THE USE OF EUV LITHOGRAPHY IN CONSUMER MICROCHIP MANUFACTURING

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Abstract—*Microchip manufacturing is quickly approaching an impasse where no further progress in the efficiency or speed of processors can be achieved. Photolithography is the current process used by companies such as Intel and NVIDIA to fabricate commercial microchips. Extreme Ultraviolet (EUV) lithography is an imminent improvement to this current manufacturing technology that uses extreme ultraviolet radiation with an incredibly small wavelength to increase efficiency, lower cost, and allow the continued development of processing power. This is beneficial to the process of lithography because its wavelength is 13.5 nanometers (nm), less than one tenth of the currently used 193 nm wavelength. A smaller wavelength leads to more densely packed components on the microchip, creating faster processing power.*

Sustainability, an emphasis on creating an enhanced economic situation for society which provides for improved quality of life, will be positively impacted by these components. An increase in accessibility to technology outweighs the large startup cost associated with EUV. In relation to economic sustainability, EUV lithography will provide for sustainability in the workplace with its applications in nearly every field. The engineering and medical fields will find EUV most advantageous for design, modeling, and analysis. Simulating extensive processes requires faster computing that processors created with EUV lithography have the potential to achieve. Another advantage of EUV lithography is a lower cost of manufacturing, due to its reduced power consumption and a diminished quantity of exposures needed during manufacturing. In turn, this allows the accessibility of technology to expand throughout society.

Key Words—EUV Lithography, Extreme Ultraviolet Radiation, Microchip Manufacturing, Photolithography, Semiconductors

LOOKING TOWARDS THE FUTURE WITH EUV LITHOGRAPHY

The current era of microchip manufacturing is facing a dilemma that could set back the incredible progress that has been made over the past century. Microchip companies are confronting obstacles to the continued increase of new ideas and development in their industry. The task of creating chips on a smaller scale that possess an increase in the number of components as well as overall speed is becoming increasingly difficult with each consecutive generation. This difficulty leads to a lack of technology in many areas of society, as well as a high cost for the most contemporary microchips [1]. A new technique in producing microchips has the potential to promote continued prosperity in the industry and overcome these hurdles, as well as increase sustainability of the microchip manufacturing industry by making its products more accessible.

Extreme Ultraviolet (EUV) lithography, a more advanced form of photolithography using extreme ultraviolet radiation with a small wavelength, could have a lasting impact on microchip manufacturing. The many benefits of EUV lithography, such as its increased efficiency, lower cost, and the motivation it brings to continue technological advancement, are what set it apart from other forms of production. While making use of the impressive benefits that this technology brings, it is key to enhance and reform its technique. *Nature Photonics*, in an article focusing on the industry perspective of EUV lithography, determined that some crucial challenges of EUV lithography are issues with ray absorption during the manufacturing process and complications with mirror reflectivity due to the sensitivity of EUV radiation [2].

Once these components of the process are handled, EUV has the potential to create a new standard for the level of computing in our society, both in capability and power. The prosperity that EUV will provide can be applied to nearly every field, but will be most advantageous in the medical and engineering fields. These benefits, as well as the challenges and their solutions, will play a crucial role in the ultimate decision to utilize EUV lithography in the microchip manufacturing industry.

SHINING A LIGHT ON EXTREME ULTRAVIOLET LITHOGRAPHY

The current manufacturing process used to produce microchips is called photolithography, and is used by most major manufacturers such as Intel, NVIDIA, and Taiwan Semiconductor Manufacturing Company, according to an article from *Computer World* [3]. The procedure begins with a silicon wafer covered in chemicals that make up a substance called a photoresist. A photoresist is a light-sensitive material, meaning that it reacts when exposed to light. This characteristic is utilized when light is shone through a mask onto a substrate. The mask contains a pattern outlining pathways and components that make up a layer of the microchip. The article from *Computer World* continues by describing that this pattern is recreated on the photoresist as the process hardens the areas exposed to light. The unexposed areas are later etched further, creating extra depth for future components [3].

This process can be seen in Figure 1. Light is shone through the top of the mask, and then focused by a lens. The pattern from the mask is carried by this light, and shrunk to the appropriate size by the lens before reaching the wafer and developing the photoresist on its surface. At the bottom of the figure, it can also be seen that this pattern is copied numerous times on each wafer, which can usually contain a few hundred microchips.

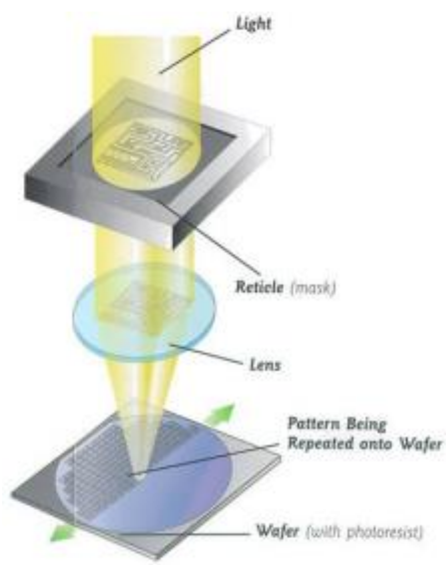

FIGURE 1 [4]
Photolithography including light source and mask

Over the past few decades, innovation surrounding lithography has been a work in progress. The first major release of the technology used mercury vapor lamps with a relatively long wavelength of 365 nm. It then progressed to krypton fluoride lasers, bringing improvements with a 248 nm wavelength. An article from *Nature* outlining EUV lithography describes the history. The most current technology—also known as Deep Ultraviolet (DUV) lithography—utilizes argon fluoride lasers with a 193 nm wavelength, decreasing the original wavelength by a factor of two [2]. Each new type of laser has various enhancements, the most important being a reduction in the number of exposures, a decrease in power consumption, and an increase in the projection resolution.

EUV lithography is becoming more prevalent in microchip manufacturing. This technique uses extreme ultraviolet radiation in place of the previous types of light to travel through the mask onto the photoresist. Using this type of radiation has many implications and benefits. EUV has a wavelength of 13.5 nm, nearly one tenth of the size of the currently used light, and one thirtieth the size of the original technology. Figure 2 organizes these four advancements and shows their wavelengths in nanometers. When looking at the improvement each advancement brought, it becomes apparent that EUV has created the largest change in wavelength reduction. While previous technologies have decreased wavelength by only a fraction, EUV has reduced the wavelength by a factor of thirteen. Furthermore, *Nature Photonics* describes the fact that EUV provides reasonable expectations that the projection resolution in photolithography can be decreased to as low as 10 nm, and possibly even further in the future [2].

Light Source Technology	Wavelength of Light (nanometers)
Mercury Vapor Lamps	365
Krypton Fluoride Lasers	248
Argon Fluoride Lasers (DUV)	193
Carbon Dioxide Lasers (EUV)	13.5

FIGURE 2 [2]
Table including four major advancements to light sources and their wavelengths

Although EUV radiation has many assets, producing the radiation is a complex process. An article from *IEEE Spectrum*—leaders in electronics and technology—discussed in detail the process used by current EUV machine manufacturer, ASML, who is leading the innovation of EUV lithography in the semiconductor industry. The process, which can be seen in Figure 3, is called laser-produced plasma. The method involves shooting carbon dioxide laser light which is produced in a system that can be seen at the bottom of the figure. The lasers are then focused and fired into 50,000 microscopic droplets of molten tin per second [5]. The orange circle in Figure 3 represents when a beam of this carbon dioxide light hits a tin droplet, heating the tin into an EUV emitting plasma. A mirror in the machine then reflects this light, casting it onto the scanner. Throughout the process, hydrogen gas is continually flowing across the mirror to ensure that particles of tin do not cover the mirror, blocking EUV light [6]. The excess tin is then collected, as seen at the bottom of the figure in the container labeled “Tin catch.” This type of light, as well as how it is emitted, is what makes EUV unique, setting it apart from alternative lithography methods.

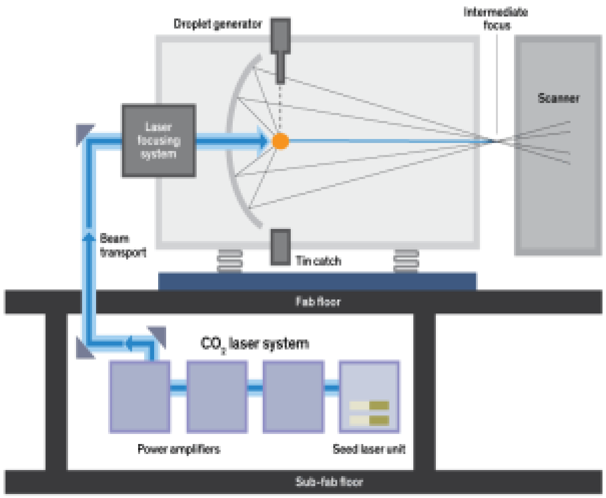

FIGURE 3 [6]
Carbon dioxide laser projected at molten tin droplets to create EUV emitting plasma

IMPROVEMENTS TO AN ESTABLISHED PROCESS

With an approaching technological advancement, it is important to consider the potential benefits. Specific areas of manufacturing that EUV lithography will influence will need to be considered as the technology progresses into its implementation phase. There are three main advantages that will be emphasized: cost effectiveness, precision, and ability to continue technological progress. Each of these areas will show the positive impact of EUV lithography, ranging from microchip manufacturing to society as a whole.

Effects of Increasing Cost Efficiency

One of the advantages of EUV lithography is its potential for great efficiency. An article from *Semiengineering* discusses concepts that make EUV lithography so cost efficient and, as a result, an improvement to the current process. The article details that the currently used form of lithography requires complex and expensive multi-patterning schemes, forcing lithography machines to pattern a photoresist multiple times [7]. Some layers of the chip require three or more separate patterns in order to be completed. Since there are multiple layers, the cost and time to produce builds exponentially. According to an article from *Nature* discussing lithography techniques in industry, consistent repetitions of the same substrate reduce the overall quantity of wafers that can be processed at a time, ultimately leading to increased costs and power consumption. This also leads to design rules that arise from the necessity of piecing together multiple simplified designs. Options are limited when this is required and often lead to the constraint of chip designers [2]. In many cases, designers are forced to spread out components, making them occupy more of the vital surface area on a microchip. This is because the ideal solution is impossible with Deep Ultraviolet lithography, but it could be solved with a more versatile etching technique.

The topic of cost benefits relating to EUV lithography is growing in popularity, and being discussed much more frequently. Over the last several years, a group working at IMEC—an international research institute specializing in nanoelectronics—has been studying the effects of these cost reductions. Arindam Mallik, a senior researcher at IMEC focusing on design technology co-optimization, has been examining a lithography process cost model that can address many questions associated with determining the cost effectiveness of the EUV process. This model shows results that—at this point—EUV is clearly more cost effective in most patterning processes, but sacrifices speed in some cases [7].

The use of the model created by Arindam Mallik at IMEC brings the idea of using both EUV and DUV lithography simultaneously in manufacturing facilities. The reasoning for this is that the cost effectiveness of EUV comes from the ability to reduce the need for multi-patterning and simplify the transitions between exposures. This gives designers the ability to fit more complex components in an even smaller area. Because of the simplification in the patterning process, power consumption is reduced, contributing to the sustainability of EUV.

In a manufacturing model which utilizes both technologies, DUV can be used for more simple designs, where its greater speed will complement the complicated patterns created with EUV. It can be concluded that regardless of whether EUV and DUV are working alongside each other, or EUV has taken a dominant role in manufacturing, EUV will have a positive impact on the efficiency in production of microchips.

Ensuring a High Quality Product with Precision

In addition to the improvements in cost efficiency that EUV brings, it also has the ability to create a much more precise product that contains less error. Photolithography is susceptible to three main types of error. As a paper prepared for the International Symposium on Microlithography details, such errors include surface figure error, mid-spatial frequency roughness (MSFR), and high-spatial frequency roughness (HSFR) [8]. Surface figure error is the simplest type of error. It can be thought of as how much the actual image deviates from its ideal placement. This is usually caused by light not reflecting perfectly off of the many mirrors required in the fabrication process. The ideal reflection can be seen in the top picture of Figure 4, where each beam is reflected symmetrically onto the surface. Often times without perfect mirrors, the beams are instead scattered slightly in an uneven pattern such as in the bottom picture of Figure 4. This causes problems as components can be shifted from their intended position, or become stretched or compressed.

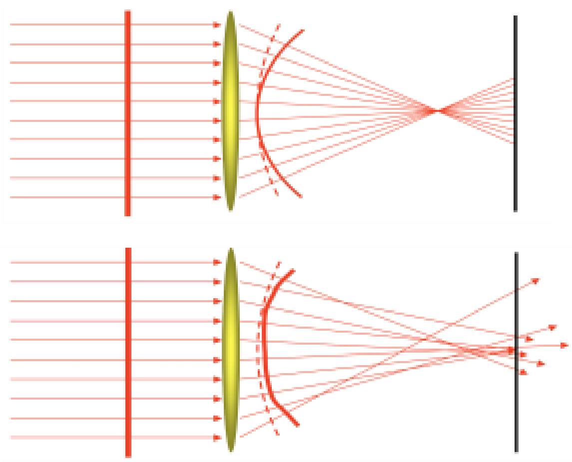

FIGURE 4 [9]
Demonstration of ideal reflection compared to reflections that cause surface figure error

MSFR is caused by scattered light at small angles, meaning that most of the light lands in the expected image area, but some deviates slightly. The paper from the International Symposium on Microlithography discusses that this effect is commonly referred to as “flare”, and the main effect is a reduction in the contrast of an image [8]. Rather than having a very defined edge between an etched line which would be a “bright” area and a non-etched section which would be a “dark” area, some of the dark area will also be illuminated, causing jagged edges. According to the International Symposium on Microlithography, HSFR is caused by light scattered at large angles. It was found that because this light will not land on the substrate, it will not affect the quality of the product, but will reduce the overall power output of the EUV light [8]. This is due to the fact that a fraction of the light does not contribute to etching of the chip, and in turn will lower the number of chips that can be processed in a given time.

All of the error values for these three categories have stringent specifications determined by the wavelength of light used in lithography. The smaller the wavelength, the less room for error, and therefore the harder it is to follow these guidelines. The paper prepared for the International Symposium on Microlithography gives specifications for these values and proceeds to explain that it is feasible for EUV to operate at these standards. The paper states, “It is clearly feasible to meet the EUVL specifications and schedule requirements. The optics industry is currently attaining figure and finish levels near those required... 0.30 nm rms [root-mean square] for figure, 0.3 nm rms for mid-spatial frequency errors, and 0.13 nm rms for high-spatial frequency errors” [8]. With the ability of EUV to meet these standards at early stages of development, it is clear that error will be minimal when using this process. The low tolerance for error ensures that customers will receive the highest quality products, and contributes to sustainability by creating microchips which will function properly in the long run.

Opening Doors for Future Technology

Technological advances are vital to improving how people carry out their lives. With each cutting edge technology comes an effective change in the standard of living. However, each subsequent improvement has less of an impact as technology continues to develop. Computing power is reaching an impasse due to a decrease in innovation in microchip design. Moore’s Law is a law of microchips which states that every additional year of advancement brings optimizations that doubles the amount of transistors on a chip. This law is becoming incompatible with the semiconductor world, as a result of the fact that current nanotechnology is incapable of being produced on a smaller scale. This effect can be seen in Figure 5, which shows a graph of processors and their year of release versus the quantity of transistors they contain. The scale for the quantity of transistors is set to double after each year, and this ideal quantity can be seen on the graph represented by the dotted line labeled “Transistors/Chip Doubling Every 2 Years.” For the years between 1970 and 2004, it can be seen that this trend was obeyed with all data points very near the dotted line. In recent years, starting around 2009, the trend begins to change, and is represented by the red line. The graph is flattening out over time, representing the fact that only very small increases in the number of transistors are being made. This is caused by the delay of many processor releases, as well as the lack of innovation in the industry.

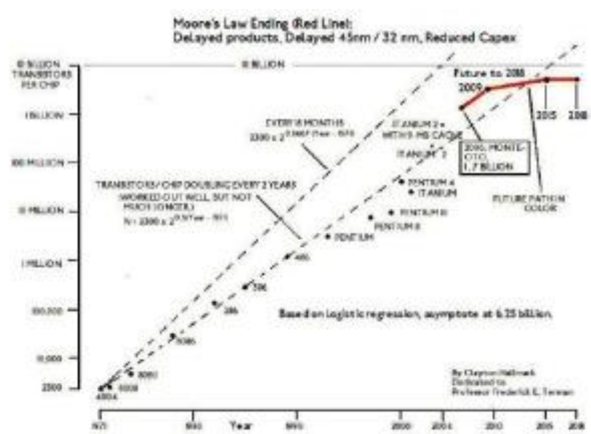

FIGURE 5 [10]
Graph of Moore’s Law showing deviance in recent years

An article from *IEEE Spectrum* explains the issues of current advancement saying, "Chipmakers are struggling to keep miniaturization on track and costs under control; the timing between successive chip generations seems to be getting longer, and chip features are not shrinking as aggressively as they used to" [6]. This poses a problem for innovators and engineers who are attempting to resolve this issue. This problem, if not dealt with, will affect not just scientists and engineers, but all of the world, due to its reliance on technology. Intelligent professionals are expected to continue to produce new technologies which make the lives of others easier. If microchips reach a point where they can no longer be produced with more computing power, then society is stuck at its current level of technology with few options for advancement.

EUV lithography has the ability to bring a significant change to the microchip manufacturing industry which is desperately trying to find a promising development. Those in the manufacturing industry will be impacted by the changes that EUV requires to infrastructure, such as the addition of vacuum chambers, which will be discussed in a later section. However, using EUV will transform lithography into a more efficient process and create more precise and overall refined microchips. Chris Mack, a lithography expert, discussed in an article from IEEE Spectrum how the struggles in the industry could be a prime opening for EUV, saying "There's a real possibility that this slowdown in Moore's Law could enable EUV to have enough time to catch up" [6]. With advancements in EUV lithography, its implementation is promising. However, it is even more vital to the bigger picture of the semiconductor industry. A main facet of sustainability that EUV aims to improve upon is innovation throughout the future; therefore, providing a means for continued advanced in microchip manufacturing technology is incredibly important. Regardless of its implementation, EUV continues to open doors for more innovative ideas and procedures in the future.

CHALLENGES WITH INTELLIGENT SOLUTIONS

After discussing the successes of EUV lithography, it is important to also highlight the features that this technology needs to improve upon. Most new technologies are not perfect, thus in order for EUV to improve its inefficiencies and uncertainties, the manufacturing industry needs to focus on these challenges now. Working through obstacles will bring solutions that can make EUV the dominant technique in manufacturing. The following sections will focus on problems of EUV ray absorption and energy dissipation during production, leading to inefficiency in manufacturing.

The Key to Stopping Absorption: Utilizing a Vacuum

All wavelengths of light are absorbed by different types of matter. This is because light is made of small particles called photons. Photons carry energy, and when they collide with the electrons in atoms, the electrons absorb that energy. It then becomes thermal energy or internal energy of the material. This occurs in many different situations, one common example being the Earth's atmosphere. A large percentage of harmful ultraviolet waves from the sun are absorbed by the oxygen and nitrogen in the atmosphere. Although this is helpful in sustaining life on Earth, this effect creates difficult problems for EUV lithography.

As mentioned before, EUV lithography makes use of the incredibly beneficial EUV light with a wavelength of 13.5 nm. Unfortunately, the greatest feature of this technology is also its weakness. The very small wavelength makes EUV light extremely susceptible to absorption. Almost any material—even air—will absorb the light completely after traveling even a short distance. Due to the fact that EUV light must travel a significant distance before reaching the substrate that it will etch, absorption is causing challenges for this technology. An article from *IEEE Spectrum* quotes Anton van Dijsseldonk, the first full time employee working on the EUV project at ASML, as saying, "The only way an EUV scanner could work was in vacuum" [6]. Therefore, without an effective solution to this issue, implementation of EUV lithography will become impossible.

A proposed and successful solution is to create a vacuum in every part of the process where EUV light will travel. This will ensure any matter that can absorb the light is removed from the chamber, as well as a higher efficiency output from the EUV lithography machine. Although a vacuum is the most accepted and pursued solution to solve this issue, there are many challenges associated with maintaining a near-vacuum environment. One significant obstacle is that each chip entering the lithography step of production must enter the machine through an airlock. There will be two parallel doors, with one closed at all times to keep the vacuum sealed off from the factory. Even with this mechanism, some air will still enter the machine with each new set of microchips. Due to this, several pumps will be needed to maintain the vacuum. According to a research paper on ultra-high vacuum chambers for EUV, in most cases two pumps will be utilized, with one positioned where the EUV light is created, and another positioned near the end of the system where the EUV light strikes the microchips [11]. The position of these pumps can be seen in Figure 6, labeled as "Differential pumping" and "to pump". Together these pumps result in an operating pressure of 10^{-3} Pa, which is ten million times less than the atmospheric pressure of Earth. The published research on the use of vacuum chambers for EUV thus attests to the fact that only an insignificant number of air molecules will remain inside of the chamber, and will allow the EUV light to work at its full potential [11].

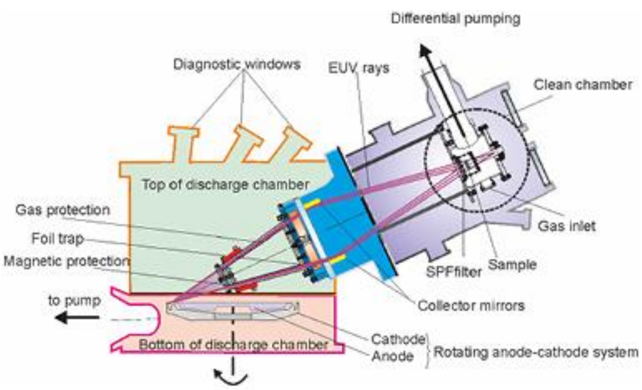

FIGURE 6 [11]
A view inside the vacuum chamber, showing where two pumps would be located

Although the extreme absorption of EUV light seems like an insurmountable obstacle to the process of photolithography, creating a vacuum inside of the lithography chamber has proven to be an adequate solution. At this time, several manufacturers have working models of vacuum pumps for this process, meaning that this challenge has been overcome and EUV is one step closer to implementation.

Inefficient Mirroring Improves with New Materials

During the process of lithography, light is traditionally shone through several lenses that aim to focus the light and shorten its wavelength. With EUV, this has become an impossibility. A paper published by the University of Alcala describing various aspects of EUV lithography has explained that all known lens materials completely absorb the light, leaving no output that can be used for the process of etching a microchip [12]. This setback has pushed developers to use a new strategy to redirect and focus the light. Instead of lenses, mirrors are used for this goal. Mirrors can be made from a wider range of substances than lenses, and therefore provide a more flexible range of options.

The mirrors that have been tested and proved most effective so far are those created with molybdenum and silicon. Different designs are comprised of between forty and one hundred alternating layers of these two materials. They have been shown to be particularly reflective for light between twelve and fourteen nanometers, a range that perfectly encompasses that of EUV light. Even with the special silicon molybdenum coatings, the mirrors are still prone to absorbing EUV light, meaning that no perfect reflection is possible at this time. A reflectivity of 72% has been achieved with these mirrors, which is greatly improved from previous tests. To get this high conversion rate, the mirrors are manufactured with extreme specifications. As an article from *Nature* describes, "The mirrors must be flat to less than 2 nm across the surface of a 30 cm mirror—equivalent to a 1 mm deviation across a 1,500 km surface" [2]. You can imagine this immense precision by thinking of a road that spans halfway across the United States, but never travels uphill or downhill by more than the thickness of a dime. Surely these mirrors are difficult to produce, but the extremely low tolerance for surface error ensures that any additional absorption by the mirrors will be insignificant.

Inside the EUV lithography machine, anywhere between six and twelve separate mirrors are used from the time light is emitted to when it reaches the substrate. An article from *Nature* further describes that with a reflection rate of 72%, the energy the light carries is reduced significantly each time it strikes a mirror. In some cases, only 2-3% of the input energy is actually put to use by the time the light reaches the substrate [2]. The lower output energy a lithography process can produce, the slower it can etch chips, and the fewer number of wafers, or sets of microchips, it can produce each hour. Fortunately, the wavelength of 13.5 nm was chosen for intelligent reasons. The process previously described for the creation of EUV light, using superheated tin droplets, is most efficient at creating 13.5 nm light. According to an article published by *Nature Photonics*, several manufacturers have already reached 70 watts (W) of power output from EUV lasers, very close to the intended goal of 100 W, and have plans to further increase this power with improvements such as increased laser focusing [2]. When the efficient production of EUV light meets the continually improving combination of silicon and molybdenum in mirrors, EUV systems are created that can produce an ample power output.

In many cases, traditional DUV lithography systems have a higher power output due to years of improvements to their lenses and mirrors. Even with this advantage, EUV performs much more efficiently, and can produce more wafers per hour with a lower power output. At this point in time, it is clear that EUV lithography has been improved to the point where it can compete directly with DUV lithography. With time, mirror technology as well as the technology used to produce EUV light will continue to improve, allowing EUV to achieve the same power output. Microchips can then be etched as quickly as they are now, but with many fewer steps, greatly increasing efficiency while reducing cost.

ADDRESSING SUSTAINABILITY IN MICROCHIP TECHNOLOGY

The topic of sustainability is important to consider when researching and developing a new technique that may be applied to an industry which could affect millions, if not billions, of people. Sustainability can be thought of as an emphasis to create an enhanced economic situation for society that provides for quality of life, including the health, comfort, and happiness experienced by an individual, both now and in the future. Achieving this definition of sustainability will include making technology accessible by making products more affordable. In addition, the current rate of advancement must be continued so that a wider range of people can experience the benefits that technology brings to everyday life. EUV lithography is an incredibly sustainable technology in this sense, due to its cheaper production costs, which leads to more efficient energy consumption, considered to be another aspect of sustainability. Because of this lower manufacturing cost, microchips can be manufactured in a more sustainable way, leading to more accessible technology for society.

We live in an age where technology is vital to everyday life, and it often feels as though everyone takes part in the easy access to computers and other digital devices. However, in many situations, this is not the case. One example where a lack of technology is apparent is in public schools of poor communities located around the world. An article from the Hechinger Report, which aims to report on innovation and inequality in education, describes that this is considered to be a large concern in cities such as Chicago, which are viewed as urban cities that are well developed [1]. A specific case that the Hechinger Report details is the Bronzeville Scholastic Institute, located in the outskirts of Chicago. The article highlights the lack of technology in the school, saying that "...24 computers are shared by nearly a thousand students from the three schools that occupy DuSable High School's campus on the South Side" [1]. Susan Patrick, president and CEO of the International Association for K-12 Online Learning, details in the article that because of the large student to computer ratio, students are "not building their technology skills, (and) they're not able to access some of the courses and supplemental materials that would help them ramp up and be successful" [1]. Because of the vast role education plays in quality of life, this is a necessary problem to resolve to create a more sustainable education system. A contributing factor to this lack of technology is the cost of capable microchips used in consumer computers, which in many cases, are very expensive [1].

The hope for less expensive technology that is more readily available to those who need it can become a reality with the implementation of EUV lithography in producing microchips. Considering that the cost of one EUV lithography machine is around $108 million, nearly two times the cost of the previous 193 nm DUV lithography machine, it may at first seem difficult to justify the sustainability of this technology. However, the sustainability of EUV lithography becomes more apparent in the long run. This is because EUV machines produce chips in a faster, more precise and error-free manner, explained in the previous sections. Being that EUV can pattern layers that would normally take three or more steps to complete, the input energy required per chip is reduced, saving the company money over time. With a lower cost of production, microchip manufacturers can sell their microchips, and the subsequent technology that they will be used in, at a reduced cost.

EUV lithography can provide technological sustainability for the Bronzeville Scholastic Institute, for schools in similar situations, and for the rest of our society. With the projected decrease in the cost to produce each microchip, these savings will be passed down to consumers. Not only will computers become less expensive, but their quality will vastly improve. This means that schools will have access to a larger number of computers, which are more capable of completing the tasks that students require, at a lower cost. A more integrated and substantial education system will lead to better quality of life for the children currently in school, and ultimately the world as children grow into the future leaders in our society. This is just one example of how the increased availability of microchips can serve to increase the quality of life in our society.

Not only are microchips produced using EUV lithography capable of increasing access to the technology in our generation, but are also capable of innovating the world of technology for many years to come. An important aspect of sustainability is the continued advancement and innovation that improves our economic situation and quality of life. An article from *Nature Photonics* describing previous lithography techniques has projected EUV lithography to continue improving throughout several years in the microchip industry, unlike many other technologies that have come before [2]. This ability to more efficiently create technology—which improves quality of life through making tasks easier, as well as spark future innovation for years to come—makes EUV a sustainable technology worth investing in.

APPLYING EUV IN THE WORLD

So far, the focus has been to highlight the incredible features of EUV lithography. These features have emphasized what sets EUV apart from current technologies, and the tremendous impact it will have on society. It is important to directly show how this new method of lithography will be used in the real world. Utilizing EUV lithography can give microchip manufacturers the ability to produce extremely powerful chips, with densely packed transistors. This advance to a new level of computing opens doors to a world of possibilities.

Many—if not all—professions take advantage of the usefulness of computers and technology in some way. Using EUV provides professions the ability to carry out everyday tasks faster, but more importantly, can handle advanced and complex processes. This technology can impact everyone who uses computers, contributing to an increase in the standard of living and an overall more developed way of life. Due to their large need for complex modeling, the medical and engineering fields will be the focus of these real world applications.

Protein Folding; A Monumental Challenge Tackled by EUV

The field of medicine would be directly affected by the implementation of EUV because it is a profession that has a strong reliance on technology. Hospitals use computers in diagnostic tests that have complex computer components, allowing doctors to take pictures, x-rays, and other scans. These machines range from Computerized Axial Tomography (CAT) scans to Magnetic Resonance Imaging (MRI) scans [13]. Many procedures are performed using electronic devices, such as the extreme example of computerized robots in surgery. This is an area where the most advanced computing is necessary in order to ensure accuracy in the care that citizens are receiving.

In addition to the hands-on applications of computers in the medical field, an increasingly common aspect of medicine is research through modeling. A specific example of a perplexing simulation in medicine is in RNA protein folding. Researchers working at the University of Illinois at Urbana-Champaign discuss the challenges of protein-folding simulations in an article published by *Nature*. The researchers indicate that they owe their use of powerful and dynamic models which study complicated processes to advances in computing power [14].

Although much progress has been made, RNA protein folding is still considered a complex simulation needing more powerful computers to be replicated. The most common problem so far is the long period of time necessary to observe a single event. This arises from the fact that with current processing power, completing all calculations can take long periods of time. The necessity to accurately describe multitudes of relative energies in separate folding patterns further adds to this processing time. The importance of this simulation and research is the increase in knowledge of the native state of a protein and how mechanisms unfold, leading the way to new solutions in medicine. EUV lithography will produce the additional power needed to model this process and other complex simulations. In the researcher's article describing protein-folding challenges, it is emphasized that they are a result of the hindered abilities of current simulation models. The researchers are adamant that advances in technology will allow protein-folding to be properly simulated, showing that EUV will be invaluable for replicating complex processes, especially RNA protein folding [14].

The Future of Engineering with EUV

As time progresses engineers have become progressively more dependent on the efficiency that computer systems deliver. Traditional engineering fields are now guided by computer technologies ranging from CAD, computer-aided design software, to computational fluid dynamics, which allows complex testing to be done virtually. These systems not only save time and money, but allow engineers to reach their full potential, and create cutting edge technology faster than ever.

Modes of transportation—such as automobiles and airplanes—are taken for granted, but their design takes countless hours of trial and error, planning, and testing. One of the most important parts of this process is the testing phase. Models are put into wind tunnels to test their drag and assure reduction in fuel efficiency is minimal. Previously, when finishing a design, engineers would need to create a 3D model of their product that they could physically test inside of a wind tunnel. Now, this situation can be modeled with software run on a computer. Due to the nature of these tests, they are incredibly resource intensive, meaning that they take a lot of processing time to complete. Although it can save hundreds of hours compared to the previous manual methods, the processes can be improved further. EUV lithography has the potential to exponentially decrease the runtime of modeling programs such as these with the more powerful processors it can deliver. The effects can be applied to every engineering discipline, and countless different processes. Some include the modeling of a novel bridge design for civil engineers, bonding of complex molecules for chemical engineers, or genetic algorithms for bioengineers.

With the increasing dependence on computers in engineering fields, the continued push in technological advancement must be maintained. Upcoming technologies such as EUV have the chance to affect any discipline, whether engineering or otherwise, with their increased processing power. These vital improvements have the opportunity to drastically improve the necessary modern modeling processes, as well as provide opportunities for the implementation of what is to come.

A TECHNOLOGICAL PROCESS FOR THE FUTURE

Photolithography is a process which has been used for many years to create microchips. EUV lithography is the newest of many advancements and improvements to this process, with its characteristically small wavelength of 13.5 nm. Due to this improvement in light technology, it has been the source of some of the largest developments in microchip manufacturing. These advancements, including growth in the efficiency of the procedure, a decreased quantity of exposure repetitions, and precision unmatched by any other method, have motivated those involved in the world of technology to continue to innovate and prolong technological advancements of society.

EUV has faced many challenges so far, and some challenges still remain, but the focus is that viable solutions are on the horizon. Two of the largest challenges facing this technology, absorption and mirror inefficiency, have already been solved by using a vacuum and utilizing different materials in mirror production. The solutions developed to each problem have made the technology competitive in the market for microchip manufacturing technology, and the continued development of these solutions will push the technology further ahead in the future.

Although new technologies always seem promising, they are very unlikely to be adopted without real world implications and use. EUV lithography will impact nearly every professional field, with two of the largest beneficiaries being engineering and the medical field. Both of these fields are synonymous with heavy focuses in research, and often simulations and modeling that are incredibly resource intensive. EUV has the opportunity to bring more powerful and efficient processors to the professionals that need them most, accelerating the advancements made in these fields each year. In addition to the application of EUV in professional fields, it also contributes to the sustainability of our society through lowering costs, making technology more accessible, and providing means to continue innovation in the microchip manufacturing industry throughout the future. The implementation of EUV lithography has a world of possibilities, but the hope is that it expands our society, driving others to advance technology and lead innovation that continues to improve our world.

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