Danmarks Tekniske Universitet

DTU Danchip

National Center for Micro- and Nanofabrication

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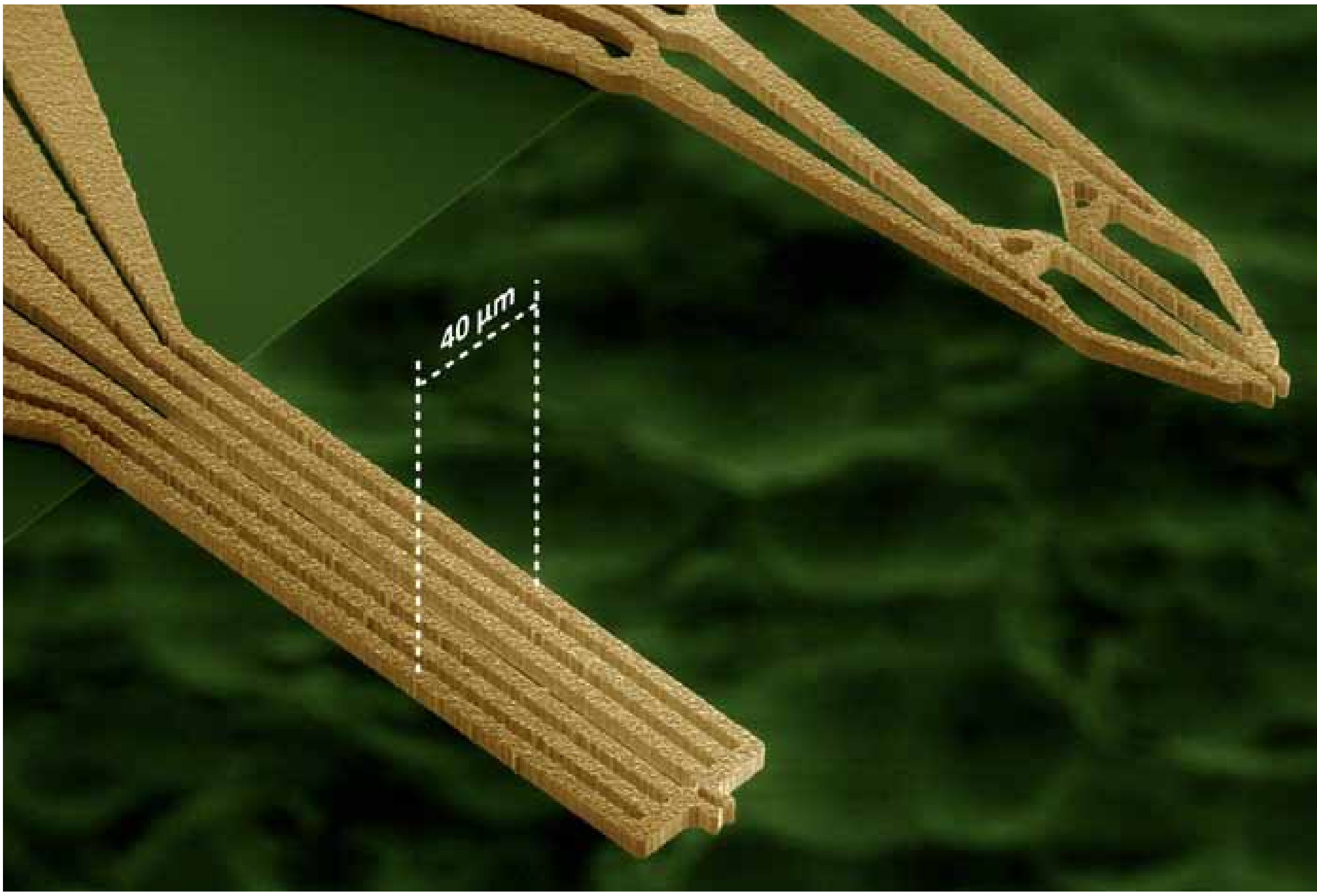
DTU - Technical University of Denmark



Silicon microgrippers for robot manipulation of carbon nanotubes actuated by electrothermal expansion.
The grippers were fabricated by DTU Nanotech.

WELCOME TO DTU DANCHIP

DTU Danchip is The National Centre for Micro- and Nanofabrication in Denmark. We play a pivotal role to industry and academia as we facilitate the development of new technology and new products based on micro - and nanotechnology.

We produce small chips and components which are integral to many of our household items, i.e. mobile phones, computers or medical equipment.

Researchers from Danish and international universities and industry have access to our technology and the knowledge of our experts. In this way we guarantee the best working conditions for industry and research communities while contributing to both economic and social development and growth.

Danchip is designed to accomodate both scientific research and production. The placement of production and research facilities under the same roof is a great advantage to the micro- and nanoindustry. The cleanroom is DTU Danchip's micro- and nanoworkshop facility covering an area of 1350 m². In our many laboratories researchers and industry fabricate chips and components with high-tech equipment.

DTU Danchip is constantly striving to promote research and development in micro- and nanotechnology. We cooperate closely with both national and international industry and several research institutions.

FACTS ON THE CLEANROOM

Total approximate value of cleanroom equipment is 300 million DKK.

The air in the cleanroom is changed 200 times per hour. This means providing the cleanroom with 350,000 m^3 fresh air every single hour.

The temperature in the cleanroom is kept at a constant 21.5°C ± 0.5 °C and the humidity is at 45 % ± 5 % to guarantee exact similar conditions all year round.

The purity of the air is secured by HEPA filters which remove 99.9 % of all particles in the air.

Micro- and nanotechnology
- working with atoms and molecules

Technology surrounding us is becoming increasingly complex, electronic and optical components which form an integral part of our daily lives are becoming smaller and smaller, demanding that we fabricate nanometer scale structures and materials.

To ensure that Denmark keeps up with this development it is crucial to maintain comprehensive proficiency in the field of nanotechnology research and production.

Micro- and nanotechnology is about fabricating structures and materials in chips which are parts of i.e. communications and medical equipment. Every chip contains electronic or electromechanical micro- and nanostructures and small electronic switches which together determine the function of the chip. For instance, a specific chip in an airbag should be able to register a collision and then deploy the airbag.

At DTU Danchip we design, fabricate and control materials and components with nanoscale dimensions. We employ top-down micro- and nanotechnology to fabricate structures simulated and designed on a computer.

Nanotechnology follows in the footsteps of microtechnology, only today we can control the tiniest building bricks on an even smaller scale. Nature knows how to put together atoms and molecules in biological processes. Now man can contribute to this process with the help of state-of-the-art high-tech equipment and put together materials, atom by atom, molecule by molecule. Or we can remove a few hundred atoms by "chopping out" sophisticated nanostructures in the most diverse materials - from the widely used silicon to such exotic elements as hafnium or irridium.

UNFATHOMABLY SMALL

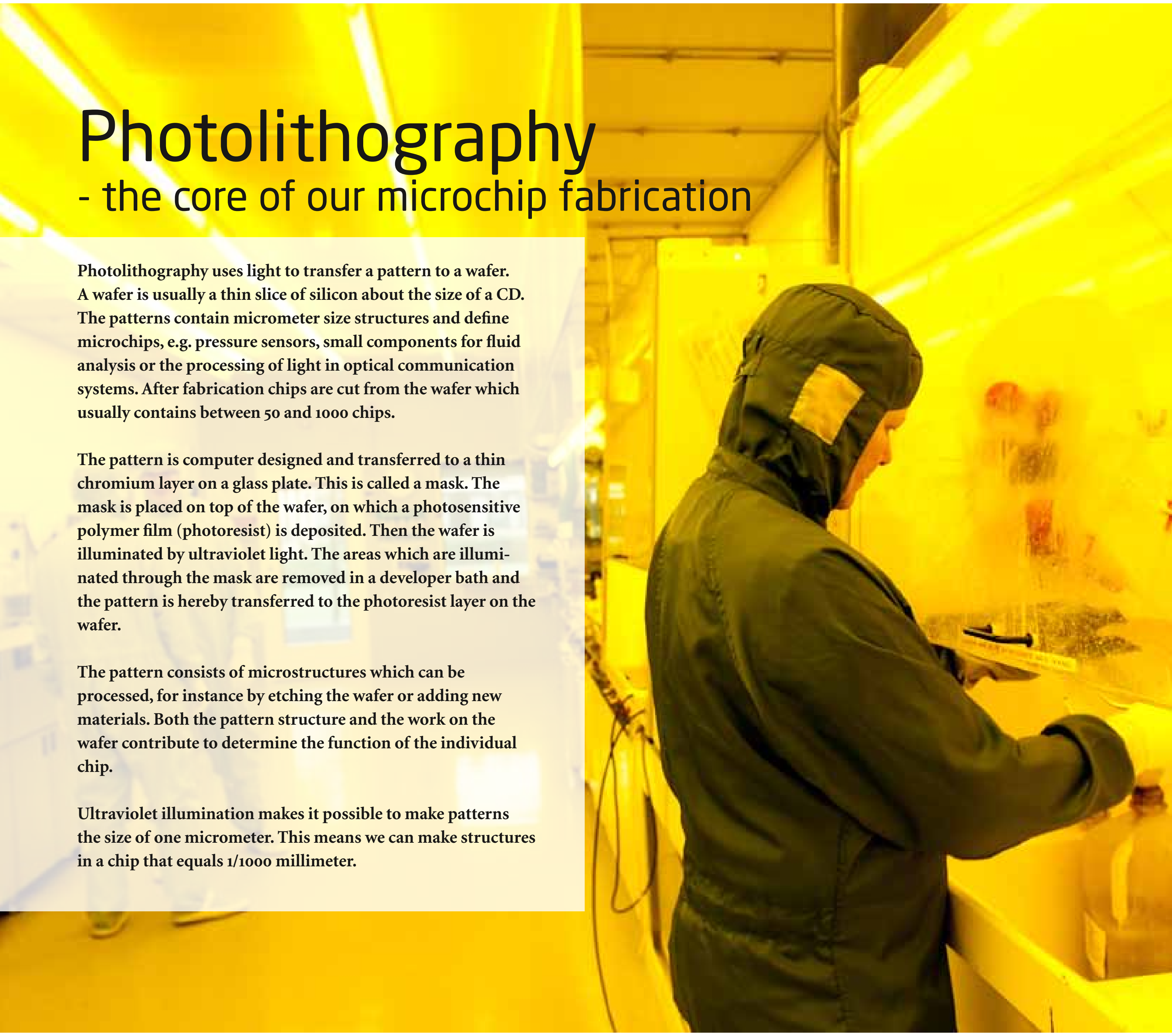
One micrometer is 0.000001 m, one millionth of a meter. You are able to see down to the size of one micrometer in a microscope. The human eye can see the width of a hair, which is around 90 micrometers.

One nanometer is 0.000000001 m. or one billionth of a meter. One nanometer is 90,000 times smaller than the diameter of a human hair. A nanometer is 1000 times smaller than a micrometer.

The small scale of operation in nanotechnology allows us to write the Bible, which has 3,566,480 letters, 500 times over on a grain of rice.

BOTTOM-UP OG TOP-DOWN NANOTECHNOLOGY

Just as Lego bricks are put together, nanotechnology can build using the smallest building bricks of the universe, atoms and molecules, and fabricate new, unique materials. This is also referred to as the bottom-up method. Or we use the top-down method, by which materials are removed from a work piece, like a sculptor carving chunks from a stone, ending up with the finished statue.



Photolithography
- the core of our microchip fabrication

Photolithography uses light to transfer a pattern to a wafer. A wafer is usually a thin slice of silicon about the size of a CD. The patterns contain micrometer size structures and define microchips, e.g. pressure sensors, small components for fluid analysis or the processing of light in optical communication systems. After fabrication chips are cut from the wafer which usually contains between 50 and 1000 chips.

The pattern is computer designed and transferred to a thin chromium layer on a glass plate. This is called a mask. The mask is placed on top of the wafer, on which a photosensitive polymer film (photoresist) is deposited. Then the wafer is illuminated by ultraviolet light. The areas which are illuminated through the mask are removed in a developer bath and the pattern is hereby transferred to the photoresist layer on the wafer.

The pattern consists of microstructures which can be processed, for instance by etching the wafer or adding new materials. Both the pattern structure and the work on the wafer contribute to determine the function of the individual chip.

Ultraviolet illumination makes it possible to make patterns the size of one micrometer. This means we can make structures in a chip that equals 1/1000 millimeter.

HOW IS A PHOTOSENSITIVE LAYER MADE?

DTU Danchip's SSE Maximus spin-coater spins at 4000 rounds per minute and distributes the photoresist onto the wafers as a uniform thin layer.

The film is a viscous liquid polymer fluid, and the rapidly spinning spin-coater ensures that the polymer layer is only one micrometer thick.

The spin-coater automatically works on a large number of wafers successively and can accommodate all needs for photoresist deposition.

Etching:
"2 1/2 dimensional design"
- wet etching and dry etching

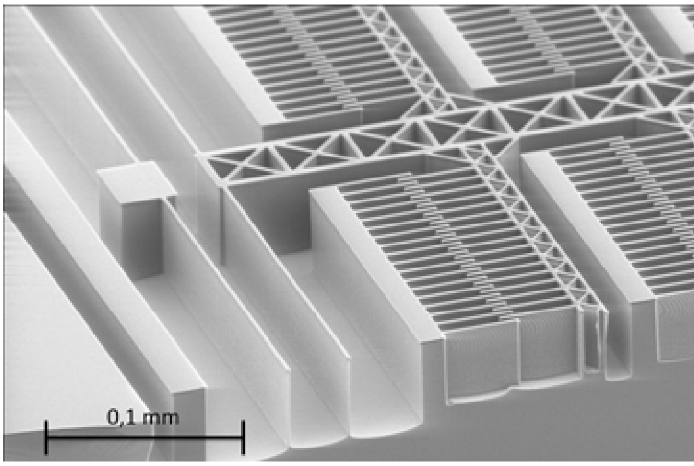
Ideally, we want to work on the substrates in three dimensions, and to have as much control over the processes in micro- and nanosize that it allows for complete freedom to design the structure of the chips. Not just on the surface, but also in depth. For in-depth design we use etching processes.

Today, it is only possible to work in what we term 2 ½ dimension. This is because we are bound by the patterns we applied to the wafer surface by photolithography. We work with both wet etching and dry etching.

In wet etching we use acids etching down through the material on the wafer surface without attacking the areas protected by the photoresist. This kind of etching is isotropic, meaning that the etching of the material is happening with similar speed in all directions. From this follows a tendency for structures defined in the photolithography pattern of the wafer to broaden.

By using dry etching, more accurate in-depth structures are achieved, as the etching is anisotropic, meaning that the etching is directional.

The dry etching takes place by creating a plasma of various gas compositions in a low pressure chamber. The molecules of the gas composition are ripped apart with the help of an electric field between two electrodes. In this way we get a reactive gas bombarding the wafer in a preferred direction (vertical).



Variable capacitors

DANCHIP AND NANOIMPRINT LITHOGRAPHY

DTU Danchip has state of the art nanoimprint lithography processing capability.

Instead of writing every single wafer by an e-beam this technology allows us to produce a series of nanostructures in the wafer.

This method allows embossing the nanopattern of a master wafer written by an e-beam, on to soft polymer. After curing it is an exact replica of the master wafer.

Nanoscale lithography
- the tool for Nature's building blocks

Using nanoscale lithography DTU Danchip is able to produce components of which the smallest structures may measure as little as 10 nanometer (0.00001 millimeter). At DTU Danchip the central equipment for nanoscale lithography is a socalled E-beam writer.

With a very accurately defined electron beam the E-beam-writer exposes the structures on a wafer on which a thin layer of photosensitive polymer is deposited. This method is also referred to as "direct writing" as we can control the electron beam as if it were a pen.

The electron beam width is only four nanometer and it is able to produce structures as small as 10 nanometers. Written "lines" are always a little wider, as the beam has a tendency to broaden on the photosensitive polymer of the wafer. The disadvantage of this method is that every single structure on the wafer has to be written one by one causing it to be relatively expensive with regards to mass production.

On the other hand, nanoscale lithography allows us to address whole new areas of applications. For instance, we can design structures which in size almost match Nature's own building blocks (atoms and molecules). In this way we can manufacture instruments sensitive to very small amounts of particular molecules, used for tracing explosives or screening DNA.

Thin film deposition

Deposition of thin layers of materials with various physical or chemical properties is a key feature of the components we fabricate. Materials are deposited in either single or multiple layers corresponding to the functionalities we want to implement in the component.

Some materials are good conductors of electricity, others are electrically insulating, transport light or have special thermal properties. The thin layers are deposited with various processes.

In the LPCVD (Low-Pressure Chemical Vapor Deposition) process molecules react in a chemical process on the surface of the wafer, creating a new material on top of the disc. The related PECVD (Plasma-Enhanced Chemical Vapor Deposition) process is also a chemical process, but now enhanced by a plasma, forming new materials on the wafer. These processes are used for the fabrication of dielectric thin films.

Furthermore, we use PVD (Physical Vapor Deposition). By one method, electron beam deposition, we deposit metals such as gold with help of an electron beam gun. As the electron beam hits the metal, it is heated and evaporates in a cloud of atoms which then settle on the surface of the wafer.

By the other method, sputter deposition, ions (charged argon atoms which are accelerated) are directed onto e.g. a gold target. As the ions hit the target, gold atoms are ejected and settle as a uniform layer on the wafer. The PVD techniques are used for deposition of both electric and dielectric materials.

METHODS FOR THIN FILM DEPOSITION

LPCVD
- Low-Pressure Chemical Vapor Deposition

CVD
- Chemical Vapor Deposition

PECVD
- Plasma-Enhanced Chemical Vapor Deposition

PVD
- Physical Vapor Deposition

Characterization
- tools for analysis and quality control

DTU Danchip monitors and assures the quality of the fabrication process and the key processes which are offered to users of the cleanroom.

With characterization equipment we can measure how our fabrication processes and products meet the desired parameters. E.g. whether the electric conductivity is correct, whether the sizes are correct, and whether the structures of the components have the appropriate shape. Using optical microscopes we can control structures with sizes down to a few micrometers.

Scanning Electron Microscopy (SEM) allows us to make images of even smaller structures than optical microscopes, as we use electrons instead of light in the visible range for generating the images. Using SEM we can see structures down to around 5-10 nanometers. We have four scanning electron microscopes, which also allow the characterization of non-conductive polymers which is usually a challenge as the polymer accumulates the electric charge of the electron beam.

DTU Danchip's Atomic Force Microscope works very similar to an old-fashioned record player, in which the pickup needle moves across the record. In AFM the needle is placed on a cantilever, which extremely accurately moves across the surface of the component, measuring the height difference down to 0.5 nanometer. The microscope makes a 3D graphic image with accurate measurements of the surface.

Metals
- precious elements in thin layers

DTU Danchip works with noble metals such as gold and platinum. The noble metals do not react with other metals, they do not change, they do not oxidize. Because the noble metals maintain their conductive properties, we use them for the production of conductors in our components.

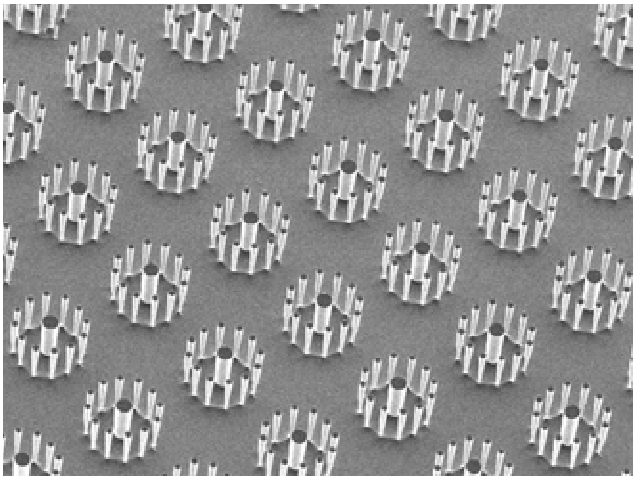
Nickel is hard and suitable for making tools for polymer injection molding. The mould contains a nickel master into which various plastics are injected, upon solidification the plastic component is released from the tool.

Titanium is as hard as steel, does not corrode, is acid and gas resistant and it is non-toxic. Titanium is used as an intermediate layer to promote adhesion of other metals such as gold and platinum.

Platinum has very special catalytic properties, allowing platinum to increase the speed of a chemical reaction without being consumed by the reaction. This is why platinum is used as a catalyst for a number of chemical processes. A main area of application is the catalyzation of oxygen reduction in fuel cells, in which an electric current is generated via the chemical reaction of hydrogen and oxygen into water.

Electron microscope imaging
- zoom in on our smallest structures

The images of the electron microscope are generated by electrons instead of light. Electron beams have a much shorter wavelength than visible light. The wavelength of the electron beam is dependent on the velocity of the electrons and the velocity can be controlled by accelerating the electrons over an electric field. In this way the electron microscope can generate images with a resolution 1000 times better than images generated by light.



1,21 mm

Microelectrodes for making electrical measurements inside living cells. Structures made by DTU Nanotech.

Deep UV lithography
- mass fabrication of nanostructures

The Deep UV Stepper Tool, a photolithography machine recently acquired by Danchip, significantly reduces the production price for nanostructure microchips. The machine is essentially a slide projector system, transferring patterns to photosensitive film with an extremely high resolution down to 150 nanometer.

The motivation for the acquisition of the machine is that it permits making smaller patterns and more complex structures on the same chip. This allows for increased applicability, lower price of fabrication and supports growth of the micro- and nanoindustry.

In a project with the Danish National Advanced Technology Foundation, DTU Danchip is introducing this technology in Denmark together with Capres, Ibsen Photonics and Ignis Photonyx.

Capres intend to use the Deep UV Stepper for the development of their unique microprobe technology used in the production of computer chips and harddisks.

Ibsen Photonics expects to add two new types of optical components to their product range of compact, handheld spectrometers.

Ignis Photonyx produces advanced planar optical filters which combine and split light signals in optical fiber networks. These filters are key components of communication networks and enable high capacity fibers to our homes. The new machine contributes to reduce the production price, due to an improved quality and performance of the individual filters.

This technology may be commercialized by the entire micro- and nano-industry in Denmark and is part of creating a faster and cheaper road from research to production.

DTU Danchip Cleanroom
- for micro- and nanofabrication

DTU Danchip is a laboratory for the fabrication of micro- and nanostructures, which researchers, students and industry can access. In this facility we develop and fabricate the chips which in the future will be integral to many of our daily products.

Fabrication of chips must take place in cleanrooms to prevent dust particles – otherwise contaminating - from settling on the micro- and nanostructures we produce.

People are the greatest source of dust, spreading millions of particles from skin, hair and clothes. This calls for strict regulations on clothing and behavior in the cleanroom. Everyone must carry a coverall, hood, boots, gloves, and if necessary hair net and beard cover to protect the room from particles. Eating and drinking is not allowed, neither is the use of mobile phones in the cleanroom. Paper must be laminated in advance, doors should be opened slowly, and conversation should be kept to a minimum.

MORE FACTS ON THE CLEANROOM

Approximate total price of equipment is 300 million DKK.

The cleanroom is 1350 m^2 and the air of the room is changed 200 times per hour - 350,000 m^3 air every hour.

The temperature is kept at a constant 21.5 °C (± 0.5 °C). The air humidity is at 45 % (± 5 %)

Number of gloves used per year: 35,000

3000 cleanroom suits are washed by a special process every year.

912,000 liters of liquid nitrogen are used every year.

We use 30 different kinds of gases.

Every year we use 7500 silicon wafers and 1300 glass wafers.

How to dress for the cleanroom

Open the bag.
Avoid tearing the suit.

Discard the bag.

Use a hair cover if necessary and then put on the cleanroom hood.

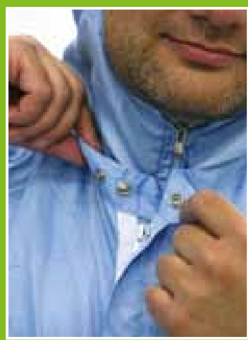
Make sure that the suit does not touch the ground.

Step into the first leg of the suit. Keep a firm hold of the other leg and the sleeves.

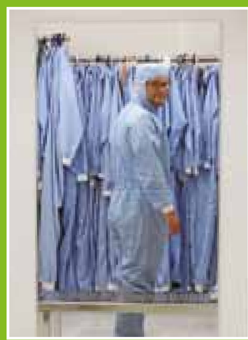
Step into the other leg, while still holding the sleeves.

Put on the rest of the suit.

Remember to wear the suit over the hood.



Close zipper and button up.



Use the mirror to check that the suit is put on properly.

Put the boots on the bench with soles facing up.

Put on boots, avoiding them touching the ground or the bench.

Swivel your bootwearing leg across the bench to the clean zone.

Remember to buckle straps.

Place gloves over the suit cuffs. Only touch gloves by the end of their cuffs.

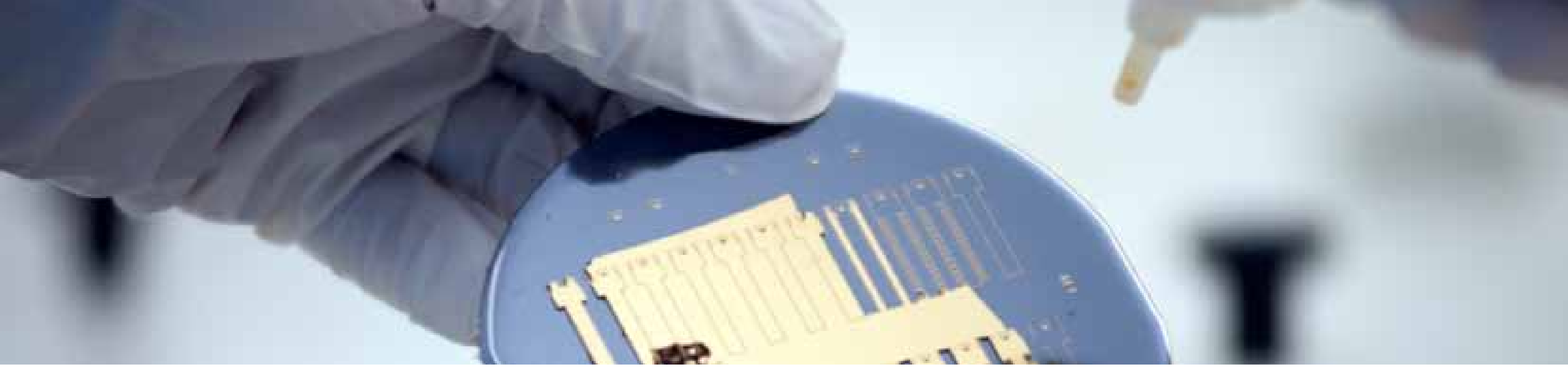
Cleanroom facilites and equipment
- world class services

DTU Danchip offers industry and academia a reliable research and production environment with a high efficiency and a steady performance. The cleanroom facility and equipment are professionally maintained by our technicians and engineers. Our consultants and process engineers are available for development and fabrication of micro- and nanosystems.

We provide access to comprehensive state of the art process equipment for lithography, etching, thermal processing, thin film deposition, wafer cleaning, packaging and characterization.

The cost of investment for industry is low, as expensive equipment can be saved by using our equipment and cleanroom facilities. Industry can do small scale production, just as they can cooperate with DTU Danchip both in the idea initiation phase or when about to start up a proper fabrication.

Cooperating with DTU Danchip gives industry a short route from idea to end product or prototype, sharing knowledge on micro- and nanoproduction, fabrication and process data. Companies also gain access to a European network of cleanroom facilites and experts and a point of entrance to DTU Danchip partners: Danish Technological Institute and Scion DTU science park.



DTU Danchip is ISO-certified

DTU Danchip is certified according to DS/EN ISO 9001:2008 standard.

ISO 9001 certification covers: "Access and use of equipment in cleanroom facilities for micro- and nanofabrication and in-sourcing of customer processes".

The ISO 9001 certificate is internationally acknowledged documentation that DTU Danchip is a reliable and professional cooperation partner, focusing on quality. Every six months an audit monitors that DTU Danchip meets the requirements of ISO 9001.

This means, that DTU Danchip continuously maintains and improves the quality of the service we deliver to our customers. The quality system supports knowledge sharing and also the pooling of the generated knowledge.

Quality Management System certified according to DS/EN ISO 9001 by Det Norske Veritas, Business Assurance, Denmark A/S

Pegasus
- quick, accurate and deep silicon etching

DTU Danchip's STS Pegasus Silicon Etching Tool is a machine etching both accurately and homogenously in silicon wafers. This plasma etching process has many applications, among others fabricating variable electric capacitors on a silicon chip. Capacitors are used in electronic circuits for a number of purposes, e.g. to make filters to choose desired frequencies on mobile phones.

The Pegasus etching tool is able to etch all the way through the silicon wafer. For instance, wafers with holes are used for lab-on-chip systems, in which the management of extremely small amounts of fluid - down to a picoliter - (0.000000000001 liter) are needed. Lab-on-chip devices are microlaboratories that fit on a chip and are used in e.g. medical equipment for the analysis of blood.

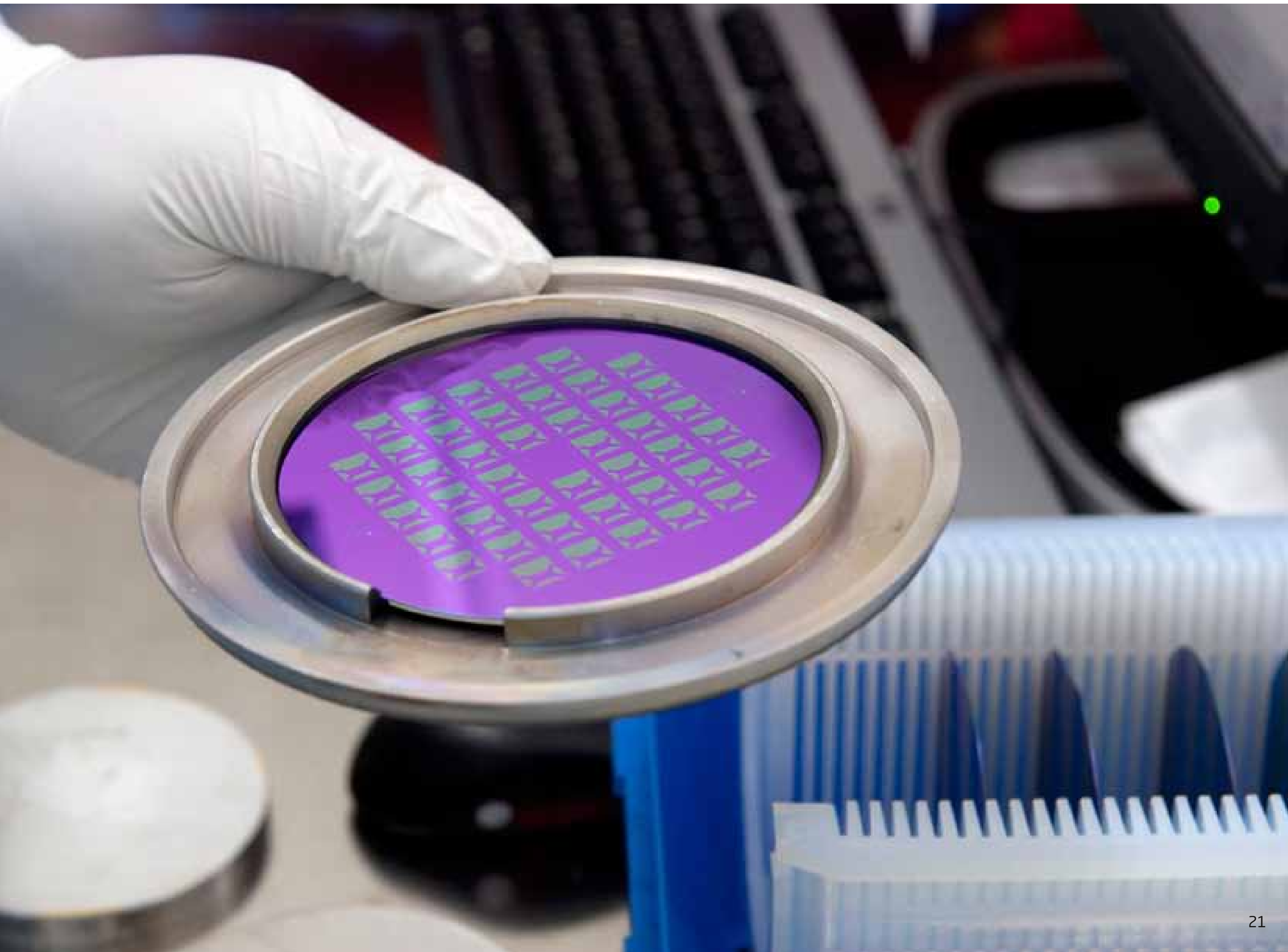
The Pegasus etching tool is equipped with a robot handling up to 25 silicon wafers. This allows for mass production and for the making of a series of tests, checking the effect of different parameters on the etching process, by changing the different gases we let in, the pressure, or the electrical power in the plasma.

The Pegasus etching tool is part of DTU Danchip's Nanostructuring Facility, supported by a research infrastructure grant from the Danish Agency for Science, Technology and Innovation, which DTU Danchip received together with Danish Technological Institute and DTU Nanotech.

Wordentec
- vapor deposition of gold, platinum, chromium and titanium

Nanometer-thin film made by pure metals such as gold, platinum, chromium and titanium can be used to build micro- and nanosystems. The metal film on the wafers acts as an electrically conductive layer - as e.g. electrodes to conduct electricity on a solar cell. Gold conducts electricity well, but does not stick to silicon very well. This is why we have to use titanium to promote gold adhesion. Unfortunately, gold and titanium tends to alloy when heated, but a platinum film placed between the gold and titanium film solves that issue.

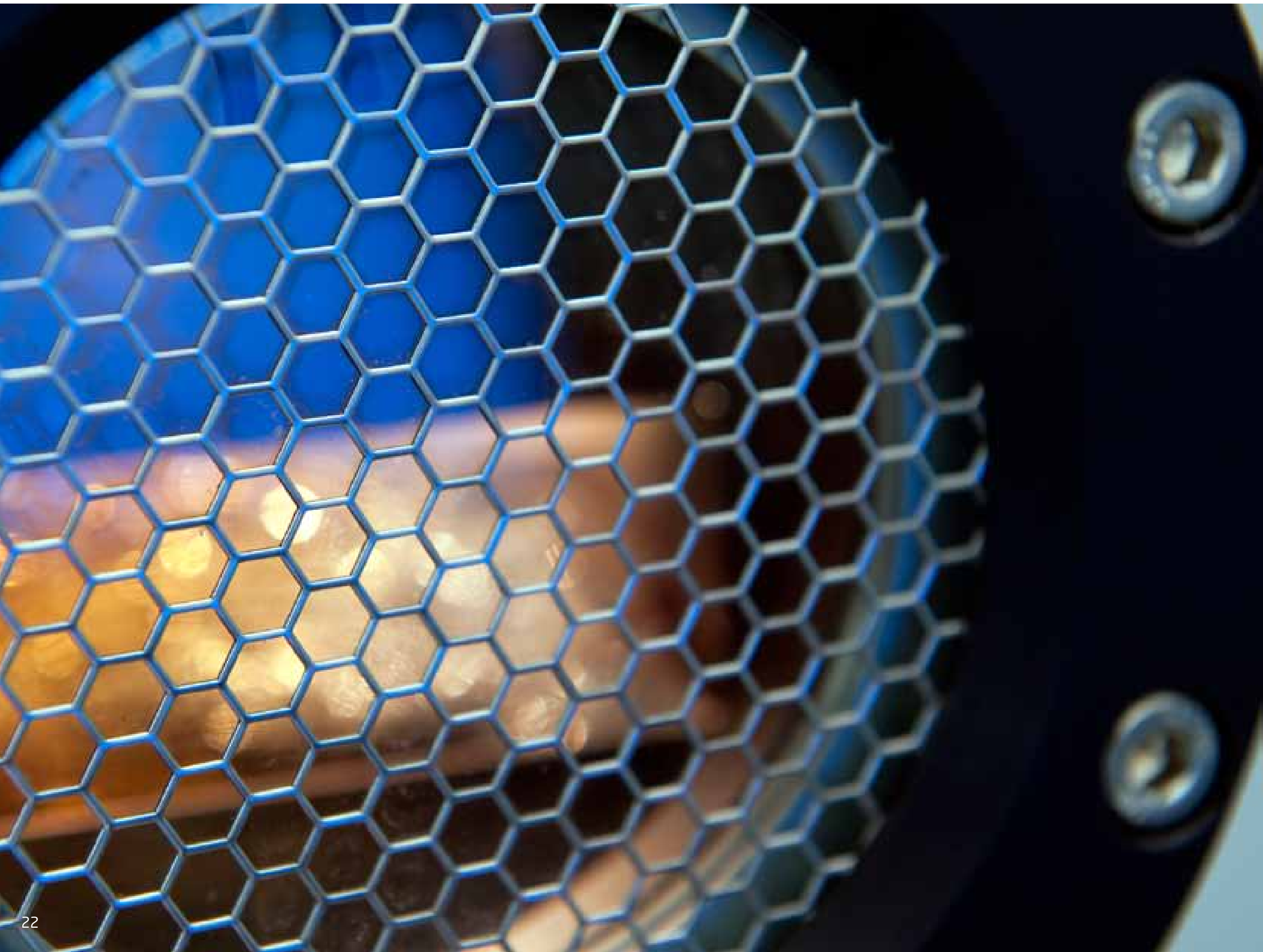
The Wordentec QCL800 handles up to 6 wafers at a time, without removal of the wafers from the vacuum of the system.



Business at DTU Danchip
- state of the art facilities for development and growth

DTU Danchip accomodates the needs of both industry and academia for access to state of the art equipment, research facilities, technology, and practical training within the field of micro- and nanofabrication technology. We deliver great flexibility in all phases of a cooperation process and help with everything from setting up companies' own equipment in the cleanroom to providing operators and engineers.

We take part in linking university research and industrial applicability. We contribute to the creation of new knowledge and enable Danish industry to make use of the present and future benefits of micro- and nanotechnology. DTU Danchip operates the largest cleanroom for micro- and nanofabrication in Denmark. Industrial and academic researchers have open access to the facilities. We cooperate with both national and international customers and research institutions.



DTU Danchip customers pay for "time used" and equipment inside our cleanroom.

DTU Danchip services

- **Direct access to DTU Danchip's wide range of equipment and expertise**
- **Installation of customer owned equipment**
- **Rent of restricted access areas inside the cleanroom**
- **Insourcing of development and production as DTU Danchip offers to carry out complex development and production work for customers**
- **Quality assurance in a controlled fabrication environment (ISO 9001)**
- **Consultancy services in connection with process design, product development and production**
- **Education of Bachelor, Master and Ph.D. students as well as education and training for industrial customers**

CAPRES - PROBES FOR ACCURATE MEASUREMENT

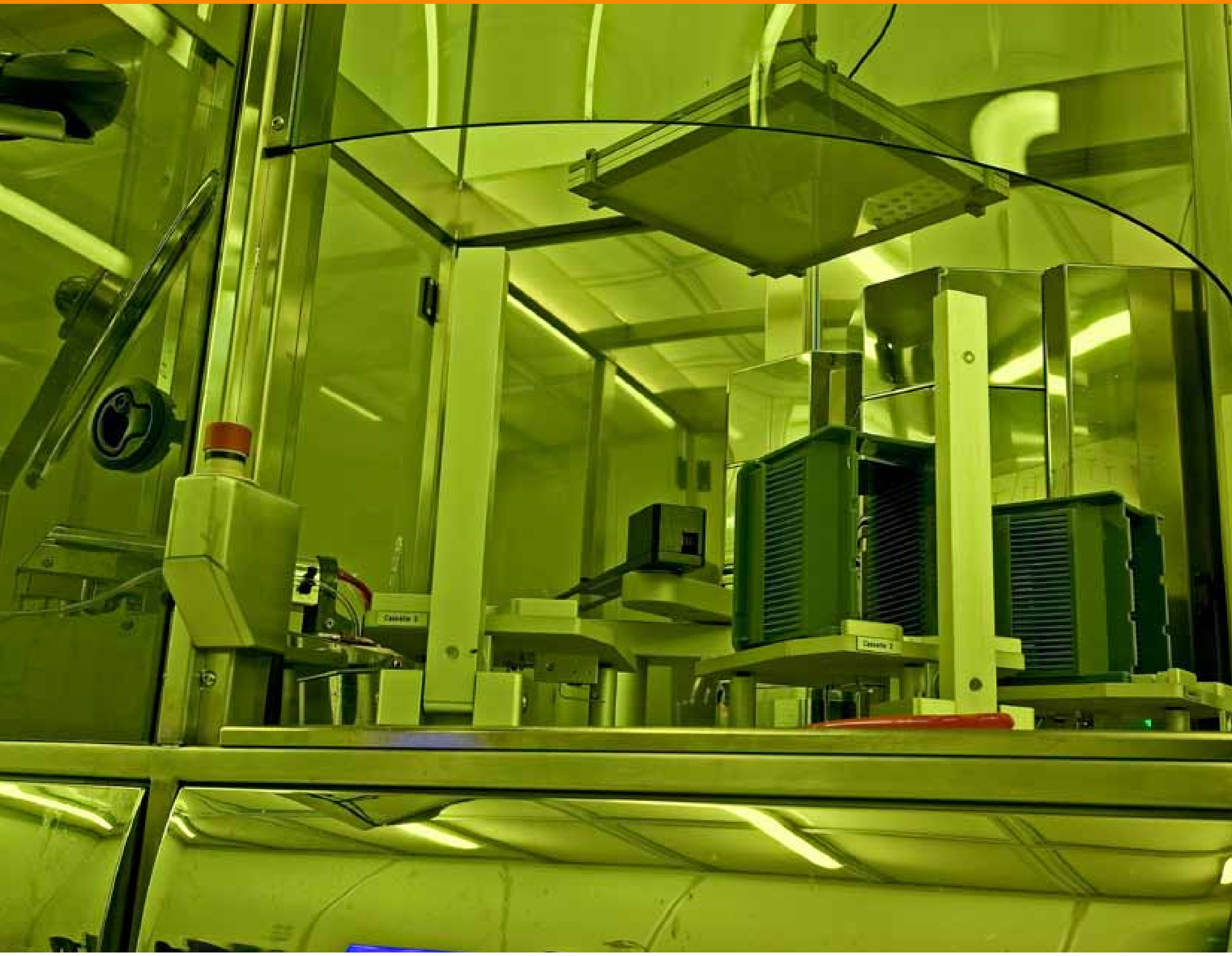
The company Capres, a DTU Nanotech spin off company, develops and produces microprobes, small measurement systems in the shape of chips with 4 or more cantilevers, making accurate measurements of electrical properties in a material. A part of Capres' advanced probes are developed and produced at DTU Danchip.

Capres and DTU Danchip are partners in the Danish National Advanced Technology Foundation project "Deep UV lithography for next generation micro machined products" on further development of the probes.

DEVELOPMENT AND GROWTH FOR DANISH INDUSTRY

DTU Danchip contributes to the development and growth of Danish industry by participating in numerous development projects. For instance, we have contributed to the pressure sensors, controlling Grundfos' most modern pumps and to the technology behind NKT's optical waveguides (components to build advanced fiber networks).

Today this technology is used by Ignis Photonyx for the production of advanced optical components for the telecommunications network.



An automatic resist spinner with robot wafer handling

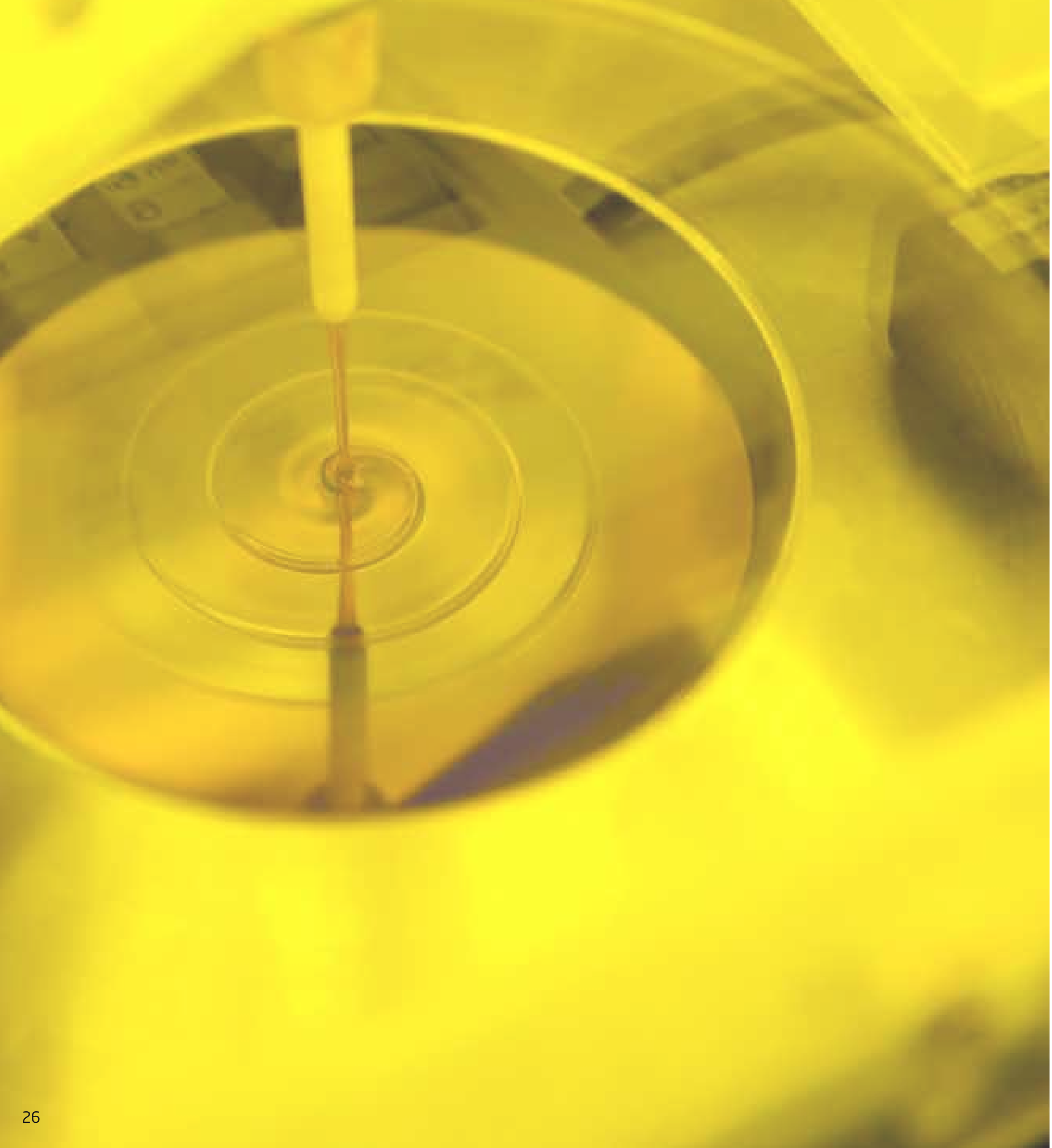
The history of DTU Danchip
- constantly growing cleanroom

The inauguration of a 560 m^2 cleanroom facility in 1993 laid the foundation for what is now DTU Danchip. The cleanroom facility was at the core of the research vision at the department which is now DTU Nanotech (former MIC).

The aim of the cleanroom facility was to be the hub of microtechnology at DTU in close collaboration with Danish industry.

In the following years the emerging Danish microtech industry and users from the research communities of DTU Nanotech and DTU Fotonik prompted a demand for cleanroom capacity. Increased capacity and more advanced equipment were needed to make miniaturizations possible and to explore various scopes of nanotechnology.

In 2002 DTU initiated an expansion of the cleanroom facility to the current 1350 m^2 with an investment of more than 100 million DKK. Following the inauguration of the new facilities DTU Danchip was created with the purpose of operating and developing the cleanroom facilites. Today, we offer researchers and industry access to supreme world class laboratories and technological equipment.



DTU Danchip
- a multicompetent staff

Research and fabrication of micro- and nanotechnology requires a broad range of skills from the staff of DTU Danchip. Our staff consist of staff members with many different types of educational background. They deliver a high level of quality and service and are part of all phases from research and development to production and day-to-day operation.

DTU Danchip employs more than 35 permanent staff. Apart from that, each week we have approx. 150 users in our cleanroom facility, from student and researchers to industry employees.

MORE INFO ON DANCHIP

Gender distribution employees: women 34% and men 66%
Nationalities employees: 7
Guests visiting cleanroom per year: 200
Companies using the cleanroom on a daily basis: 10
Reseachers using the cleanroom on a daily basis: 45
Students: 150

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