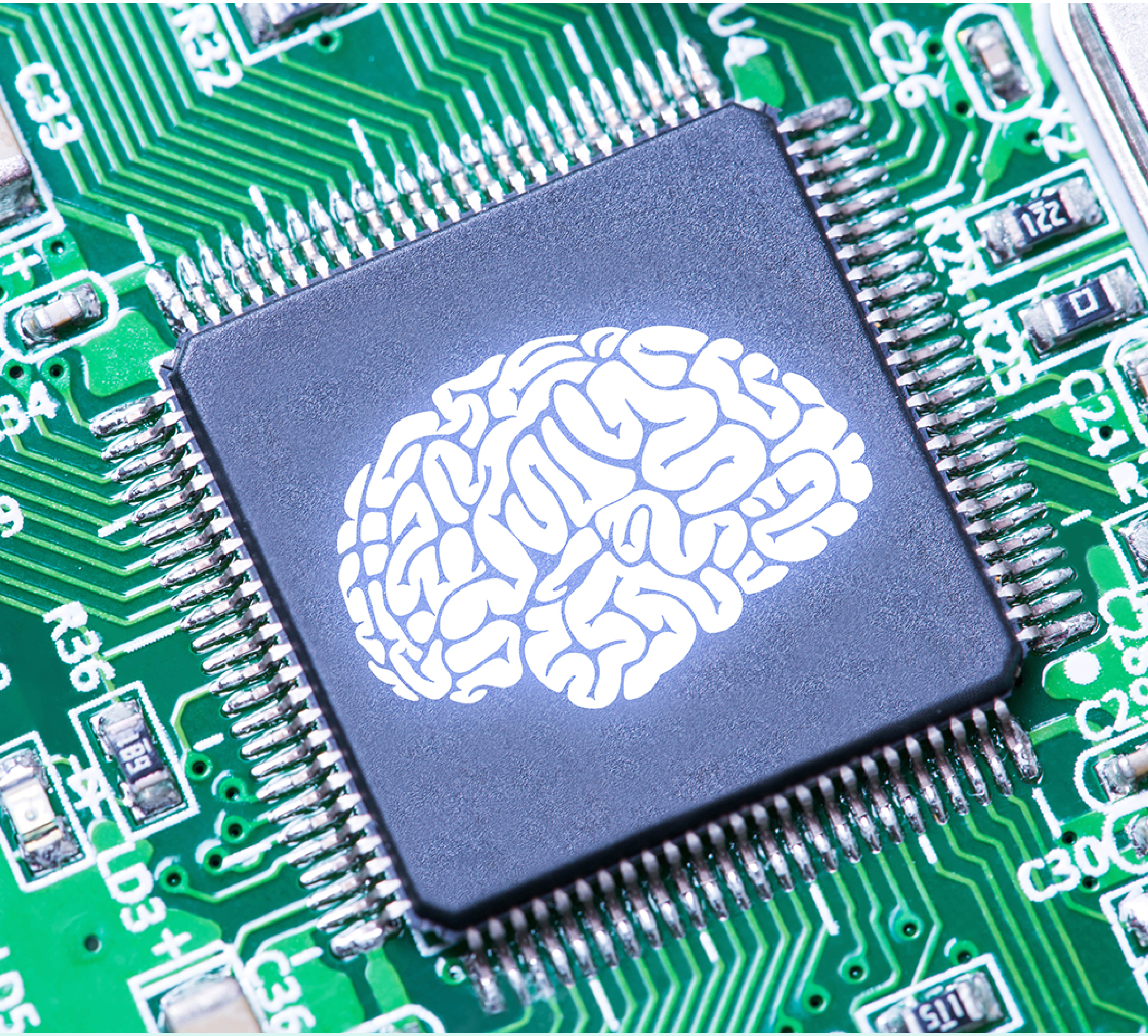
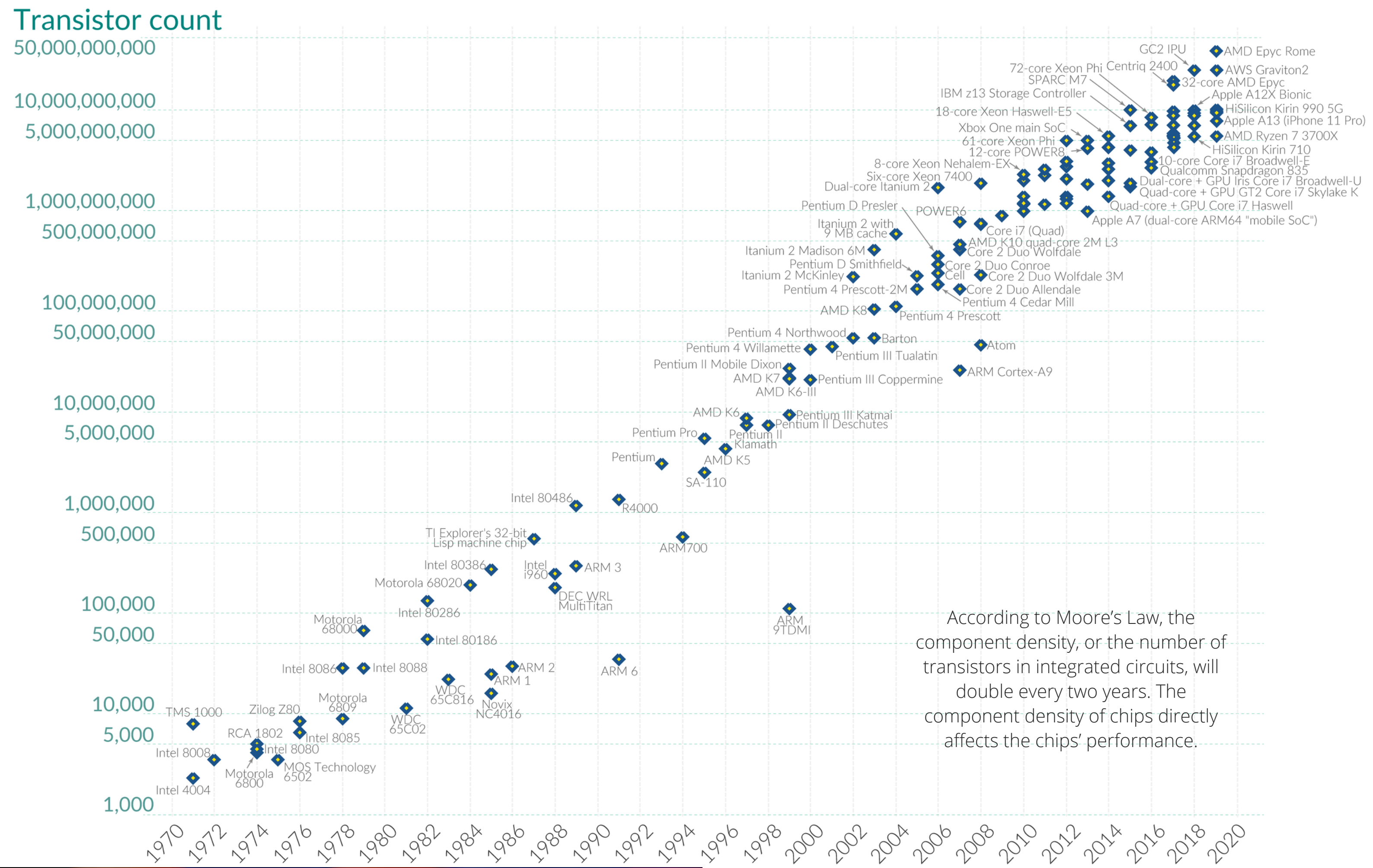
96969Y,
HSINCHU, TAIWAN



PHOTOLITHOGRAPHY: BACKBONE OF TECHNOLOGY

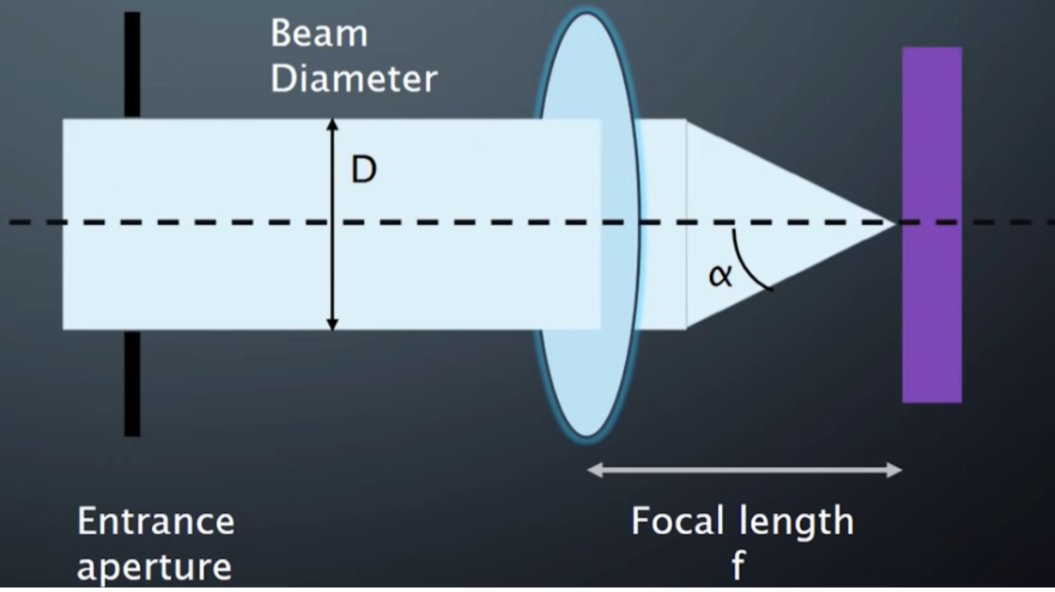
ALBERT, SANHORN, STEVE, JEFFREY, JIM, THOMAS, CHIWEI



INTRODUCTION

Digital devices have become an unparalleled component of our lives. In 2021, over 78% of the global population owns a smartphone. The factor behind the digital device improvements is the increasing performance of chips, which are found in smartphones, laptops, monitors, and other devices. To increase the chip performance, the component density must be increased.

$$NA = n \sin \alpha$$

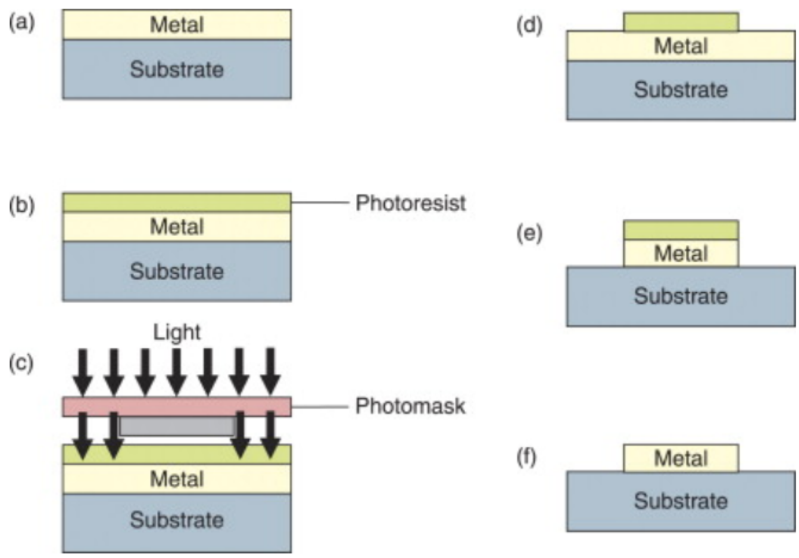


$$R \sim \frac{\lambda}{NA}$$

The resolution (R), the smallest degree of detail in photolithography, is affected by the optical system's numerical aperture (NA) and the light's wavelength (λ). The numerical aperture is determined by the index of refraction and the max half-angle of the collimated beam.

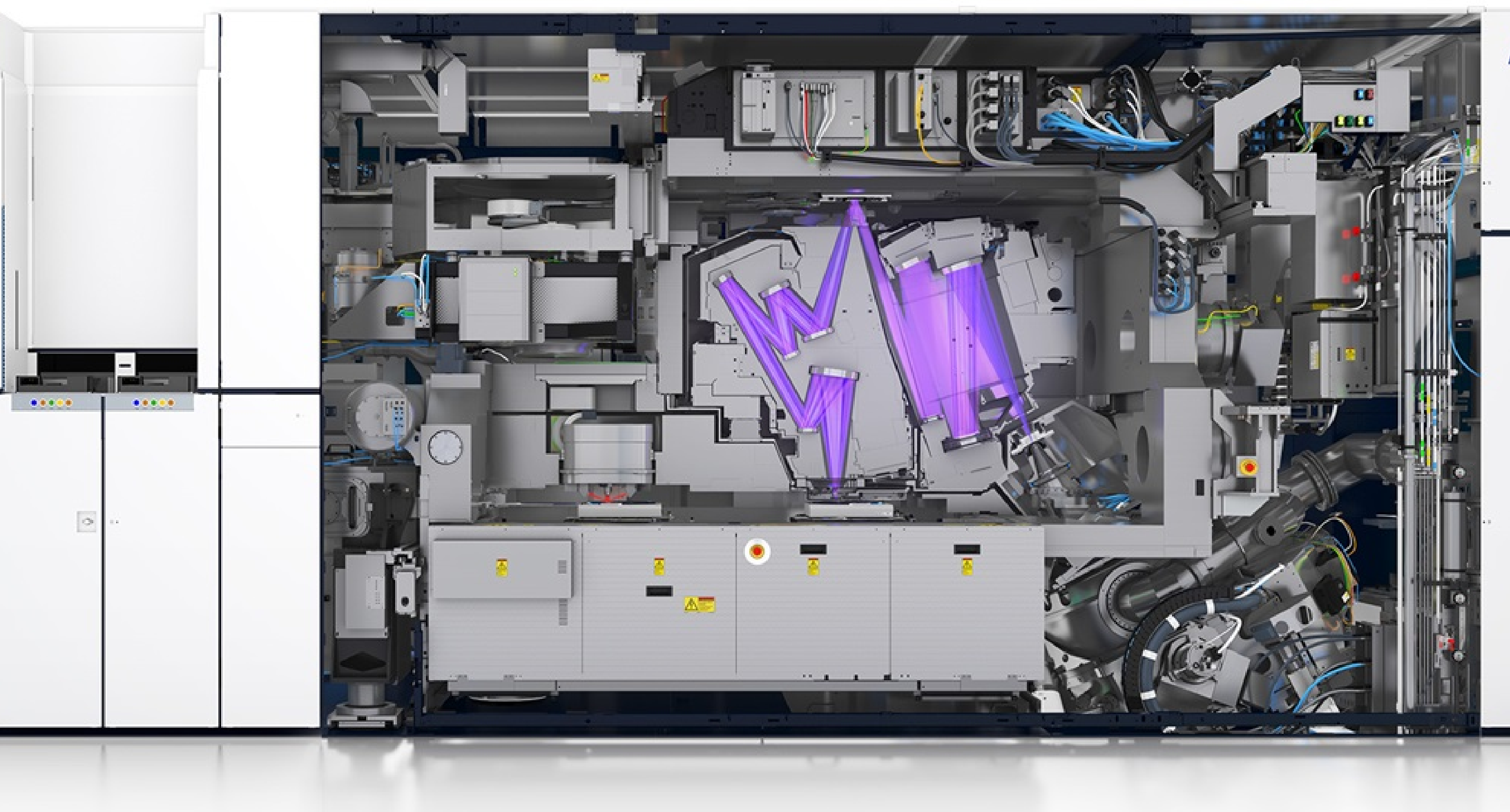
The microfabrication of the chips is called photolithography. Photolithography machines transfer photons from an optical mask to create a geometric pattern on a layer of photoresist on a silicon wafer. Smaller wavelengths of light create a smaller (higher quality) resolution, allowing higher component densities in chips.

The photolithographic machines used to produce chips become the crux of the issue. Recent developments of the machines aim to shrink the wavelength to enhance the resolution, producing smaller and more powerful chips. As consumers, we always seek the newest and fastest devices. However, we never pause and try to understand the underlying technology that brings us the 5G, self-driving cars, and the ever-improving smartphones. Our team wishes to use this opportunity to grasp concepts in photolithography as it is the backbone behind the growth of STEM industries. To explore the construction of photolithographic machines, we interviewed Dr. Anthony Yen from Taiwan, known for his achievements in electrical engineering.



The substrate, or the silicon wafer, is covered with a layer of photosensitive, chemical photoresist. As light goes through a photomask, it reacts with the photoresist. The reacted photoresist is then developed and heated. The open metal areas are etched away and the photoresist is removed.

Dr. Anthony Yen worked for the Taiwan Semiconductor Manufacturing Company (TSMC), one of the largest semiconductors in the world. Now, he is the Vice President and Head of Technology Development Center for Advanced Semiconductor Materials Lithography (ASML), which supplies photolithographic machines to TSMC.



The EUV machine (above) emits a wavelength of 13.5 nm. That is a significant improvement from the 193 nm conventional DUV machines can produce.

A staunch follower of Moore's law, he believes that improving photolithographic machines "could transition TSMC to a generation of the most advanced 3-nanometer chip in the world." He helped develop extreme ultraviolet (EUV) lithography that enables machines to emit wavelengths significantly smaller than conventional deep ultraviolet (DUV) lithography machines. These machines allow semiconductor companies like TSMC to produce smaller and more efficient chips. The development of EUV machines is accompanied by an engineering design process similar to that of our team.

"Could transition TSMC to a generation of the most advanced 3-nanometer chip in the world."

TSMC (top) is one of the biggest customers of ASML (bottom). ASML supplies TSMC with advanced EUV machines that allows TMSC to continuously make smaller chips.

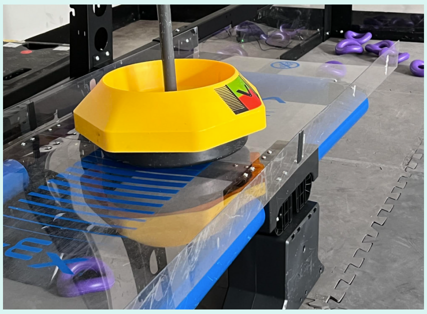
ENGINEERING DESIGN PROCESS

1.

First, the problem and objective are identified. Approaching the 21st century, the component density of chips became physically limited because DUV machines offer limited resolutions. The objective is to create a technology that produces smaller chips.

In vex, our objective is to score high. One problem is to balance goals on the elevated platform, ensuring a rewarding 40 points.

DUV machine from ASML.

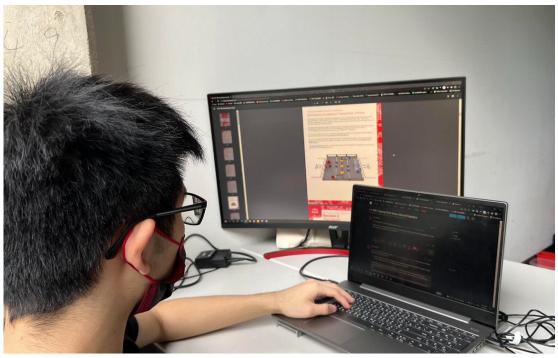

Goal balanced on elevated platform.

2.

Next, developers like Dr. Yen works on r&d with universities and research institutes to derive and explore theoretical concepts.

Meanwhile, our team independently peruses the game manual for rules. We scan online forums to look for examples.

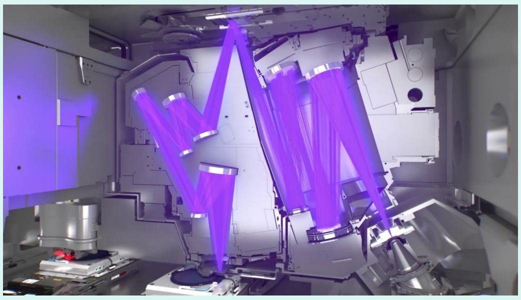

ASML collaborates with more than 180 universities and institutions around the globe.


Our team member checks updates from VEX Forum and the Game Manual.

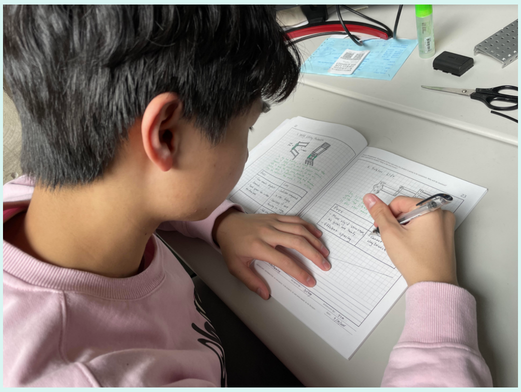
3.

After researching, developers in ASML came up with an alternative: EUV machines that use smaller wavelengths.

We brainstorm various designs — DR4B lift, scissor lift, clawbot claw, and pneumatics claw— and sketch and record them on our engineering notebook for future reference and evaluation.



EUV technology from ASML.



The notebook manager recording designs

4.

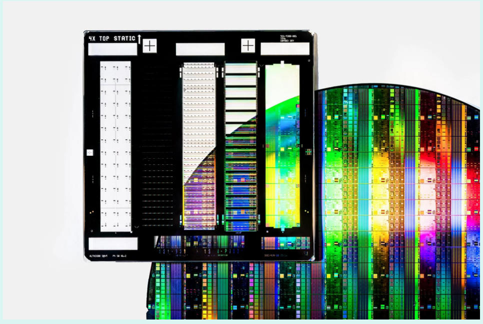
ASML gauges the machine’s performance versus the cost to evaluate its effectiveness. The higher the optical performance, the more valuable the machine is. ASML has to find a balance between spending huge costs on EUV machines and developing promising EUV technologies that could help the company compensate for the costs in the long run.

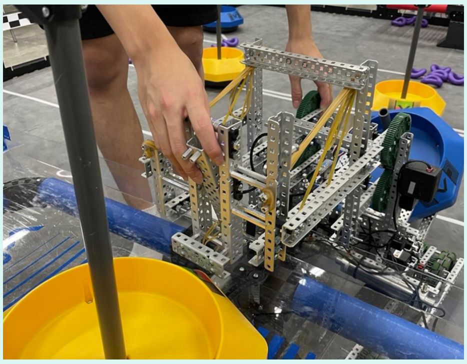
However, our team does not aim to make a profit but to maximize the performance of the mechanism. We consider lifting speed, the grip of the claw, weight, and strength. However, we do consider the cost due to limited components.

5.

Before producing a prototype based on past evaluations, the company runs numerous simulations of the machines. As hundreds of machines are produced at once, the company could not afford to make a mistake in its design.

Instead of going through simulations, our team directly builds a prototype, because modifications are easy on one robot. As a prototype, we constructed a rotational lift with a vertical pneumatics claw.

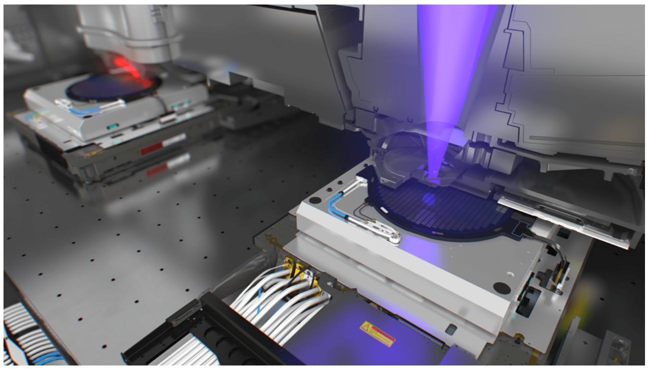

Computational lithography from ASML allows it to run simulations before production

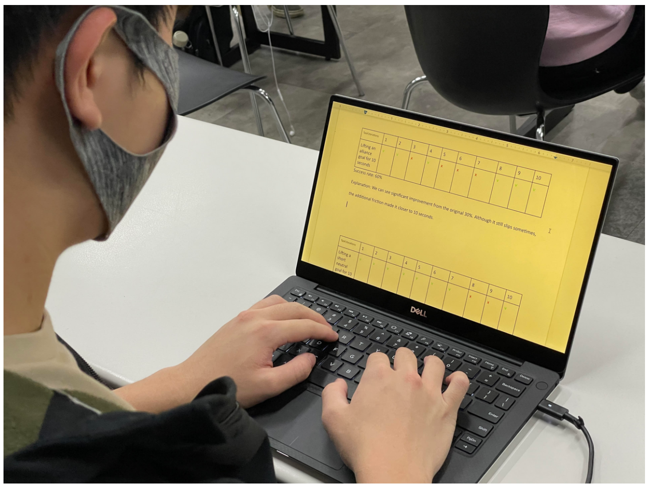

Our initial prototype of a scissor lift with pneumatics claw.

6.

To test and evaluate the prototype before production, ASML developers use microscopes to compare the resolution produced by different chemicals by exposing them under standard patterns. The company also evaluates its prototype’s cost versus its performance.

Our team evaluates our lift mechanism by making it perform various tasks for multiple iterations. We must ensure that the lift could consistently bring goals to elevated platforms without losing grip. The lift, when lifting a goal, also should not tip the robot from shifting the center of mass.

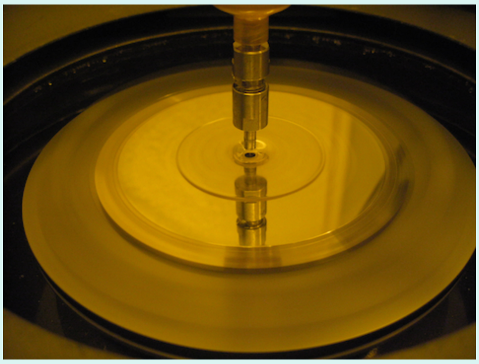

Different photoresists are tested under the same wavelength to gauge their chemical effectiveness.


Our builder is evaluating and recording the mechanism's ability to hold and grip goals.

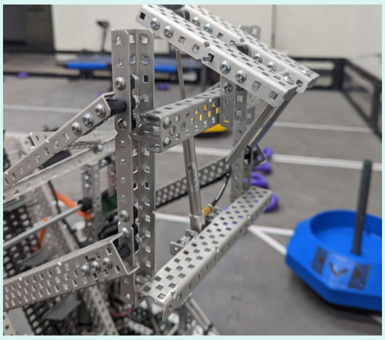
7.

After evaluation, improvements are made. New chemical photoresists are applied to the silicon wafers. Based on theories, new machine parameters are used to enhance the photolithographic resolution.

We modify the claw tooth length for better grip and the gear ratios to increase the torque of the lift to maximize the weight it could carry.



New photoresists are applied and coated on silicon wafers to improve the optical resolution.



Our improved pneumatics claw system with longer teeths for deeper grip of goals.

8.

Finally, ASML starts producing new EUV machines. The machines are supplied to semiconductor manufacturers such as TSMC, enabling these companies to continue Moore's law, produce more powerful chips, and fuel the expansion of digitalization.

Our team would finalize the robot. The robot would demonstrate quality and consistency resulting from the strict adherence to a thorough engineering design process.

A finalized and produced EUV machine from ASML.

Our drivers are practicing with our finalized robot, preparing for upcoming competitions

VEX, CAREER, AND BEYOND

VEX is an amalgamation of computer science, electrical engineering, and mechanical engineering: all of which are important fields cooperating to drive the growth of technology in the 21st century. In fact, VEX arms us with the cooperation skills necessary to thrive in the STEM industries. Builders must accommodate programmers' needs, such as the implementation of encoder wheels and GPS. Programmers must accommodate for drivers' preferences of controls. Drivers must accommodate builders' robotic mechanisms, structures, and drivetrains. Notebook managers act as a bridge between the three roles through communication, as documentation requires them to understand every process.

More importantly, in VEX, we experience a preview of how professionals in STEM careers apply the engineering design process to achieve their goals and realize their ideas. From the early brainstorming process, we learn to gather fragments of inspiration and grow them into new, coherent ideas. From the rigorous evaluation, we learn to select and focus on the best of our ideas. From the continuous testing and redesigning, we learn to face the weaknesses of our idea and patiently hone it to perfection.

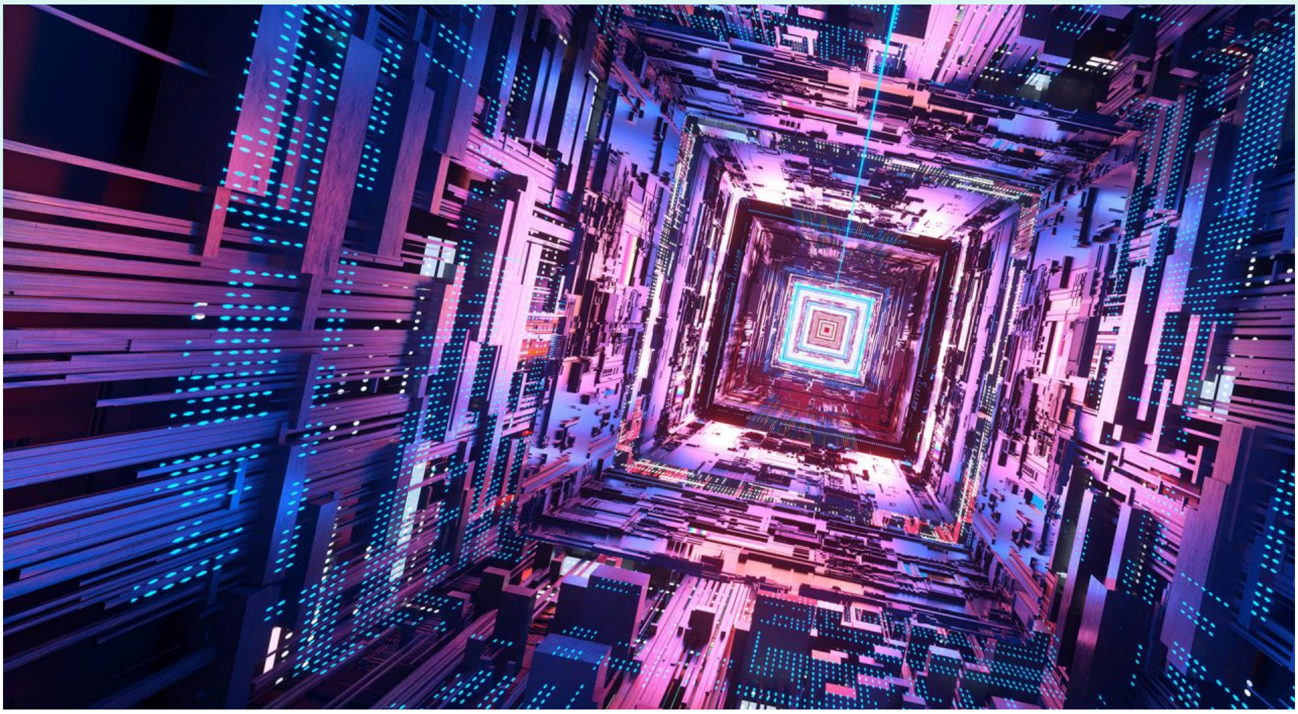
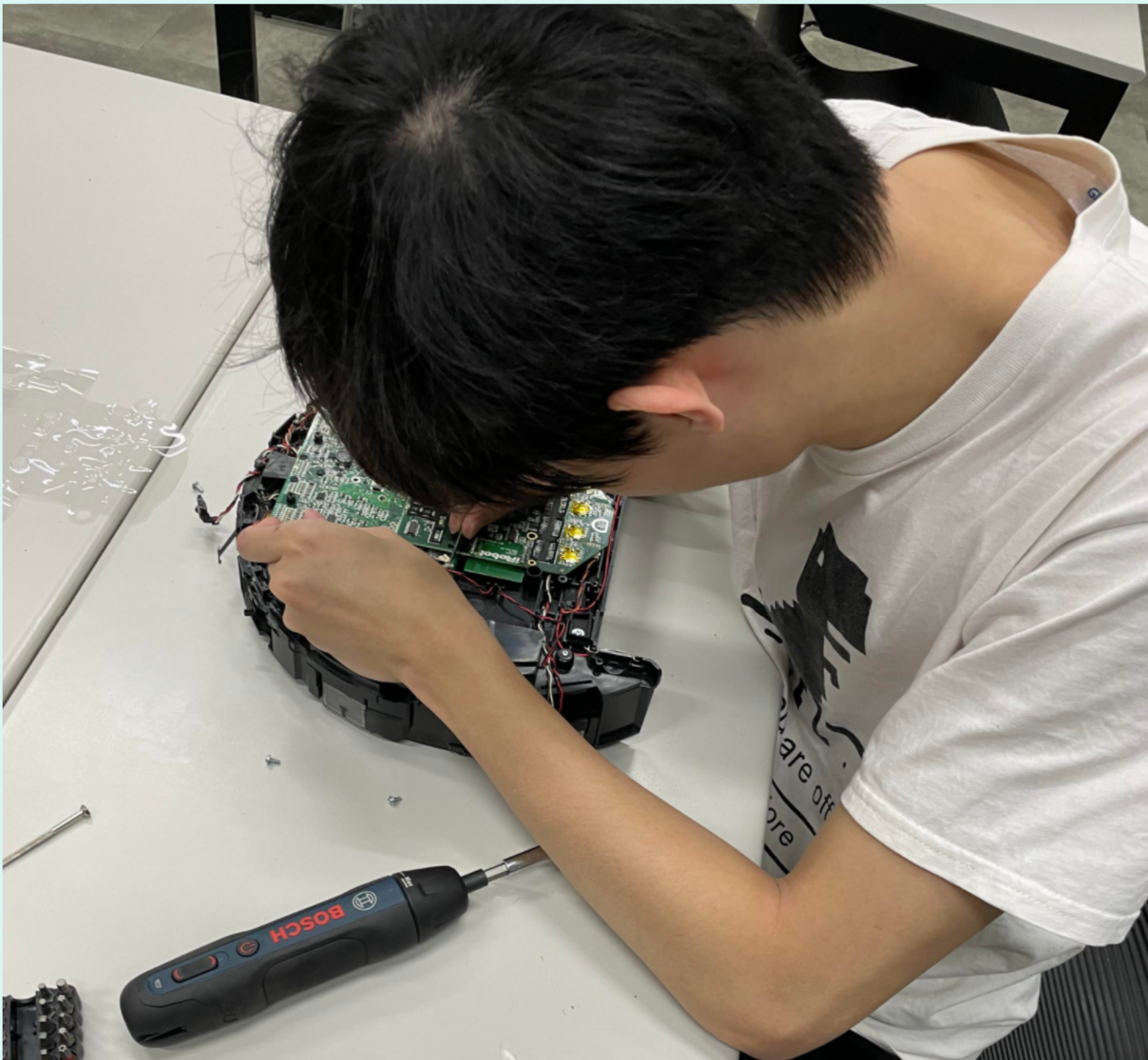
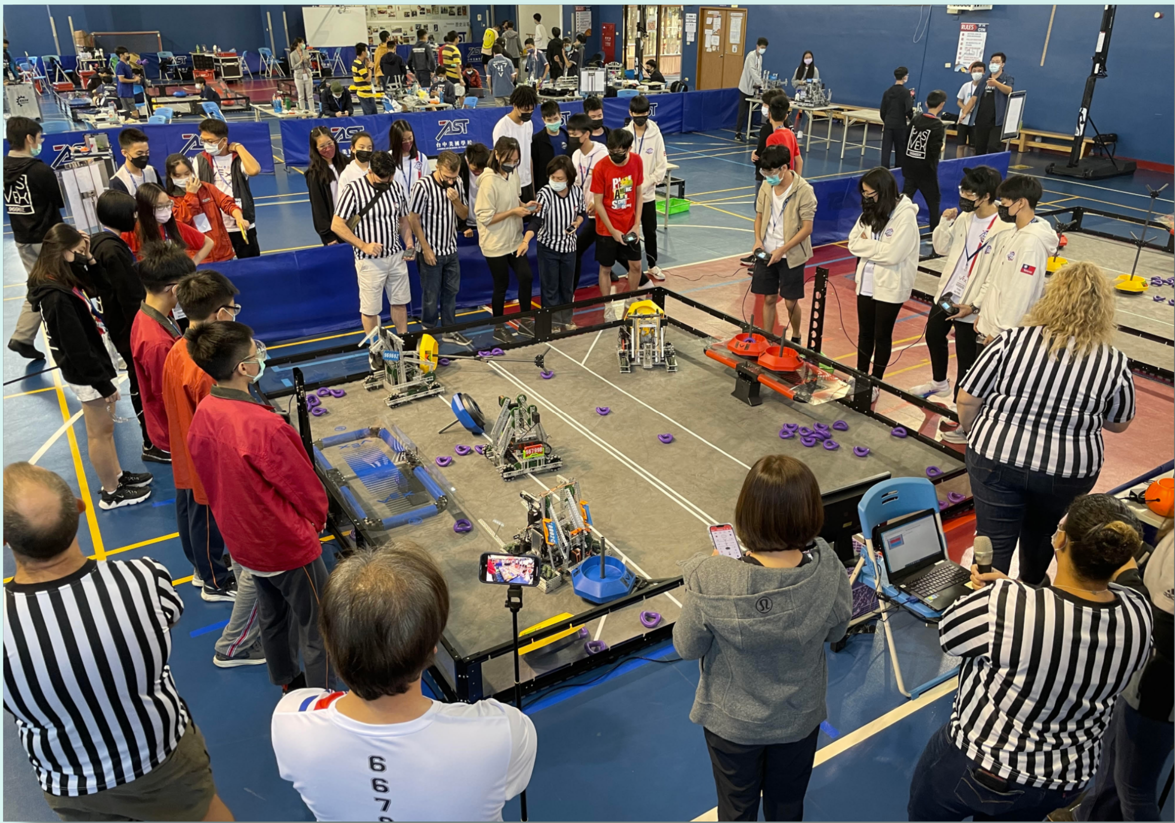


PHOTO GALLERY



Our builder disects an iRobot Roomba 880 to learn more about its circuit boards and chips.



Our team (top right team) brought our finalized robot to compete in competitions.

Team photo after visiting Hsinchu Science Park

WORKS CITED (SOURCES)

A Q&A With Tony Yen, VP of Tech Development at ASML. https://www.morningbrew.com/emerging-tech/stories/2021/03/15/qa-tony-yen-vp-tech-development-asml?__cf_chl_f_tk=OLfL9DcFAoAW6RjXGyGoCcWbfSYE_rpqv_n.pgePf_U-1642536832-0-gaNycGzNDBE. Accessed 19 Jan. 2022.

Comprehensive Nanoscience and Technology | ScienceDirect. www.sciencedirect.com/referencework/9780123743961/comprehensive-nanoscience-and-technology. Accessed 19 Jan. 2022.

Extreme-Ultraviolet Lithography - an Overview | ScienceDirect Topics. www.sciencedirect.com/topics/materials-science/extreme-ultraviolet-lithography. Accessed 19 Jan. 2022.

IEEE. www.ieee.org/ns/periodicals/EDS/EDS-APRIL-2021-HTML-V2/index.html. Accessed 19 Jan. 2022.

Moore's Law: the Future of Si Microelectronics. www.sciencedirect.com/science/article/pii/S1369702106715395. Accessed 19 Jan. 2022.

Photolithography - an Overview | ScienceDirect Topics. www.sciencedirect.com/topics/physics-and-astronomy/photolithography. Accessed 19 Jan. 2022.

Reiff, Nathan. 10 Biggest Semiconductor Companies. Investopedia, 24 Jan. 2016, www.investopedia.com/articles/markets/012216/worlds-top-10-semiconductor-companies-tsmintc.asp. Accessed 19 Jan. 2022.

Smartphone Penetration Worldwide | Statista. https://www.statista.com/statistics/203734/global-smartphone-penetration-per-capita-since-2005/. Accessed 19 Jan. 2022.

WORKS CITED (PICTURES)

Asml. ASML Participates in Research Partnerships to Support the Future of Technology. ASML, 7 Apr. 2021, www.asml.com/en/. Accessed 19 Jan. 2022.

Comprehensive Nanoscience and Technology | ScienceDirect. www.sciencedirect.com/referencework/9780123743961/comprehensive-nanoscience-and-technology. Accessed 19 Jan. 2022.

Computational Lithography - Products. www.asml.com/en/. Accessed 19 Jan. 2022.

“Cost Effective Icon - Download Cost Effective Icon 3852420 | Noun Project.” The Noun Project, thenounproject.com/icon/cost-effective-3852420/. Accessed 19 Jan. 2022.

“Electrical Engineering inside Our EUV Machine.” YouTube, 14 May 2019, www.youtube.com/watch?v=w9816ZKVm2A. Accessed 19 Jan. 2022.

File:ASML Logo.svg - Wikimedia Commons. commons.wikimedia.org/wiki/File:ASML_Logo.svg. Accessed 19 Jan. 2022.

How Microchips Are Made | ASML . www.asml.com/en/. Accessed 19 Jan. 2022.

“Moore's Law.” Wikipedia: The Free Encyclopedia, Wikimedia Foundation, Inc., 7 Jan. 2022, en.wikipedia.org/wiki/Moore%27s_law. Accessed 19 Jan. 2022.

Moore, Samuel K. Efinix’s Programmable Chips Could Push AI Out to the Edges. IEEE Spectrum, 5 Oct. 2017, spectrum.ieee.org/efinixs-programmable-chips-could-push-ai-out-to-the-edges. Accessed 19 Jan. 2022.

“Perspectives | Technology | Macquarie Group.” Macquarie, www.macquarie.com/au/en/perspectives/technology.html. Accessed 19 Jan. 2022.

See ASML's DUV Lithography Systems. www.asml.com/en/. Accessed 19 Jan. 2022.

Shilov, Anton. EUV Demand Is Up: EUV Device Manufacturer ASML Beats Sales Estimates. AnandTech, 16 Oct. 2019, www.anandtech.com/show/14992/euv-demand-up-at-asml. Accessed 19 Jan. 2022.

“TSMC.” Wikipedia: The Free Encyclopedia, Wikimedia Foundation, Inc., 4 Jan. 2022, en.wikipedia.org/wiki/TSMC. Accessed 19 Jan. 2022.

"There's a way to do it better - find it."

THOMAS EDISON