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A

Seminar report

On

EUVL

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of ECE

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Preface

I have made this report file on the topic **EUVL**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude towho assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

ABSTRACT

Silicon has been the heart of the world's technology boom for nearly half a century. Each year, manufacturers bring out the next great computer chip that boosts computing power and allows our Personal Computers to do more than we imagined just a decade ago. The current technology used to make microprocessors, deep ultraviolet lithography will begin to reach its limit around 2005. At that time, chipmakers will have to look to other technologies to cram more transistors onto silicon to create powerful chips. Many are already looking at extreme-ultraviolet lithography (EUVL) as a way to extend the life of silicon at least until the end of the decade.

Akin to photography, lithography is used to print circuits onto microchips Extreme Ultraviolet Lithography (EUVL) will open a new chapter in semiconductor technology. In the race to provide the Next Generation Lithography (NGL) for faster, more efficient computer chips, EUV Lithography is the clear frontrunner. Here we discusses the basic concepts and current state of development of EUV lithography (EUVL), a

relatively new form of lithography that uses extreme ultraviolet (EUV) radiation with a wavelength in the range of 10 to 14 nanometers (nm) to carry out projection imaging. EUVL is one technology vying to become the successor to optical lithography.

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1. INTRODUCTION

Silicon has been the heart of the world's technology boom for nearly half a century, but microprocessor manufacturers have all but squeezed the life out of it. The current technology used to make microprocessors will begin to reach its limit around 2005. At that time, chipmakers will have to look to other technologies to cram more transistors onto silicon to create more powerful chips. Many are already looking at **extreme-ultraviolet lithography** (EUVL) as a way to extend the life of silicon at least until the end of the decade.

Potential successors to optical projection lithography are being aggressively developed. These are known as "Next-Generation Lithographies" (NGL's). EUV lithography (EUVL) is one of the leading NGL technologies; others include x-ray lithography, ion-beam projection lithography, and electron-beam projection lithography. Using **extreme-ultraviolet** (EUV) light to carve transistors in silicon wafers will lead to microprocessors that are up to 100 times faster than today's most powerful chips, and to memory chips with similar increases in storage capacity.

2. EUVL DEFINITION

Extreme ultraviolet lithography (EUVL) is an advanced technology for making microprocessors a hundred times more powerful than those made today.

EUVL is one technology vying to replace the optical lithography used to make today's microcircuits. It works by burning intense beams of ultraviolet light that are reflected from a circuit design pattern into a silicon wafer. EUVL is similar to optical lithography in which light is refracted through camera lenses onto the wafer. However, extreme ultraviolet light, operating at a different wavelength, has different properties and must be reflected from mirrors rather than refracted through lenses. The challenge is to build mirrors perfect enough to reflect the light with sufficient precision

2.1 EUV RADIATION

We know that Ultraviolet radiations are very shortwave (very low wavelength) with high energy. If we further reduce the wavelength it becomes Extreme Ultraviolet radiation. Current lithography techniques have been pushed just about as far as they can go. They use light in the deep ultraviolet range- at about 248-nanometer wavelengths-to print 150- to 120-nanometer-size features on a chip. (A nanometer is a billionth of a meter.) In the next half dozen years, manufacturers plan to make chips with features measuring from 100 to 70 nanometers, using deep ultraviolet light of 193- and 157-nanometer wavelengths. Beyond that point, smaller features require wavelengths in the extreme ultraviolet (EUV) range. Light at these wavelengths is absorbed instead of transmitted by conventional lenses

2.2 LITHOGRAPHY

Computers have become much more compact and increasingly powerful largely because of lithography, a basically photographic process that allows more and more features to be crammed onto a computer chip.

Lithography is akin to photography in that it uses light to transfer images onto a substrate. Light is directed onto a mask—a sort of stencil of an integrated circuit pattern—and the image of that pattern is then projected onto a semiconductor wafer covered with light-sensitive photoresist. Creating circuits with smaller and smaller features has required using shorter and shorter wavelengths of light.

3. WHY EUVL?

The current process used to pack more and more transistors onto a chip is called **deep-ultraviolet lithography**, which is a photography-like technique that focuses light through lenses to carve circuit patterns on silicon wafers. Manufacturers are concerned that this technique might soon be problematic as the laws of physics intervene.

Intel, AMD, and Motorola have joined with the U.S. Department of Energy in a three-year venture to develop a microchip with etched circuit lines smaller than 0.1 micron in width. (Today's circuits are generally .18 micron or greater.) A microprocessor made with the EUVL technology would be a hundred times more powerful than today's. Memory chips would be able to store 1,000 times more information than they can today. The aim is to have a commercial manufacturing process ready before 2005.

Processors built using EUV technology are expected to reach speeds of up to 10 GHz in 2005-2006. By comparison, the fastest Pentium 4 processor today is 1.5 GHz.

3.1 MOORE'S LAW

Each year, manufacturers bring out the next great computer chip that boosts computing power and allows our personal computers to do more than we imagined just a decade ago. Intel founder **Gordon Moore** predicted this technology phenomenon more than 35 years

ago, when he said that the number of transistors on a microprocessor would double every 18 months. This became known as **Moore's Law**.

Industry experts believe that deep-ultraviolet lithography will reach its limits around 2004 and 2005, which means that Moore's law would also come to an end without a new chipmaking technology. But once deep-ultraviolet hits its ceiling, we will see chipmakers move to a new lithography process that will enable them to produce the industry's first 10-gigahertz (GHz) microprocessor by 2007. By comparison, the fastest Intel Pentium 4 processor (as of May 2001) is 2.4 GHz. EUVL could add another 10 years to Moore's Law.

"EUV lithography allows us to make chips with feature sizes that are small enough to support 10 GHz clock speed. It doesn't necessarily make it happen," Don Sweeney, EUV Lithography program manager at Lawrence Livermore National Laboratory (LLNL), said. "The first thing we need to do is to make integrated circuits down to 30 nanometers, and EUV lithography will clearly do that." By comparison, the smallest circuit that can be created by deep-ultraviolet lithography is 100 nanometers.

3.2 THE INCREDIBLE SHRINKING CHIPS

Twenty five years ago, the computing equivalent of today's laptop was a room full of computer hardware and a cartload of punch cards. Since then, computers have become much more compact and increasingly powerful largely because of lithography

Why are smaller computer chips better and faster? It might seem a paradox, but as the size decreases, the chips become more powerful. It's as simple as getting to grandma's house faster if she lives next door rather

than across town: the electronic signals zipping around the circuitry to solve computing problems have less distance to travel. Today's chip contains about 3,260 times more transistors than the chip of 1971.

A microprocessor -- also known as a **CPU** or central processing unit -- is a complete computation engine that is fabricated on a single chip. The first microprocessor was the Intel 4004, introduced in 1971. The 4004 was not very powerful -- all it could do was add and subtract, and it could only do that 4 bits at a time. But it was amazing that everything was on one chip.

The first microprocessor to make it into a home computer was the Intel 8080, a complete 8-bit computer on one chip, introduced in 1974. The PC market moved from the 8088 to the 80286 to the 80386 to the 80486 to the Pentium to the Pentium II to the Pentium III to the Pentium 4. All of these microprocessors are made by Intel and all of them are improvements on the basic design of the 8088. The Pentium 4 can execute any piece of code that ran on the original 8088, but it does it about 5,000 times faster!

A microprocessor sometimes called a *logic chip*. It is the "engine" that goes into motion when you turn your computer on. A microprocessor is designed to perform arithmetic and logic operations that make use of small number-holding areas called *registers*. Typical microprocessor operations include adding, subtracting, comparing two numbers, and fetching numbers from one area to another. These operations are the result of a set of instructions that are part of the microprocessor design. When the computer is turned on, the microprocessor is designed to get the first instruction from the basic input/output system (BIOS) that comes with the computer as part of its memory. After that, either the BIOS, or the

operating system that BIOS loads into computer memory, or an application program is "driving" the microprocessor, giving it instructions to perform. The following table helps you to understand the differences between the different processors that Intel has introduced over the years.

Name	Date	Transistors	Microns	Clock speed	Data width	MIPS
8080	1974	6,000	6	2 MHz	8 bits	0.64
8088	1979	29,000	3	5 MHz	16 bits 8-bit bus	0.33
80286	1982	134,000	1.5	6 MHz	16 bits	1
80386	1985	275,000	1.5	16 MHz	32 bits	5
80486	1989	1,200,000	1	25 MHz	32 bits	20
Pentium	1993	3,100,000	0.8	60 MHz	32 bits 64-bit bus	100
Pentium II	1997	7,500,000	0.35	233 MHz	32 bits 64-bit bus	~300
Pentium III	1999	9,500,000	0.25	450 MHz	32 bits 64-bit bus	~510
Pentium 4	2000	42,000,000	0.18	1.5 GHz	32 bits 64-bit bus	~1,700

4. EUVL TECHNOLOGY

In many respects, EUVL retains the look and feel of optical lithography as practiced today. For example, the basic optical design tools that are used for EUV imaging system design and for EUV image simulations are also used today for optical projection lithography. Nonetheless, in other respects EUVL technology is very different from what the industry is familiar with. Most of these differences arise because the properties of materials in the EUV are very different from their properties in the visible and UV ranges.

Foremost among those differences is the fact that EUV radiation is strongly absorbed in virtually all materials, even gases. EUV imaging must be carried out in a near vacuum. Absorption also rules out the use of refractive optical elements, such as lenses and transmission masks. Thus EUVL imaging systems are entirely reflective. Ironically, the EUV reflectivity of individual materials at near-normal incidence is very low. In order to achieve reasonable reflectivity's near normal incidence, surfaces must be coated with multilayer, thin-film coatings known as distributed Bragg reflectors. The best of these functions in the region between 11 and 14 nm. EUV absorption in standard optical photoresists is very high, and new resist and processing techniques will be required for application in EUVL.

Lithography is one of the key technologies that enable Intel to meet the challenge of Moore's Law by allowing a 30% decrease in the size of printed dimensions every two years. Intel has been an industry leader in advanced lithography with the early introduction of 248 nm and 193 nm lithography tools into high volume manufacturing. Intel is continuing this

trend with strong investments in Extreme Ultraviolet (EUV) research at our Hillsboro, Oregon, and Santa Clara, California, sites.

The completion of the prototype machine (Engineering Test Stand) marks a major milestone for the program, since we have proven that EUV lithography works," said Chuck Gwyn, program manager of the EUV Limited Liability Company. "Our next step is to transfer the technology to lithography equipment manufacturers to develop beta and production tools."

Processors built using EUV technology are expected to reach speeds of up to 10 GHz in 2005-2006. By comparison, the fastest Pentium 4 processor today is 1.5 GHz. The prototype machine, called the Engineering Test Stand, was developed by industry-government collaboration among three U.S. Department of Energy national laboratories and a consortium of semiconductor companies called the EUV LLC. The consortium includes Intel Corporation, Motorola Inc., Advanced Micro Devices Inc., Micron Technology Inc., Infineon Technologies, and International The ETS was assembled at Sandia in Livermore, Calif. It will be used by LLC partners and lithography tool suppliers during the next year to refine the technology and get it ready to create a prototype commercial machine that meets industry requirements for high-volume chip production. The EUV LLC has developed relationships with more than 40 U.S.-based infrastructure companies to ensure that all of the key components can be attained for commercialization Business Machines

5. HOW EUV CHIPMAKING WORK

For describing the EUV chipmaking process we should have a clear idea of chipmaking process. Both are described in the following sections

Ultraviolet lithography can produce lines for integrated circuits as small as 39 nm in one recent test. To help sustain Moore's law and cram more and more gates and memory units into a given space, manufacturers of microchips must make the lines in their circuitry ever smaller. This usually means working with a shorter-wavelength light beam for creating the patterns used for inscribing fine features on silicon or metal surfaces. The form of lithography currently in mass production now can produce a half-pitch size (equal lines and spaces in between) of 90 nm and isolated line widths of 65 nm. To produce a later generation after that you would need even shorter wavelengths.

Silicon chips could be made more quickly and cheaply using a new technique developed by physicists in the US. Stephen Chou and colleagues at Princeton University have successfully imprinted patterns onto silicon using quartz moulds instead of the usual combination of lithography and etching. With a resolution of just 10 nm and an 'imprint time' of 250 ns, the new process could revolutionize the semiconductor industry - and keep 'Moore's Law' on track for another 25 years

5.1 CHIPMAKING

Lithography is akin to photography in that it uses light to transfer images onto a substrate. In the case of a camera, the substrate is film. Silicon is the traditional substrate used in chipmaking. To create the integrated circuit design that's on a microprocessor, light is directed onto a **mask**. A mask is like a stencil of the circuit pattern. The light shines through the mask and then through a series of optical lenses that shrink the image down. This small image is then projected onto a silicon, or semiconductor, wafer.

The wafer is covered with a light-sensitive, liquid plastic called **photoresist**. The mask is placed over the wafer, and when light shines through the mask and hits the silicon wafer, it hardens the photoresist that isn't covered by the mask. The photoresist that is not exposed to light remains somewhat gooey and is chemically washed away, leaving only the hardened photoresist and exposed silicon wafer.

The key to creating more powerful microprocessors is the size of the light's wavelength. The shorter the wavelength, the more transistors can be etched onto the silicon wafer. More transistors equals a more powerful, faster microprocessor. That's the big reason why an Intel **Pentium 4** processor, which has 42 million transistors, is faster than the **Pentium 3**, which has 28 million transistors.

As of 2001, deep-ultraviolet lithography uses a wavelength of 240 nanometers. A nanometer is one-billionth of a meter. As chipmakers reduce to 100-nanometer wavelengths, they will need a new chipmaking technology. The problem posed by using deep-ultraviolet lithography is that as the light's wavelengths get smaller, the light gets absorbed by the glass

lenses that are intended to focus it. The result is that the light doesn't make it to the silicon, so no circuit pattern is created on the wafer.

This is where EUVL will take over. In EUVL, glass lenses will be replaced by **mirrors** to focus light. In the next section, you will learn just how EUVL will be used to produce chips that are at least five times more powerful than the most powerful chips made in 2001.

The components on a microchip are made by carving patterns into layers of doped and undoped silicon. In the standard technique, light is shone through a stencil onto a silicon wafer that is coated with a light-sensitive polymer known as a resist. Chemical etching then removes the regions of silicon coated with either the unexposed or the exposed polymer, until the desired structure is achieved. Finally, the remaining polymer is washed off.

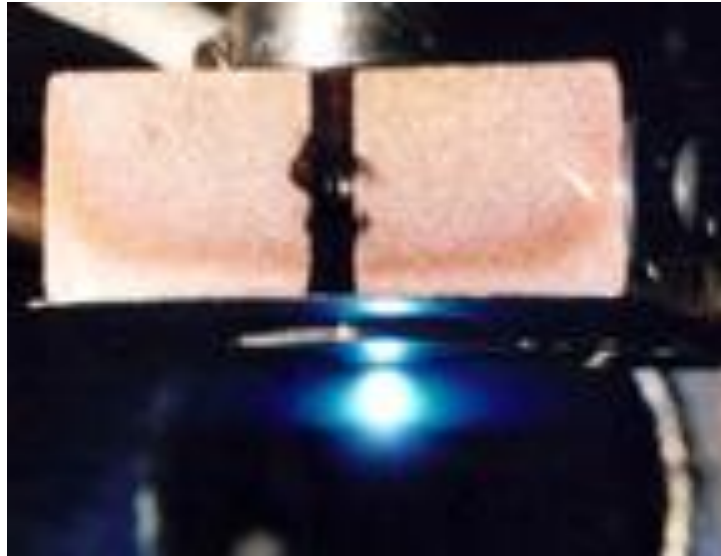
But such 'photolithography' is expensive and complex, and the resolution of the technique is fast approaching the diffraction limit. This means that it will not be able to make features much smaller than the current minimum size of about 130 nm - and that the semiconductor industry could soon violate one of its guiding principles, Moore's Law. Coined in 1965, this law described how the density of components on a chip doubled every 18 months, and was soon adopted by the semiconductor industry as a target.

Now Moore's Law could be back on track. Chou and co-workers say that their technique - known as laser-assisted direct imprint - can create features as small as 10 nm on silicon wafers. The new process also eliminates the need for the resist and washing steps

5.2 THE EUVL PROCESS

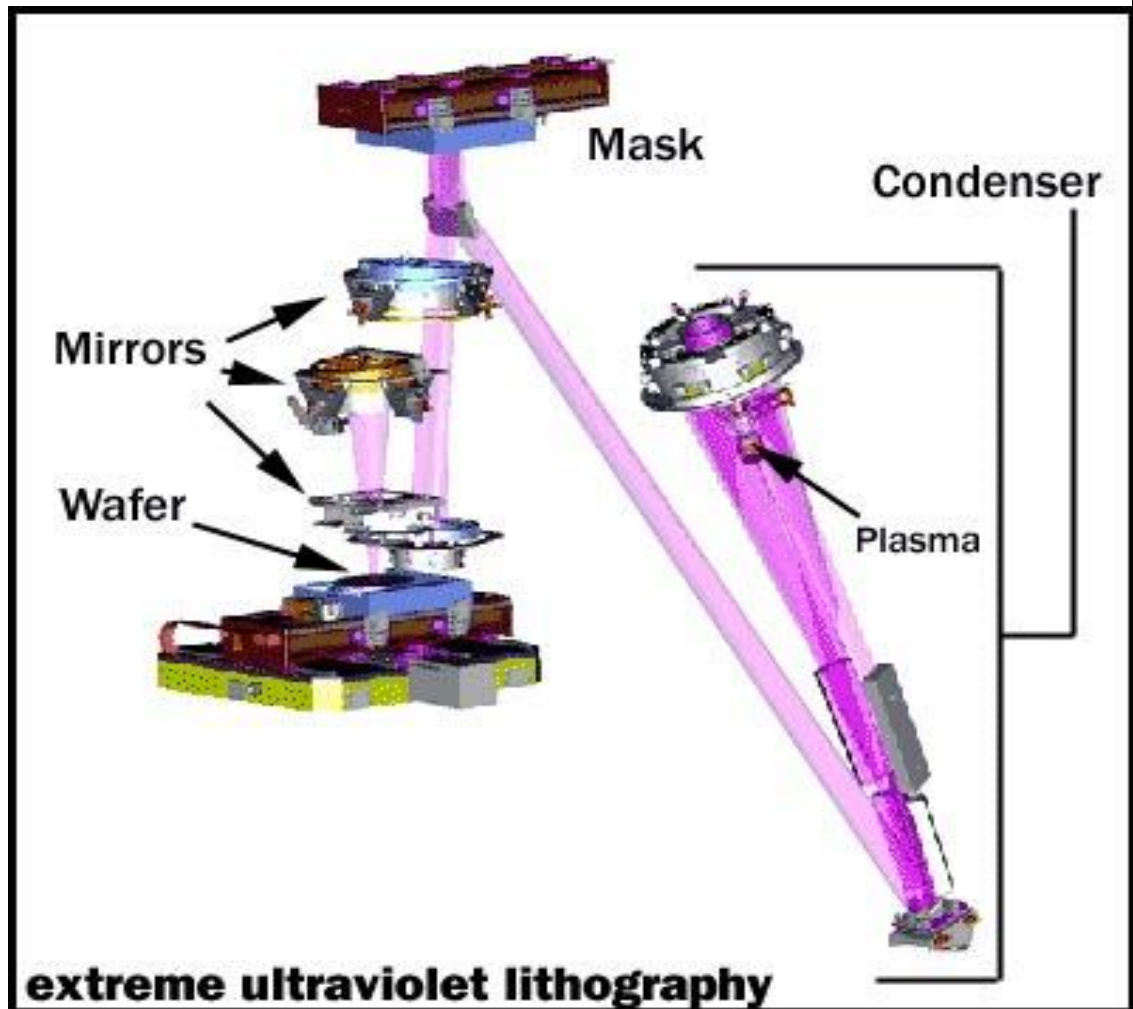
Here's how EUVL works:

1. A laser is directed at a jet of **xenon gas**. When the laser hits the xenon gas, it heats the gas up and creates plasma.



This source of extreme ultraviolet light is based on a plasma created when a laser is focused on a beam of xenon gas clusters expanding at supersonic speeds. (Besides invisible-to-the-eye extreme ultraviolet light, some visible light is also created, as seen in the blue glow in the photo.)

2. Once the plasma is created, electrons begin to come off of it and it radiates light at 13 nanometers, which is too short for the human eye to see.



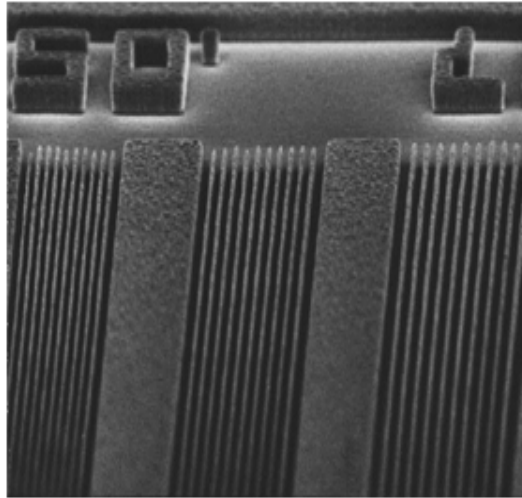
Engineering Test Stand

3. The light travels into a **condenser**, which gathers in the light so that it is directed onto the **mask**.
4. A representation of one level of a computer chip is patterned onto a mirror by applying an **absorber** to some parts of the mirror but not to others. This creates the mask.
5. The pattern on the mask is reflected onto a series of four to six **curved mirrors**, reducing the size of the image and focusing the image onto the silicon wafer. Each mirror bends the light slightly to form the image that will be transferred onto the wafer. This is just like how the lenses in your camera bend light to form an image on film.

The ETS (Engineering Test Stand, also called prototype machine) includes a condenser optics box and a projection optics box. Both boxes house complex optical trains of precision concave and convex spherical mirrors.

The conventional method for making the reflective masks for EUV lithography is called magnetron sputtering. But the defect rate for the process is about 10,000 defects per square centimeter, far too many for successful EUV lithography. The new process, embodied in Veeco's IBSD-350, produces precise, uniform, highly reflective masks with 81 alternating layers of molybdenum and silicon, each 3 to 4 nanometers thick. As the machine directs a beam of ions at the masks, the ions physically collide with each mask and form a vapor, which is precisely deposited on it at a defect density of less than 0.1 per square centimeter--a 100,000-fold improvement over conventional methods. This process also holds great promise for a number of other applications using virtually any material or combination of materials including metals, semiconductors, and insulators. A near-term possibility is making very-low-defect-density films for ultrahigh-density heads for the magnetic recording industry

The main role of the condenser optics box is to bring light to the reflective pattern on the mask. "We want to bring as much light to the mask and, ultimately, the wafer, as possible," explains Sweeney. "The more light we deliver, the shorter the exposure time. It's like taking a picture with a camera. A picture taken in bright noonday sun requires a shorter exposure time than does a picture of the same scene taken at twilight."

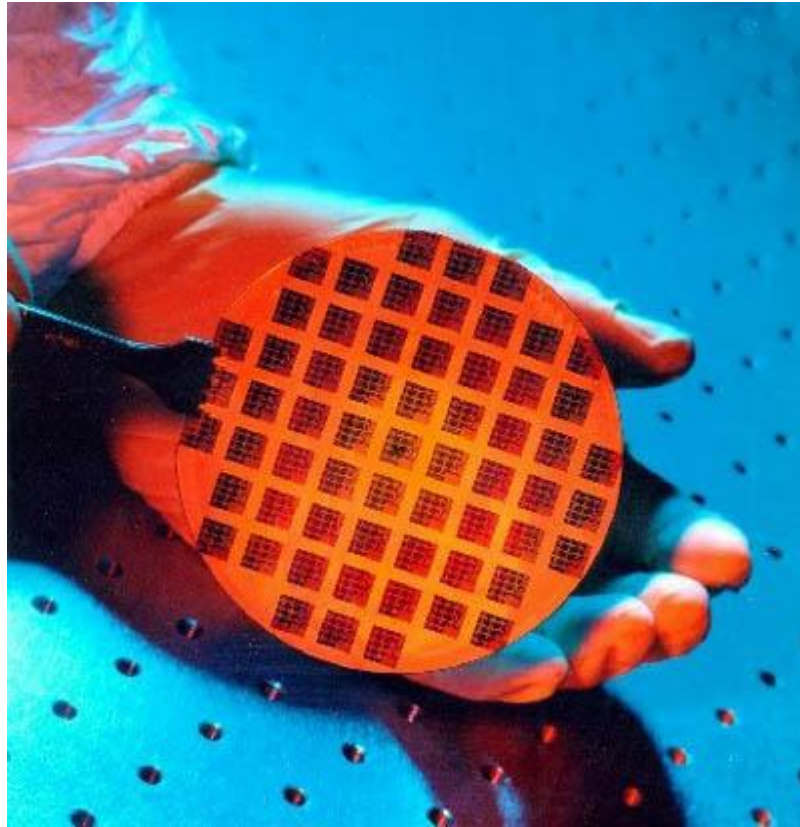


Using a prototype system, the Virtual National Laboratory has successfully printed lines as small as 50 nanometers (billionths of a meter) wide in photoresist. Current lithographic tools used in the semiconductor industry print patterns with 180-nanometer-size features.



For the semiconductor industry, brighter EUV images mean shorter exposure times, which translate to manufacturing more chips at a faster rate. The optics design team from Lawrence Livermore and Sandia designed a condenser optics system that collects and transports a significant fraction of the EUV light from the source to the reflective mask. Once the image is reflected from the mask, it travels through the projection optics system. According to Sweeney, the projection optics box is the optical heart of the lithographic exposure system. "It is to the system what an engine is to a car," he explains. The four mirrors of the ETS projection optics system reduce the image and form it onto the wafer. "Again, imagine using a pocket camera. The camera lens transmits an image to the film, which-like the wafer-has a light-sensitive surface," says Sweeney.

The optics teams are now working on advanced designs for the projection optics. They have a six-mirror design that promises to extend EUVL systems so that they can print features as small as 30 nanometers- a significant jump from the 70-nanometer limit of the ETS. According to Sweeney, extendability to smaller features is an important requirement for whatever lithographic technology the semiconductor industry finally decides



This wafer was patterned on a prototype device using extreme-ultraviolet lithography (EUVL).

This wafer was patterned on an integrated laboratory research system capable of printing proof-of-principle, functioning microelectronic devices using extreme ultraviolet lithography (EUVL). The EUV lithography research tool was assembled at Sandia National Laboratories in Livermore, Calif., which has joined with two other Department of Energy laboratories - Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory - creating a Virtual National Laboratory to help develop EUV lithography for commercial use.

According to Sweeney, Deputy Program leader for Extreme Ultraviolet Lithography and Advanced Optics. In Lawrence Livermore National laboratory, California, the entire process relies on wavelength. If you make the wavelength short, you get a better image. He says to think in terms of taking a still photo with a camera.

"When you take a photograph of something, the quality of the image depends on a lot of things," he said. "And the first thing it depends on is the wavelength of the light that you're using to make the photograph. The shorter the wavelength, the better the image can be. That's just a law of nature."

As of 2001, microchips being made with deep-ultraviolet lithography are made with 248-nanometer light. As of May 2001, some manufacturers are transitioning over to 193-nanometer light. With EUVL, chips will be made with 13-nanometer light. Based on the law that smaller wavelengths create a better image, 13-nanometer light will increase the quality of the pattern projected onto a silicon wafer, thus improving microprocessor speeds. This entire process has to take place in a **vacuum** because these wavelengths of light are so short that even air would absorb them. Additionally, EUVL uses concave and convex mirrors coated with multiple layers of molybdenum and silicon -- this coating can reflect nearly 70 percent of EUV light at a wavelength of 13.4 nanometers. The other 30 percent is absorbed by the mirror. Without the coating, the light would be almost totally absorbed before reaching the wafer. The mirror surfaces have to be nearly perfect; even small defects in coatings can destroy the shape of the optics and distort the printed circuit pattern, causing problems in chip function. Hence Before new lithography tools are even built, Chip makers must develop and demonstrate the necessary mask making capabilities.

6. CONCLUSION

Extreme Ultraviolet Lithography (EUVL) will open a new chapter in semiconductor technology. In the race to provide the Next Generation Lithography (NGL) for faster, more efficient computer chips, EUV Lithography is the clear frontrunner. At EUV Technology,

Successful implementation of EUVL would enable projection photolithography to remain the semiconductor industry's patterning technology of choice for years to come. However, much work remains to be done in order to determine whether or not EUVL will ever be ready for the production line. Furthermore, the time scale during which EUVL, and in fact any NGL technology, has to prove itself is somewhat uncertain.

Several years ago, it was assumed that an NGL would be needed by around 2005 in order to implement the 0.1 μm generation of chips. Currently, industry consensus is that 193nm lithography will have to do the job, even though it will be difficult to do so. There has recently emerged talk of using light at 157 nm to push the current optical technology even further, which would further postpone the entry point for an NGL technology. It thus becomes crucial for any potential NGL to be able to address the printing of feature sizes of 50 nm and smaller! EUVL does have that capability.

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