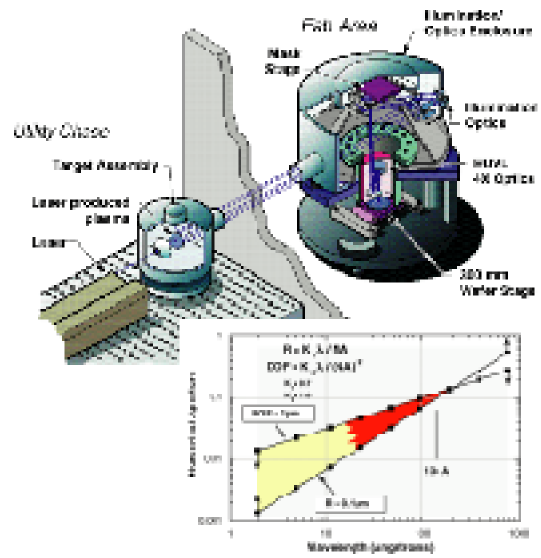
Advanced Manufacturing Technologies

Fact Sheet

Extreme Ultraviolet Lithography (EUVL)



Conceptual design for commercial EUVL image reduction equipment, called a stepper. Inset: Optical design space for EUVL showing both large depth-of-focus and 0.1 micron resolution.

EUVL is extendable to the 0.03 micron generation and is an extension of deep ultraviolet lithography. It uses…

- **13 nm exposure radiation**
- **Robust reflective mask substrates**
- **4x mask-to-wafer projection**
- **Multilayer reflective coatings**
- **Laser produced plasma light source**
- **Precision aspheric reflective mirrors**
- **Magnetically levitated stage technology**

High-tech project packs more microelectronics into smaller and smaller packages

When it comes to microelectronics, the notion that good things come in small packages can be rewritten to say that better things come in smaller packages. This "shrinking" technology has fueled intense competition among microelectronics manufacturers to reduce the size of the features on integrated circuits (ICs).

Industry experts predict that soon, feature sizes will become smaller than the wavelengths of light currently used to produce them. It is estimated that by the year 2000, semiconductor devices will require advanced patterning technologies that can print less than 0.2 micrometers wide (a micrometer is approximately 1/100th the width of a human hair).

The challenge of producing such small features with optical lithography is somewhat like trying to paint a thin line with a wide brush. A promising technique, however, that may help produce devices on this scale is extreme ultraviolet lithography (EUVL). EUV rays have wavelengths from 50 to 250 angstroms (an angstrom is 10,000 times smaller than a micrometer) and provide finer resolution than does visible light. They also have lower energy than hard x-rays, the kind used in medical imaging, so they penetrate only a few tenths of micrometers into most materials. Hard x-rays penetrate deeply, sometimes causing damage.

Currently, researchers at Sandia, Lawrence Livermore National Laboratory, and Lawrence Berkeley National Laboratory are collaborating as a single entity, called the Virtual National Laboratory (VNL), to develop this patterning technique using extreme ultraviolet (EUV) light. The VNL collaboration in EUVL is being funded by a consortium of leading U.S. IC manufacturers under a Cooperative Research and Development Agreement.

"Keeping pace with the competitive microelectronics manufacturing environment requires cooperation between national laboratories and U.S. industry," says Sandia project manager Richard Stulen. "Sandia's continuing mission to provide research and development to enhance the nation's well-being will help U.S. microelectronics manufacturers remain competitive in the world market."

Reducing component size

In projection lithography, a circuit pattern, or blueprint, is transferred from a mask to a silicon wafer. The process is similar to exposing a film negative onto photographic paper, except that the transferred image is reduced, rather than enlarged, in order to make the electronic components smaller. A special camera, images and reduces the circuit design. In Sandia's current system the image from a mask is reduced in size by a factor of 10 as it is printed onto a wafer. Because EUV photons have wavelengths that are much shorter than visible light rays, they can achieve smaller or finer-resolution images during the exposure process.

The shorter wavelengths pose a different set of problems. Wavelengths shorter than about 1800 angstroms are not transmitted through traditional

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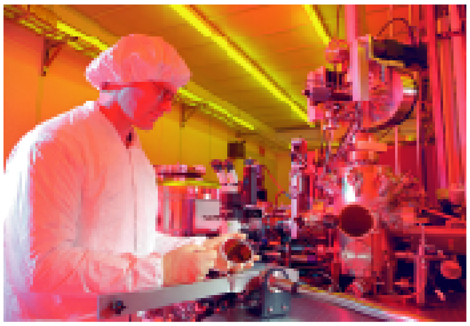


Researcher Kurt Berger inspects a silicon wafer before loading and alignment in Sandia's EUVL 10x Microstepper.

optical-lens materials; instead, they are absorbed. Therefore, reduction systems must use reflective surfaces instead of glass lenses. But even with reflective optics, EUV rays are strongly absorbed. To solve this problem, special multilayer coatings of synthetic materials have been developed to dramatically improve the reflection of EUV rays.

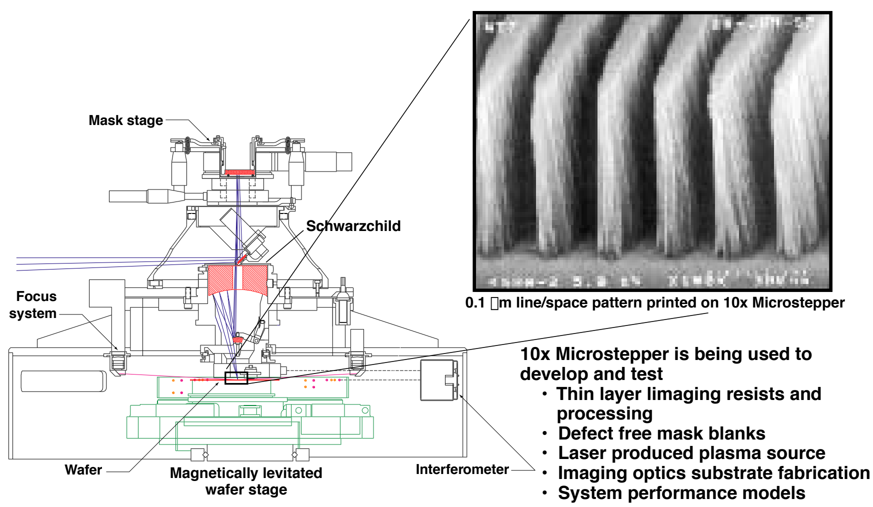
The ability to use reflective masks is an important feature of EUVL. EUV rays bounce off a highly reflective mask that contains the IC pattern and then are imaged by a camera containing reflective mirrors, which focus the reflected rays onto the wafer.

Sandia also has been developing a laser-plasma source (LPS) for generating EUV radiation. The LPS uses an Nd:YAG laser, which focuses 5-nanosecond pulses of light onto a beam of weakly bound xenon clusters containing many thousands of atoms each. The clusters absorb the incident laser energy as effectively as a solid target, thereby becoming heated and vaporized. The vaporized plume becomes an extremely hot plasma, which produces a flash of radiation that includes EUV rays. Future manufacturing EUVL tools will likely require high-repetition lasers with an average power of over 1000 watts.

Sandia, with the VNL, is now developing the next-generation laboratory EUVL tool, called the Engineering Test Stand (ETS). The ETS will have a high-power LPS and a 4x reduction camera with a print field area that is more than 10,000 times larger than Sandia's current 10x Microstepper. Like its predecessor microstepper system, located in Sandia's Integrated Manufacturing Technologies Laboratory, the ETS will use a magnetically levitated stage and a wafer alignment system. The principal objective of the ETS is to accomplish all of the EUV-specific system learning necessary for commercial lithography tool suppliers to begin manufacturing EUVL tools.

Near-term Spin-off Technologies

Although EUVL is not projected for volume production of ICs until 2004, Sandia's achievements likely will apply to a number of significant near-term lithographic tools. These spin-offs include high-precision magnetically levitated wafer stages, surface imaging resists, high-precision metrology, and the fabrication of experimental electronic devices. For example, the 10x Microstepper was employed recently to fabricate the world's first solid state electronic device using EUVL: a field-effect transistor with a 0.1-micrometer gate. Our 0.1-micrometer patterning and overlay capability will continue to provide a testbed for advanced device studies, resist processing, wafer stages and control systems, and mask defect studies in conjunction with our industrial, university, and VNL partners.



Schematic of the camera, exposure region, and wafer stage of the 10x Microstepper. Inset: Scanning electron micrograph of a test pattern of 0.1-micrometer lines and spaces patterned with EUVL in the Microstepper.

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