“EXTREME ULTRAVIOLET LITHOGRAPHY”

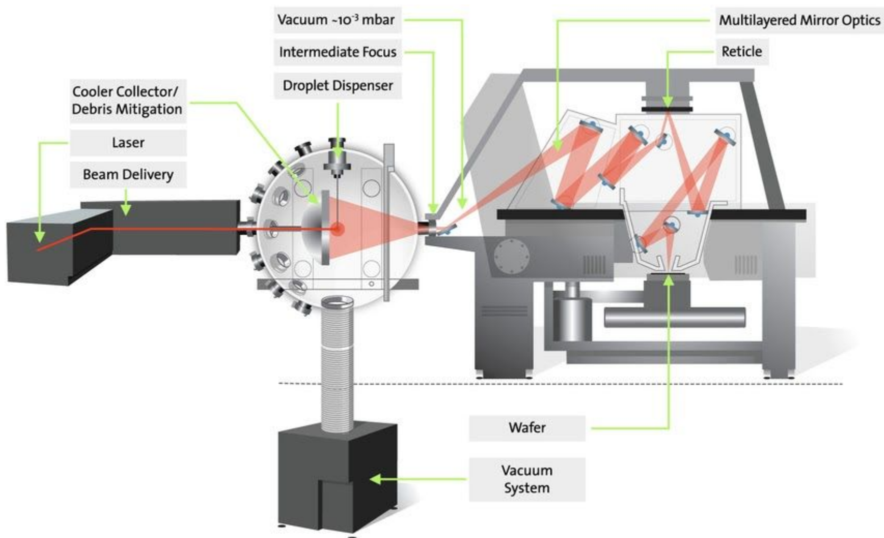
A Brief Introduction - Jonathan Falvey 19239718

For our report on a modern technological development, we decided to cover the innovation that is Extreme Ultraviolet Lithography (which from here on will be referred to as EUV). It is arguably the most complex and intricate machinery we’ve seen so far in integrated chip technology. We have chosen EUV as it is an ingenious technology that has postponed the supposed deadline of Moore’s Law by what could hopefully be many years. This report seeks to explore numerous aspects of EUV, from its conception in 1986, the theory behind its operation, and the history of its development all the way up to its recent implementation in modern society. Lastly, we will discuss what this groundbreaking innovation will mean for the future of our technology.

What is EUV? - Jonathan Falvey 19239718

Extreme Ultraviolet Lithography is a process in chip production based on photolithography and is currently employed by dutch company ASML, one of the leading semiconductor suppliers in the industry. ASML and their tools are essential to producing the chips for massive companies such as Intel and Samsung. On ASML’s webpage there is a link to a video they made in collaboration with Youtube channel Seeker, a channel dedicated to keeping viewers informed and up to date with the latest science and technology news. The video in question explains what exactly EUV is, highlights the process that the EUV tool executes when ingraining a pattern on a silicon wafer, and also features interviews with experts from ASML and Intel on EUV and the theory surrounding it. This video will serve as a basis and a reference for the majority of the information documented in this report.

The process EUV entails is complex but certainly clever. A mask, which can be thought of as a blueprint, is etched into the surface of a silicon wafer using light. The light source used is produced when a miniscule droplet of tin, that is fired across the vessel and is intercepted by not one, but two high power pulse laser beams that are created from gas compounds such as carbon dioxide or argon fluoride. For a long time, ASML found that they weren’t meeting anywhere near the required power for the machine to work with just one pulse laser beam. That was until 2015, when they discovered that they could time it precisely so that a second pulse laser beam could intercept the previously excited tin droplet to give it the boost in power it needed to form the plasma that emits the EUV light. The plasma produced will then be bounced off several mirrors and the mask, and then targeted at the wafer. You can see an illustration of the process in the diagram on the next page. Just imagining the intricacy of this system that allows it to be so accurate enables us to visualise how complex this system truly is.



Source: https://www.researchgate.net/figure/Schematic-of-a-laser-produced-plasma-EUV-scanner_fig1_244994879

The objective of pursuing innovations like EUV is to shorten the wavelength of the light towards the right of the electromagnetic spectrum pictured below, as the shorter the wavelength, the finer the imprints created will become. Finer imprints allow for more compact semiconductor chip designs in accordance with Moore's Law, as more transistors can be crammed onto the chip. Over the years, the wavelength has been cut from 365nm, to 248nm, to 193nm. Previously an attempt was made at 157nm, but it failed, costing the industry dearly and progress stagnated. Now, with the implementation of EUV we have hit wavelengths as short as 13.5nm. That's almost 15 times shorter!

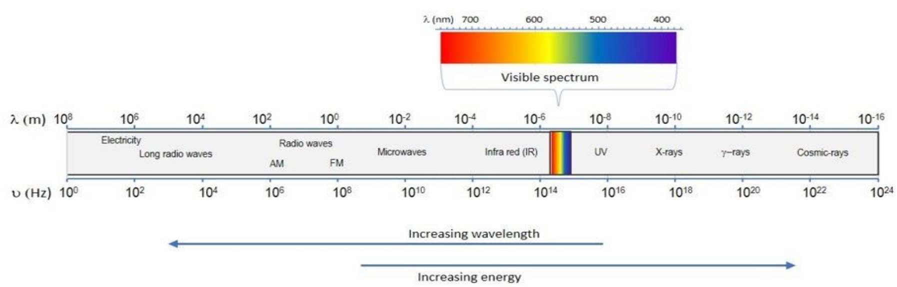


Image courtesy of https://www.engineeringtoolbox.com/electromagnetic-spectrum-d_1929.html

The Physics Behind EUV - Jonathan Falvey 19239718

The key theory behind the operation of EUV lies in the physics of waves. Waves have the simple function of transporting energy. There are different types of waves but in relation to EUV we are only concerned with one type of wave: Electromagnetic waves. The light that allows you to read this is an electromagnetic wave. Other examples would include radio waves, the waves in your microwave, and x-rays. Two of the key properties of these waves that are utilised by EUV are their ability to reflect off surfaces, and refract. I already mentioned how the reflection works. The EUV light reflects off several mirrors and the photomask before finally etching the contents of the mask onto the silicon wafer. The light travels in straight lines, as such it is necessary to direct the light using mirrors so that it can be targeted at the wafer.

Before EUV, Argon Fluoride (ArF) gas was used to produce the light used in lithography. ArF produced a wavelength of about 193nm. In Physics, it is known that the wavelength of an electromagnetic wave is proportional to its frequency. (Wavelength = (Speed of light/frequency)). What this means is that as the frequency of the wave increases, the wavelength will decrease as a consequence. That poses the question “How do we increase the frequency?” and the answer to that is that we need more energy. This is illuminated by the relationship between energy and frequency of an electromagnetic wave. (Frequency = (Energy / Planck’s constant))

Knowing that, we can now deduce that to shorten the wavelength of the light used in lithography, we need to supply more energy. In other words, we need more power. This deduction is evidenced by the EUV machine’s massive Megawatt power consumption. A large percentage of that power is dedicated to the numerous components inside the EUV tool. According to Gigaphoton, Sematech Symposium Japan, 532 Kilowatts of that power consumption is expended by producing the high energy lasers that are used to create the EUV emitting plasma. This is more than 10 times the power consumption of the 49 Kilowatt ArF lasers used prior. As such, we can understand how we managed to achieve a new wavelength that is almost 15 times shorter than the previous shortest wavelength of 193nm.