An employee works on an EUV illumination system from ZEISS SMT

EUV LITHOGRAPHY

EUV lithography optics from ZEISS

New light for digitalization

Navigation

The light of the future

In 1970, there was room for about 1,000 transistors on a microchip. Today there are 57 billion (semiconductor) components on an area only slightly larger than a fingertip. Mikrochips show structures 5,000 times finer than a human hair and are produced with light of the extremely short wavelength of 13.5 nanometers. For this purpose, EUV lithography optics from ZEISS SMT are used in production (no distribution in Germany). EUV technology is pushing the boundaries of what is technologically possible. For the next technological breakthrough. For future trends such as autonomous driving, artificial intelligence and 5G. For a digitalized life and work.

Smaller size, more power, more energy efficient

Transistors are the crucial component in the manufacture of microchips. The more of these switching units there is in a computer chip, the more powerful the processor. And the development is rapid. Intel co-founder Gordon Moore established the law named after him in 1965, according to which the number of transistors on a microchip doubles every two years. A challenge that ZEISS SMT has been facing for more than 50 years – with success. Most recently, in 2019, together with strategic partner ASML, TRUMPF, the Fraunhofer Institute IOF and around 1,200 other partners, a further technological leap was achieved. This perpetuates Moore's Law: EUV lithography. This was awarded the German Future Prize by German Federal President Frank-Walter Steinmeier in 2020.

German Future Prize for EUV lithography

Together with TRUMPF and the Fraunhofer Institute IOF, we won the 2020 award

This video was made for German television and is therefore only available in German

Source: ZDF

Shorter, more precise, finer

EUV stands for "extreme ultraviolet" light. The light visible to humans has wavelengths between 400 and 800 nanometers. The range of ultraviolet light begins below 400 nanometers. The leading lithography process to date using "deep ultraviolet light" (DUV) operates at a wavelength of 193 nanometers. This makes structures with dimensions of 40 nanometers possible. EUV lithography uses light with an extremely short wavelength of 13.5 nanometers. Thus enables structures with dimensions of less than 20 nanometers.

The world's most powerful pulsed industrial laser

To produce light with this wavelength, a special light source is needed. First of all, this is a high-power CO_2 laser from TRUMPF. With 30 kilowatts of power – about twice as much as classic industrial lasers that cut through centimeter thick steel – it is the most powerful pulsed industrial laser in the world. But the laser itself does not yet produce extreme ultraviolet light.

To the homepage of TRUMPF

This is how extreme ultraviolet light is created

In order to generate the EUV light, ASML and TRUMPF designed a unique light source. In a plasma source developed by ASML, 50,000 droplets of tin are fired into a vacuum chamber every second. In there they are struck by two consecutive pulses from a high-power CO_2 laser from TRUMPF. The so-called pre-pulse hits the tin droplets so that they virtually swell up. The trailing main pulse now hits the droplet at full power. This ignites the tin plasma, which emits the EUV radiation. To generate EUV light, the plasma has to be heated to a temperature of nearly 220,000 degrees Celsius. This is almost 40 times hotter than the average surface temperature of the sun.

Optics with extreme precision

Since extreme ultraviolet light is absorbed by all materials – including air, ZEISS SMT created an optical system for the EUV lithography machine. This operates in the vacuum chamber and is made up of curved mirrors. Even the smallest irregularities lead to imaging errors. Therefore, the world's most precise mirror with a multilayer coating (so-called Bragg mirror) was developed for EUV lithography. If you were to enlarge such an EUV mirror to the size of Germany, the largest unevenness – the Zugspitze, so to speak – would be a whole 0.1 millimeters high.

Exceptional coating

Extremely thin layers of silicon and molybdenum – only a few atomic layers thick – are vapor-deposited onto the glass surface. For this, up to 100 layers lie on top of each other here. A single layer would only reflect a good one percent of the light – the loss would be far too great. To increase the efficiency of the mirrors, ZEISS SMT has developed a unique coating system together with the Fraunhofer Institute IOF that requires atomic-based precision. The layer thicknesses are only a few nanometers thin. The result is a reflectivity that makes up to 70 percent of the light usable. This happens through constructive interference: the EUV light is reflected by individual layers in each case. When these are precisely superimposed, the light is amplified because the individual radiation waves are perfectly superimposed.

Precision to the Moon

Because the mirrors have to be held in position as precisely as possible during the exposure process, an entirely new mechatronics concept was required for maximum tilt stability. The results speak for themselves. If one of these EUV mirrors were to redirect a laser beam and aim it at the Moon, it would be able to hit a ping pong ball in the Moon's surface.

Mirrorblock enables precise wafer positioning

The mirrorblock is part of the wafer stage and has precisely manufactured support structures for wafers and optical sensors. It enables precise alignment of the wafer to the mask and projection optics for the wafer exposure. Despite thermal loads and high dynamic stress in the wafer scanner, the mirrorblock keeps its shape almost perfectly.

The lithography process: like a slide projector

As with a slide projector, the light passes through the photomask on which the blueprint – the template – is located. Instead of being enlarged in size, it is reduced. The structures are thus imaged on the wafer coated with a light sensitive photoresist film. In the next step, the exposed parts are etched away. The free areas are filled with copper and the wafer is polished. Then a new silicon layer and photoresist film are applied – and the lithography process starts all over again. This is repeated up to 100 times. In the end, the processed wafer is then cut into many small pieces. The microchips are ready.

How microchips are manufactured – with optics from ZEISS

High-NA-EUV technology

The next technological breakthrough in sight

Larger angles, even more power

A new generation is born

ZEISS SMT develops so-called optics for High-NA-EUV lithography with a larger aperture angle (NA = numerical aperture). The resolution is thus significantly improved once again – and the transistor density on microchips increases by a factor of three. This further perpetuates Moore's Law.

More about the High-NA-EUV technology

Enabeling future technology through teamwork

At ZEISS SMT, we combine precision, innovation, and partnership to push the boundaries of what is technologically possible. Yet, future technologies are not developed in isolation: We work together closely with customers, research institutions, and industry partner - often over many years. More than 30 years of research and development have paid off: The development team from ZEISS SMT, TRUMPF, and the Fraunhofer Institute was awarded the German Future Prize for EUV technology in 2020.

Learn more about our awards

EUV technology highlights

EUV lithography optics from ZEISS SMT: No sales in Germany

Illumination system

The optical EUV system from ZEISS SMT consists on the one hand of the illumination system. In it, the EUV light from the source is converted into the appropriate illumination for the structures on the mask. The illumination system consists of 15,000 individual parts weighing 1.5 tonnes.

Projection optics

On the other hand, the optical EUV system consists of the projection optics - with six mirrors. These are the world's most precise mirrors for imaging the mask structures in the nanometer range onto the photoresist-coated wafer. This requires around 20,000 individual parts weighing 2 tonnes.

Mirrorblock

The mirrorblock is part of the wafer stage and has precisely manufactured support structures for wafers and optical sensors. The mirrorblock thus enables the wafer to be precisely aligned with the mask and projection

Frequently Asked Questions

What is EUV lithography?

Lithography systems use light to create billions of tiny structures on thin silicon wafers. Together, these structures form an integrated circuit or microchip. The more structures chip manufacturers can fit on a chip, the faster and more powerful it is. ZEISS Semiconductor Manufacturing Technology enables microchip manufacturers worldwide to produce even smaller structures and thus more efficient microchips. Extreme ultraviolet lithography (EUV) realizes this by using light with a much shorter wavelength (13.5 nanometers) than previous lithography machines (shortest wavelength 193 nanometers).

Overview of the wavelengths of the lithography technologies

How does an EUV system work?

A lithography system is essentially a type of slide projector in which a blueprint of the pattern to be printed (referred to as a "mask") is illuminated with EUV light (wavelength 13.5nm). The projection optics then focusses the pattern onto the silicon wafer, which has previously been coated with a photosensitive photoresist. The unexposed parts are then etched away, revealing the pattern. This pattern is finally used to fabricate the microstructures.
EUV light is absorbed by materials (even air), therefore the EUV system has a large vacuum chamber in which the light is directed by reflecting mirrors. To generate the light, an EUV system uses a high-energy CO2 laser from the company TRUMPF. This laser generates a tin plasma that emits EUV light. The resulting light is then focused into an EUV beam using an EUV collector from ZEISS.

SMT Magazine article: ´How does EUV lithography work?´

What is EUV lithography used for?

The semiconductor industry is one of the most innovative in the world, enabling various trends such as artificial intelligence, virtual reality, healthcare applications, self-driving cars or Internet of Things. This requires computing power through even more cost-effective, energy-efficient and powerful microchips. To produce these superlative chips, more and more transistors have to fit into ever tighter spaces. The light previously used in semiconductor production is too long-wave for this. That is why many semiconductor companies are relying on the new generation of machines for chip production that work with extreme ultraviolet light (EUV wavelength 13.5 nanometers). EUV lithography enables finer structures and thus even more powerful microchips.

SMT Magazine article: ´EUV Lithography: A European Joint Project´

What comes after EUV lithography?

In addition to DUV technology, EUV technology is also being further developed and advanced with precision. With the help of a higher numerical aperture (
High-NA
) and multipatterning, the technology currently supports the demand for even smaller structures in the semiconductor industry (Moore's Law) well into the next decade. For the time after that, ZEISS is investigating several options in accordance with its own 'Seeing Beyond' tagline in order to continue Moore's Law in the future.

To High-NA-EUV technology

Light of the future

EUV explained in detail in our SMT Magazine

SMT MAGAZINE

How does EUV lithography works?

SMT MAGAZINE

An European Joint project

Learn more about semiconductor manufacturing optics at ZEISS

DUV lithography

Optical lithography

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