Chapter 1 Introduction

Commitment

Advances in semiconductor technology have impacted the whole world on such a fundamental level over the last 20 years. It's nearly impossible to imagine what our lives would be like today without the humble computer chip. ASML jumped into the game in 1984, and rose from the bottom to the top in an explosive story of success.

ASML's drive to be at the forefront of this technological revolution has tremendously influenced who we are today. We started small, in a field that was already full of major players. Many people thought we wouldn't make it. But little by little we advanced our market share, because we believed in ourselves and we were totally committed to what we were doing. It's a story of passion.

One of the keys to our success is that we've never stopped changing — never stopped pushing ourselves to achieve more. Our competitors have found it impossible to catch up with us in terms of our technological innovation. We kept the company at the forefront of technology, and we demonstrated a strong commitment to our customers and suppliers. Our success has not come through luck. It's been hard work, sweat and sheer determination in the face of what must have seemed insurmountable odds at times. It's a story of individuals achieving greatness together.

And so this book tells those stories. Stories about our history, often in the words of the people who were there first-hand. We start the story with what the industry looked like before ASML, and we continue with the birth of our company. We then look at ASML in four 5-year periods from 1984 until 2004. Finally, we look ahead to imagine what the future might hold for us.

Difficult times will surely lay ahead for our industry and our company. But we are better prepared to deal with the future than we have ever been before. We'll be taking our technology and our business to new heights as we work together. Because together we will create our future. It's a future that will be built on the lessons of the past, fueled by imagination and driven by commitment.

The world
before ASML

The PAS 2000

None of those looking on in April 1984, when ASML was born could have described the occasion as promising. An industry shake-out was looming, and few people could have foreseen that we would soon be moving into a sunny era of "chips with everything," in which life without the integrated circuit would be unimaginable

A problem of contact

Its family history, however, was impeccable. In the early 1970s, in the face of demand for increasingly complex ICs, the semiconductor industry was struggling to solve problems associated with the established technique of contact printing circuit patterns on wafers: the damage caused to the mask and the wafer, poor resolution and the difficulty of ensuring accurate alignment. It was clear that, before long, the old technique would need to be replaced.

Enter the stepper

The whole idea of stepping exposure on a wafer originated in 1971 at Philips Research (known also as the Nat Lab) by a team led by Herman van Heek. Based on this idea, they began developing the first wafer stepper, called the Silicon Repeater Mark 1 (see photo on page 12).

The stepper looked at the possibility of adapting photo repeaters with projection masks for printing on silicon. This would mean projecting light through a mask. This mask would have a circuit pattern, which would be projected onto a photosensitive layer on the wafer. Because this involved no contact between the mask and the wafer, the problem of damage was eliminated. And by projecting the light through lenses, the image could be reduced, making smaller chips possible. Such reduction also reduced any imperfections in the mask, improving the reliability of the IC. Accurate alignment of the various layers remained essential, of course. To ensure this, Philips developed a “through the lens” system (rather like a reflex camera).

At the time, the 1:1 projection system developed by Perkin Elmer (later SVG) was a better alternative to the stepper because it was cheaper and faster. ASML’s stepper was way too slow and suffered severe dynamics problems due to the moving lens, a new team led by Steef Wittekoek was formed to solve

The Silicon Repeater 2

these problems and add some features like a lager wafer size (5 inch) and a dual wavelength lens to make it usable in the IC lab of Philips Research. This second machine was called the Silicon Repeater Mark 2 (see photo on page 10).

The resulting machine was acclaimed at international conferences as a breakthrough in semiconductor production.

Go or no go?

However, the new machine presented Philips with an economic dilemma. The company needed the machine itself, but it was obviously too expensive to mass produce just for its own use, and the company lacked the expertise to market it itself. Meanwhile, other companies were developing — and marketing — alternative solutions to the same problems.

Something had to be done quickly. But what? Abandon the stepper, and buy the same sort of equipment that other chip manufacturers bought? No, Philips could not bring itself to cast off such a unique technology, and the job losses that would inevitably follow would be too painful. Could some other party, perhaps, be persuaded to join forces in making and marketing the product?

Finding a partner was difficult. Intensive talks were held with a number of American companies about the possibility of joint production or investment. But in the end there were no takers, and Philips was back to square one.

Close at hand

But happiness often lies much closer than we think. The ideal partner turned out to be only a few miles up the road from Philips. A Dutch company called Advanced Semiconductor Materials International (ASMI) had grown from being an agent for semiconductor equipment to a manufacturer of front- and back-end equipment for the industry in its own right. Though small, it was internationally very active, and its entrepreneurial CEO, Arthur del Prado, was always on the look-out for opportunities. Here, he thought, was a definite opportunity.

ASML's first building, behind Philips

A good idea?

Lithography equipment like the stepper would complement ASMI's existing range, and enable the company to offer its customers "one-stop shopping." And getting Philips as a customer and research partner could be very advantageous. For its part, Philips had never thought of ASMI as a possible partner. Not only was the company too small, but it lacked, in Philips' eyes, the experience and expertise needed in this field to succeed. What did ASMI know about lithography, after all? What's more, this was becoming an increasingly expensive business to get into. Only the big boys would survive, and it was certainly no place for amateurs.

But George de Kruyff, head of Philips Industrial and Electro-Acoustical products, and Willem Troost, head of Industrial Data Processing Systems, decided to risk it: ASMI would become their partner in a joint venture.

A doubtful prognosis

And so the new company began to develop. It would be a 50/50 joint venture of Nederlandse Philips Bedrijven BV and ASMI. Experts saw no need for a new company in this field. There were already too many established players, and yet another would never be able to gain a toehold in the market. What's more, they said, a big shake-out was just around the corner. An industrial or economic crisis could not be ruled out.

The brave Philips employees who were being transferred to the new company saw the whole operation as simply a delayed lay-off — but without the safety net provided by Philips' compensation programs. They did not, frankly, expect to be in work for much longer. And the new CEO, Gjalt Smit, did not realize at first just what a difficult task he had taken on.

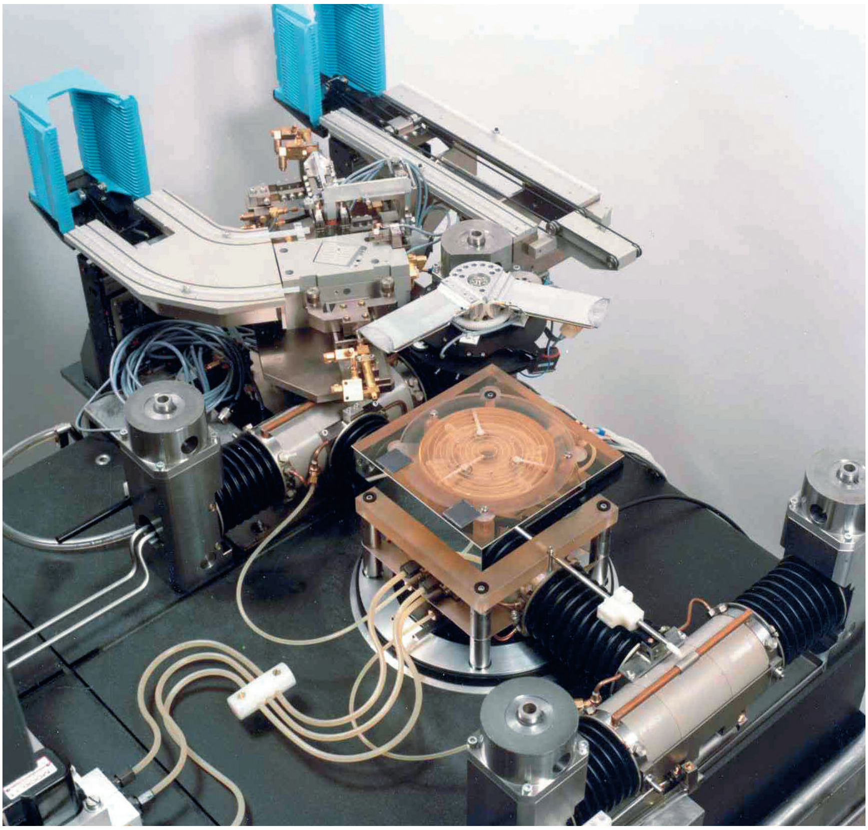
Silver lining

Finally, the new company was born on April 1, 1984 (a highly appropriate date, some would later suggest). It was named ASM Lithography, or ASML for short.

Twenty years
of technological innovation

The Silicon Repeater Mark 1 - SIRE 1

Over the past fifty years, everyday life has changed almost beyond recognition. In large measure, this is all due to the integrated circuit (IC) and its seemingly unstoppable progress toward becoming both unimaginably small and unimaginably powerful.



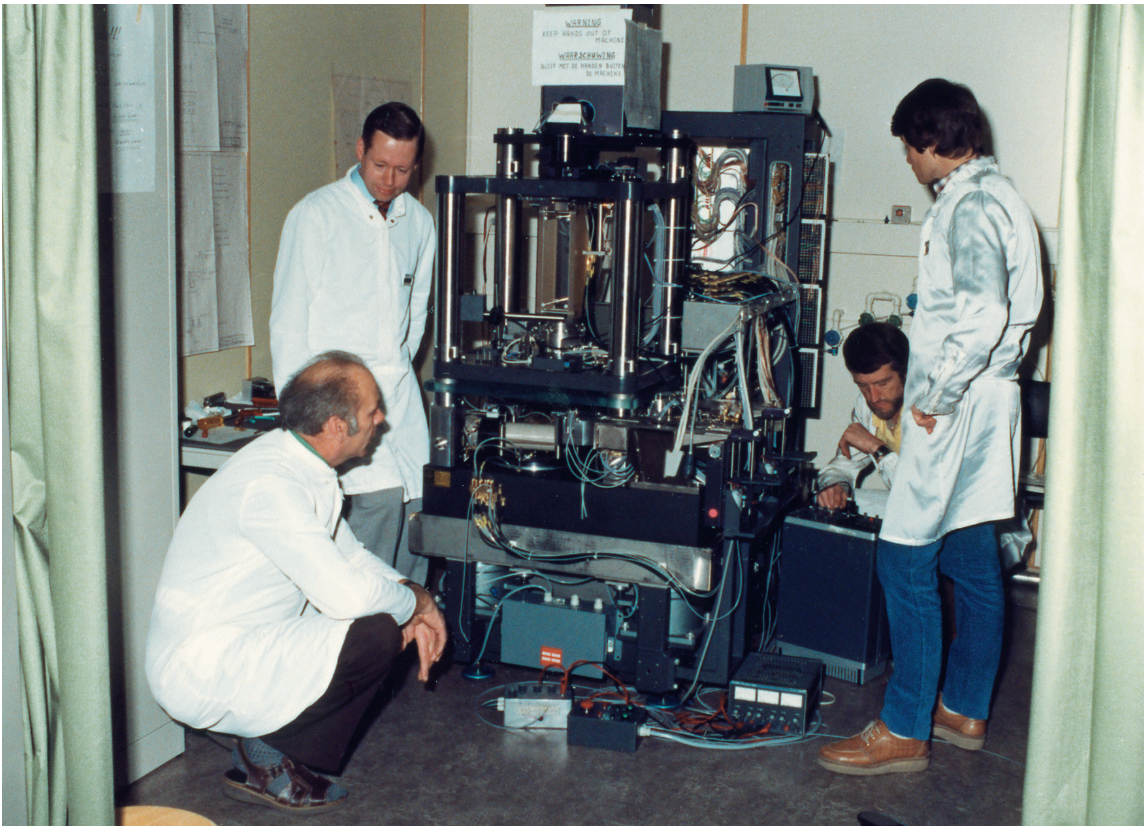
The hydraulic stage of the PAS 2000

The original IC, made in 1958, held only one transistor, three resistors and a capacitor and was the size of an adult's little finger. Today, an IC smaller than the smallest coin can hold 125 million transistors. Gordon Moore's prediction (made some 40 years ago and revised a little later) that the number of transistors that could be squeezed onto a chip would double every two years turned out to be accurate — and it still holds true today.

ASML has played a vital part in this development. The technological advances we have made have not only helped to keep the momentum of change going at the rate Moore predicted, but have been instrumental in taking us from the very back of the field, where we entered in 1984, to our position today as one of the leading suppliers of microlithography equipment in the semiconductor industry.

Key enabling technology

By making it possible to etch many millions of electrical circuits in layers on a wafer of silicon, microlithography is the key enabling technology in the increasing miniaturization of electronics. And yet the principles of the process and its role in chipmaking are straightforward enough. A mask, or glass stencil, is first made with the patterns of the circuits that will form one layer of the final chip. Light of a certain wavelength is then shone through this mask, and a series of lenses reduces and focuses the resulting image onto one small part of the surface of a silicon wafer. The wafer (200 or 300 mm in diameter) has been coated with a special



The integration team of the PAS 2000

light-sensitive polymer, or photoresist. Where it is exposed to the light, this material becomes soft, but where the mask protects it from exposure, it remains hard. After the patterned image has been projected onto the photoresist, the soft areas are washed away, revealing the circuit patterns traced in photoresist on the silicon. Subsequently, chemicals will be used to etch away the exposed areas of silicon. Additional steps then finish off the first layer, and the whole process is repeated for the other layers (up to 40).

This is the process followed for a single chip, but in practice many identical chips are made from one wafer. After exposing one small area, the microlithography system then moves on to expose the next small area, and so on, across the whole wafer. Particular accuracy is required in aligning each layer with the previous layer so that the many connections between the layers will be made properly. When all the layers are complete across the whole wafer, the wafer is cut into many identical chips.

Smaller, sharper – but how?

To keep pace with Moore's Law, we need to be able to project more and more circuits onto the same surface area. This means that the lines in the image need to be smaller, finer and sharper. Two factors are important here: the wavelength of the light used (the shorter, the better!) and the accuracy with which the light is captured and focused. Finding suitable sources of light and ways of improving image resolution has therefore been one of our major challenges over the past two decades.

Faster, more reliable – but how?

In the semiconductor industry, small on its own is not beautiful. Manufacturers need to be able to make their chips to a consistently high standard and with speed and efficiency. So another major challenge for us has been to find ways of reducing the size without compromising quality.

Never-ending search...

In summary, technologically speaking, the story of ASML is essentially the never-ending pursuit of increasingly smaller images with increasingly higher resolution, combined with increasingly higher throughput (more chips produced in the same time). In the short life of our company, we have met this challenge head on. We can be proud of what we have accomplished for the industry, and through it, for society at large.

Brick wall?

What will the future hold? We are already working in the realms of light with wavelengths so short that even the air absorbs it. Is there a limit, a “brick wall” looming that will bring Moore’s Law to a sudden halt? Or will we discover new, revolutionary solutions that will take us through that brick wall?

But we are running ahead of ourselves. Let us start where all good stories start: at the beginning. It is 1984, and a new joint venture has just been created...

Interview **Arthur del Prado**

Arthur del Prado, CEO and President of ASM International, recalls the vision behind his decision to co-found ASML in 1984.

ASM Lithography

By the 1980s, when the capital equipment industry was still in its infancy, I could see that by extending ASM International's business in front-end processing to include back-end activities through alliances, we would be able to offer customers unprecedented benefits. The stepper developed by Philips Nat Lab seemed just such an opportunity, and one Philips couldn't bring to market itself. The company tried repeatedly to find a partner in the U.S., without success, and it took a whole year to convince Philips that our comparatively small yet highly international business could be the solution it was looking for. Finally, in 1984, ASM Lithography was born, led by a core team of ASM International and Philips executives.

The alliance was one of three key ASM International ventures in the '80s. As it turned out, all three — ASML, our epitaxial reactor, and the ion implanter we later sold to Varian — went on to set global standards in their fields! However, the financial community was slow to see the possibilities involved, and the start-up costs and investment required to commercialize the stepper proved too great in light of the downturn in the late '80s and other ASM International priorities. We were therefore obliged to withdraw from the venture. Today, I see ASML's success as evidence of the innovative climate in the Netherlands, which allowed this company to grow and succeed.

Interview **Willem Troost**

Willem Troost, later ASML's second CEO, recalls the financial constraints and apathy the stepper project faced in its early days.

Scarce resources

As the Managing Director of Advanced Automation Systems within Philips' I&E division in the 1970s, my job was to explore high-tech developments within the company that might be commercially promising. The Nat Lab's lithography stepper clearly had promise and so was "drawn" into my group for possible commercialization. From the outset, however, I&E was reluctant to commit investment that could be used for existing activities. With no development or production resources, we had to rely on a network of groups across Philips. Even when we got our first order for 5 steppers from Philips Semiconductors, it took two years of monthly meetings, at which Philips' management expressed concern about our ability to deliver, before agreement was reached.

Although a joint venture seemed the solution, talks with potential U.S. partners failed. When Arthur del Prado, ASMI's entrepreneurial CEO, expressed interest, it seemed ideal: ASMI had an established market, subsidiaries in the U.S. and Asia, and localized R&D and manufacturing. Even then, pushing the deal through took a year, in which time the stepper's development stagnated and competitors moved ahead.

The joint venture erected its first premises, wooden barracks, in a single weekend! I remained involved as a member of ASML's Board and the key interface with Philips until my retirement from Philips in '85, helping with issues such as the transfer of staff. Little did I know that just a few years later I would become the company's second CEO.

Interview **Steef Wittekoek**

Steef Wittekoek, the man at the helm of the development of the stepper in the 1970s and later ASML's first Executive Scientist, recalls the difficult development of this technological breakthrough.

The birth of the stepper

In 1973, Philips asked me to lead a team of Nat Lab researchers to develop an improved version of the first wafer stepper, which was meant as an alternative for the contact printing of silicon wafers. The semiconductor capital equipment industry didn't yet exist, and large companies often developed their own production tools. The Nat Lab had already produced photo repeaters using projection masks, and our task was to see if this technology could be applied to silicon.

We knew it could be done in theory, but making it happen took real teamwork between the 20 to 30 experts in the group. Other companies were also applying themselves to the problem, and this spurred us on to develop the necessary subsystems as quickly as possible, including the xy table and the alignment system, on which I personally worked. Our greatest challenge was to create a system that offered both high resolution and high speed. ASML's first working stepper, SIRE 1, in 1974, was far too slow. However, even though Perkin Elmer had introduced its successful 1:1 scanner around that time, we were confident that wafer steppers would prove superior technologically. The second generation we produced in 1978 was faster, and we built a few prototypes. It was pretty hands-on work, as most of the system was produced within the Nat Lab itself!

Although we were all excited by and proud of our achievements, the team became increasingly frustrated during the early '80s as the project stalled. By 1983, we had a product, but it still had a number of problems, including its hydraulically driven stepping stage and inadequate lens system. Meanwhile, GCA had introduced a wafer stepper that dominated the market. Philips couldn't bring our costly stepper machines to market, and despite growing interest from many companies, including Varian, Cobilt, GCA and Perkin Elmer, as well as potential users such as Bell Labs and IBM, negotiations with others to produce the system failed.

Discouraged, I transferred to the U.S. to work for Philips Medical Systems on magnetic resonance imaging at Columbia

Presbyterian Hospital. Ironically, it was during my absence that Philips found a partner, ASMI, right on its own doorstep! When Gjalt Smit flew to New York to invite me to join the joint venture as Executive Scientist, acting both as ASML's technological conscience and its ambassador, it was truly a dream come true. The "brainchild" I had worked on for so long was finally going to become a reality. Of course, by then, several other competitors and new technical challenges had emerged: our work had only just begun…

“The brainchild I had worked on for so long was finally going to become a reality.”