has added nanoimprint lithography to its list of semiconductor products which include wafer aligners, bonders, coaters, and inspection systems. "We already have a worldwide infrastructure and field-proven components," says CEO Peter Podesser referring to EV Group's skill at transferring R&D processes to manufacturing volumes for their existing clients. With over 50 Nanoimprint lithography machines installed worldwide, EV Group is another company to watch.

I believe one or all or these companies will eventually be snapped up by bigger chip makers or at least form strategic alliances. The addressable industries are just too massive for one company alone. Nanoimprinting faces a few major obstacles before it can become an EUV killer and break into big silicon, though. "The industry needs better alignment accuracy than what we've done," says Chou. "Second, we need solid data on defect density and must identify sources of defects. Eventually the chip companies will want good alignment and defect free production. If we show a clear path to these two goals, I'm sure the silicon industry would pay a lot of attention."

Opportunities for Investors

Obducat is the only publicly traded of the four nanoimprinting companies, trading on the Swedish stock exchange. If you want to buy shares, you'll have to contact a brokerage firm to see if it trades through various Swedish brokerage firms like Enskilda or Swedebank.

As *Forbes/Wolfe Nanotech Report* readers know, the tools companies have been first to benefit from the nanotechnology revolution. Like **Veeco Instruments** [VECO] and **FEI Company** [FEIC], Obducat sells technology relevant for multiple markets. From semiconductors to MEMS devices to optical components and data storage, each industry will increasingly look for nanofabrication methods like nanoimprinting to stay competitive. It's just a matter of time.

INSIDER SUMMARY

- NanoImprint Lithography (NIL) is a "waffle-iron" stamping process using a viscous liquid, a press and a heat or UV light source to solidify sub-100 nanometer size structures.
- Concept of NIL was invented by Princeton's Stephen Chou.
- Molecular Imprints, NanoNex, Obducat, and EV Group are the main players.
- Molecular Imprints backed by semiconductor heavyweights Motorola and KLA-Tencor; has $12 million in venture funding.
- Most of these companies will end up being either bought by major chipmakers or forming tight alliances with them.

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