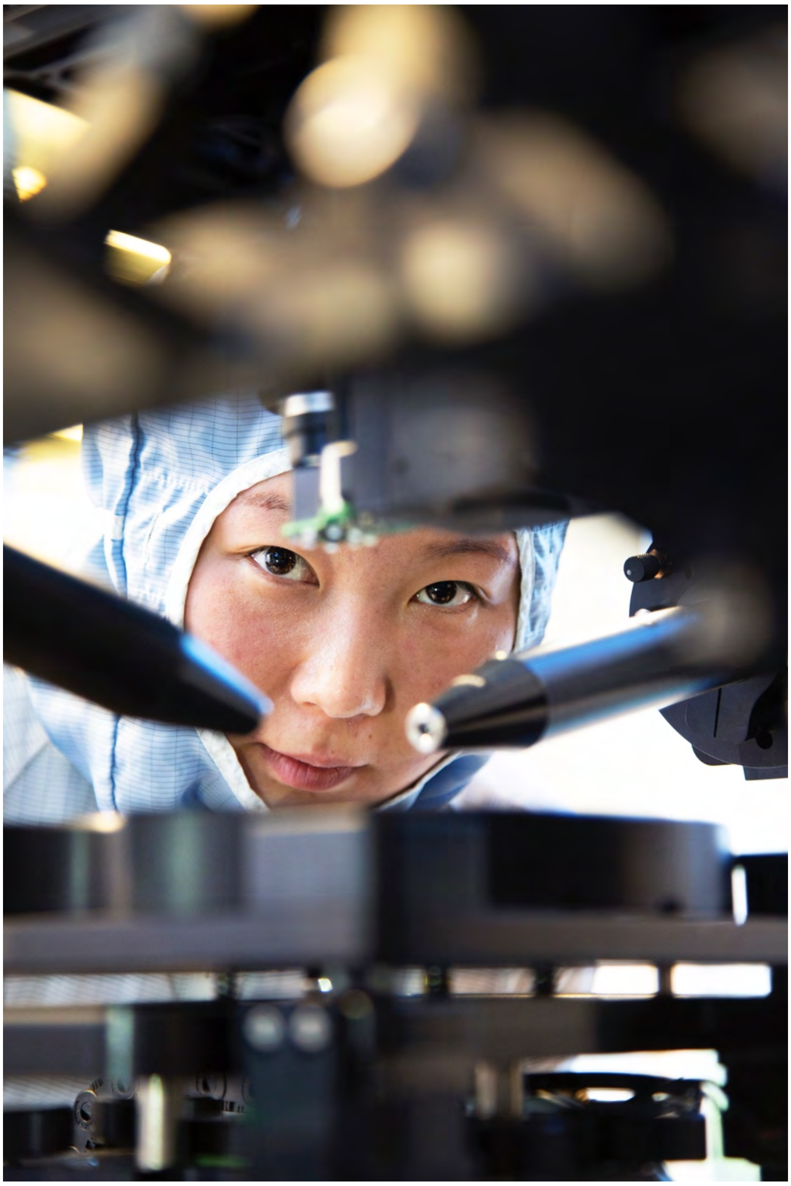


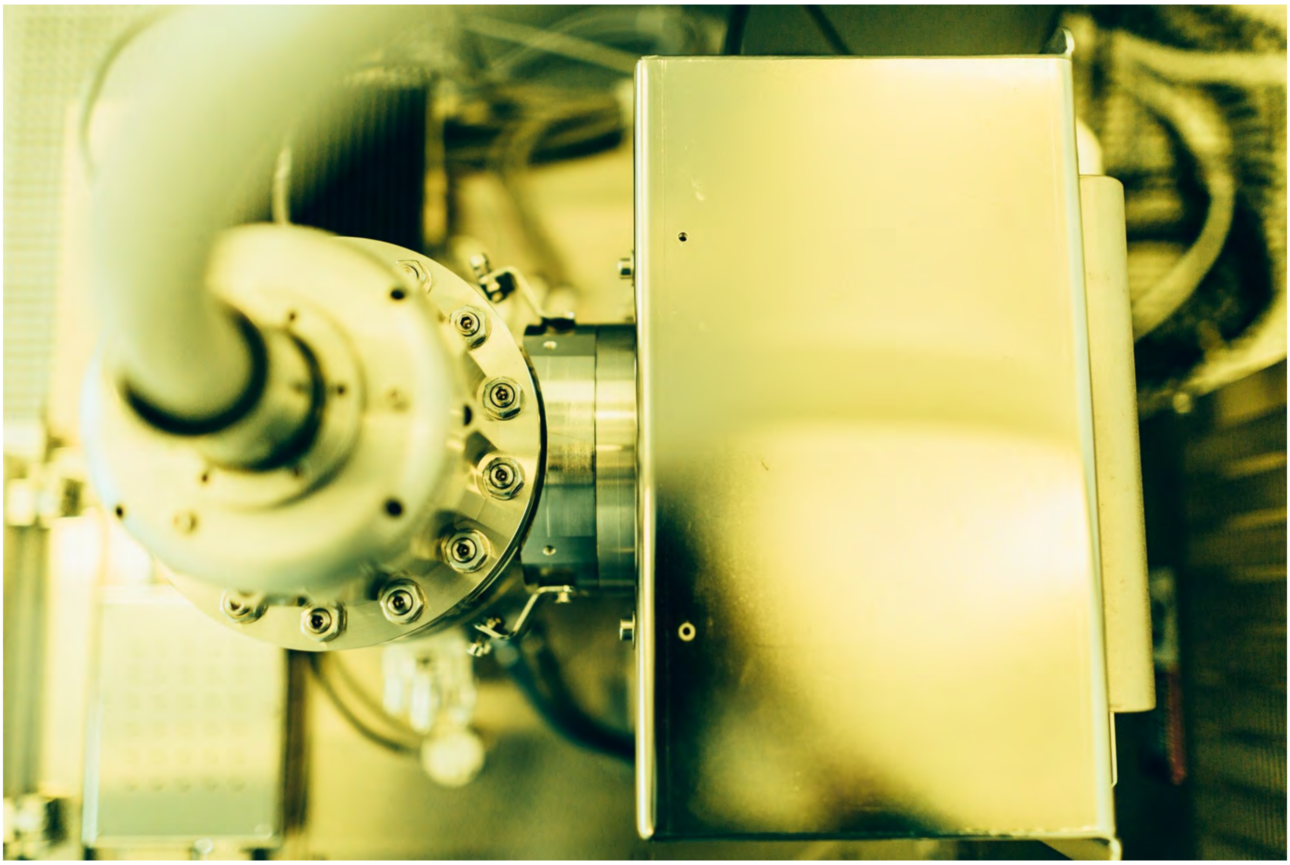
Myfab Report 2020

Myfab - The Swedish Research Infrastructure for Micro and Nano Fabrication
www.myfab.se

INTRODUCTION

Myfab, founded in 2004, is a national facility since 2010 and is Sweden's open-access research infrastructure (RI) for micro and nano fabrication with four cleanroom laboratories: Myfab Chalmers, Myfab KTH, Myfab Lund and Myfab Uppsala.

Myfab is the best possible environment for the development and fabrication of materials and device structures for advanced research in physics, materials science, nanoscience, chemistry, life sciences and nanoelectronics in Sweden. From the Myfab environment 737 publications and 45 doctorial theses were produced during 2020, and during the five-year period 2016 – 2020, 3696 peer-reviewed publications and 272 PhD students have emerged, which demonstrate Myfab's capability for the development and fabrication of materials and device structures for advanced research in Sweden. Myfab is the place where synthesis – or creation – of new materials, structures, devices and miniaturized systems on the nanoscale are made. Research at Myfab is multi- and cross-disciplinary, and the birthplace of ideas and the playground for their realization. Myfab is the starting point for value chains, where devices are integrated as key enabling components in a system.



Myfab brings together Sweden's leading nanofabrication labs under a common umbrella, creating a national resource that makes a permanent staff member of 73 people (57 full-time equivalents), a total of 5400 m^2 of clean room area, more than 700 tools and processes openly available to researchers around Sweden and internationally, with the aim of ensuring Sweden's competitiveness in important research areas. In 2020 the national infrastructure had 784 unique users.

We offer user-fee based user access with practically no waiting time to experienced and new users, from academic institutions and industry. Myfab's clean-room staff and expertise serve the users by developing and maintaining processes and tools, and by providing educational courses, process advice and support.

Further, Myfab is part of the Nordic Nanolab Network, where management, experts and users collaborate extensively in improving operations, process development, tool maintenance, user services, problem solving and by arranging common user meetings.

Myfab's distributed research infrastructure (RI) offers both the flexibility needed to advance state-of-the-art science and technology, as well as a quality assured environment for small and medium size manufacturing for spin-off companies and Small and Medium Sized Enterprises (SMEs). Today more than 100 organisations use Myfab, 85 of them are companies. During a 5-year period, typically 20 – 30 start-ups emerge from the environment.

Myfab has set the standard in Europe for efficient user access, follow-up and planning through our operations practices supported by the tailor-made Myfab LIMS system. Myfab LIMS itself, is continuously developed through a community formed by Myfab and six other national RI's in Finland, Norway, Ireland, France, Portugal and Latvia.

Being Sweden's national research infrastructure for micro and nanofabrication, Myfab attracts a vast majority of Sweden's micro- and nanotechnology researchers and entrepreneurs within a wide range of fields. Myfab LIMS was introduced at all Myfab laboratories in 2008, and over the twelve years since it has assisted users to access to the whole infrastructure and provided important information to management for both operations and strategic development of the infrastructure.

From its statistics, we learn that in 2020, 646 (86 %) users come from academia and 138 (14 %) were commercial users from either industry or research institutes. The total number of booked tool-hours was 165 304. New and potentially returning users, with no previous experience from Myfab, are invited to apply for funding for their first project through Myfab Access.

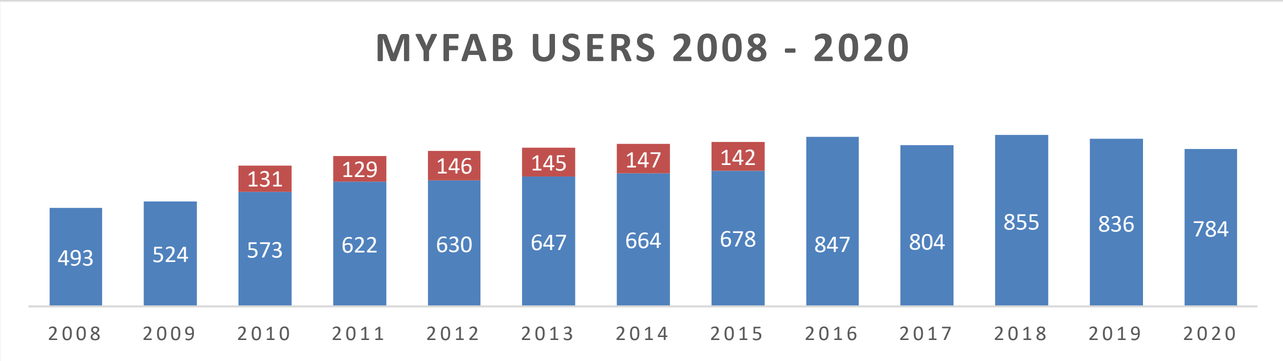


Figure 1: Myfab statistics – from Myfab LIMS 2008 - 2020. Myfab Lund started using Myfab LIMS in 2010; their corresponding number of active users is presented in orange on top of the blue bars for 2010 – 2015. The number of booked hours ranges from 165 000 – 200 000 per year during the last decade.

Figure 1 shows the number of active users for the years 2008-2020. The reduced headcount for 2020 is attributed to the Covid-19 pandemic and associated restrictions. During 2020, about 86 per cent of the users were from academia and cover a broad range of scientific areas, several are international users from various universities. About 14 per cent of our users are non-academic users, from industry or institutes, who use our infrastructure for production, product development, or for carrying out research projects. Myfab offers, especially important to small and medium sized companies, a unique possibility for access to micro- and nanotechnology tools and expertise. Myfab has often been the launching point for a number of spin-off companies emanating from the research environments using the infrastructure. These spin-offs create an immense societal impact, and we estimate that their total turnover is well beyond one billion SEK per year. Interestingly, the commercial usage of Myfab showed an increase by 13.6% during 2020 as compared to 2019.

COVID-19 PANDEMIC EFFECTS AND ACTIONS

The Covid-19 pandemic has forced Myfab to introduce new routines to minimize the spread of the virus. Myfab's cleanroom laboratories have followed all rules and recommendations given by the Public Health Agency of Sweden as well as the rules set up by the host universities. Generally, during most of 2020 the universities have recommended that as much as possible work should be carried out from home, but at the same time, necessary laboratory work has been allowed. The presence of Myfab's staff at the laboratories has been reduced, and new routines to secure distancing between uses have been implemented. We interpret that the 11.6% reduction in total lab usage in 2020 compared to earlier years as a direct effect of the pandemic, the recommendations to work from home and defering non-critical work. Interestingly, the commercial usage has actually increased during (+13.6%) last year, but the academic usage has dropped by 14.8%.

NEW PERIOD OF OPERATION 2020 - 2024

Myfab's fifth period of operation started on 1 January 2020 and is promoted by a new model for governing national research infrastructures. Common for all national research infrastructures in Sweden since 2020 is that they have a governing board, the General Assembly (GA or Stämman in Swedish), which is in charge of general conditions including the consortium agreements and commitments of the participating universities. Myfab's GA thus consists of four members, one each from Chalmers (host), KTH, Lund University and Uppsala University respectively. During five meetings in January – March 2020, the General Assembly worked out details in the Consortium Agreement and agreed to the Main Contract between the host university (Chalmers) and the Swedish Research Council (SRC).

The steering group, with members recommended by the General Assembly was appointed by Chalmers University of Technology (Chalmers) and was in operation in June. The Steering group currently consists of seven members. Four of them are representatives proposed by the participating universities, one is an industrial representative, one international representative and finally one from another Swedish university. The steering group is in charge of Myfab's activities during the current period of operation, which ends on 31 December 2024. The steering group normally has four physical meetings each year, where the director also participates. The steering group decides on the use of the SRC funding and takes strategic decisions on Myfab's activities. Through this process we make sure that operations and strategic development are aligned and support the need of our users in the best possible way.

The director is in charge of operations and to implement the decisions by the steering group. The operational management consists of the director and the four laboratory managers and is in charge of day-to-day operation and collaboration with the steering group and the owner group. The over-all structure of Myfab's management gives a balance between the bodies involved.

Myfab LIMS

We have as usual continued to develop our laboratory management system. During the second half of 2020 with a slight increase in the effort to speed up our development. The process manager module has been evaluated by a few users and is now prepared for a more extensive testing by more nodes. We have also developed an alpha version of a module for registration of spare parts and vacuum pumps. Otherwise, we have continued with around a dozen minor improvements and roughly the same amount of bug fixes.

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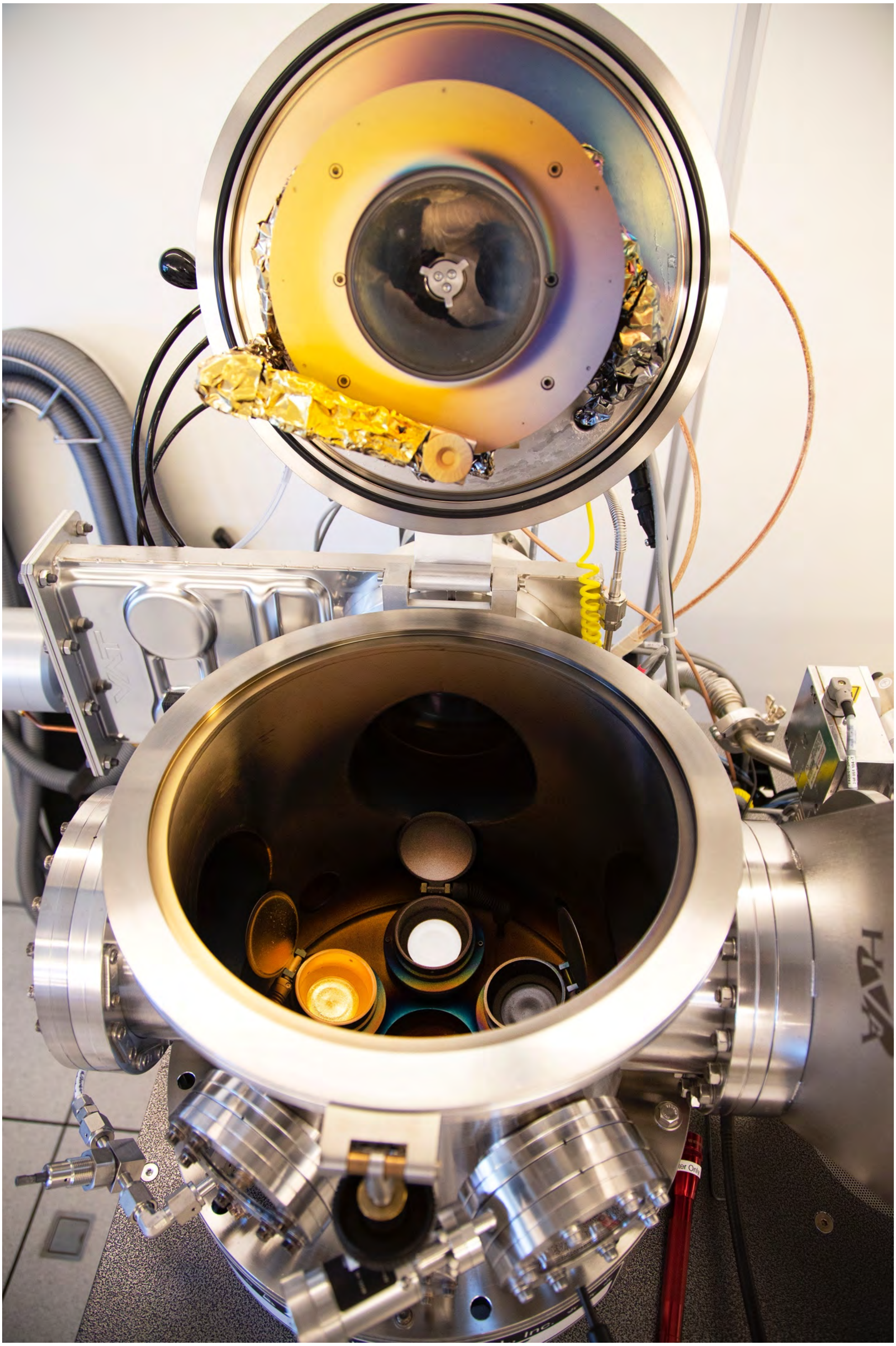


The Nordic Nanolab Network

Myfab is part of the Nordic Nanolab Network (NNN) which encompass active collaboration by the management, experts and users of the national nanofabrication research infrastructures in the Nordic countries. NNN is most important for the development of all twelve laboratories involved and is the leading regional network in Europe.

During 2020, NNN only managed to conduct one management meeting in Oslo in January, before the Covid-19 implied travel restrictions were introduced. Several electronic meetings have been carried out and means to mitigate the effect of travel and find new means for collaboration have been discussed. The Nordic Nanolab Network management team decided during autumn 2020 to re-schedule the third Nordic Nanolab User Meeting (NNUM), originally scheduled for 10 – 11 May 2021 in Gothenburg to 6 – 7 May 2022. As a new way to interact with the Nordic user community NNN decided to arrange a topical webinar during 10 – 11 May 2021.

The Nordic Nanolab Expert Network (NNEN) consists of expert groups with members from the Nordic countries and organized in five topical areas: dry etching, thin films, lithography, characterization (in cleanrooms) and facility management. Each NNEN technology group has about 20 active members and meets normally twice per year with lunch-to-lunch meetings. During 2020 most interactions within the NNEN have been carried out through electronic meetings and through the Basecamp platform. The NNEN activities are a very efficient way of promoting staff competence and knowledge transfer / development in the most relevant areas for the research infrastructure as a whole and its users.

EuroNanoLab

Myfab is part of EuroNanoLab and was one of the co-founders during spring 2016. Today the EuroNanoLab consortium consists of the national research infrastructures of fourteen countries and one international organisation, with a total of 44 cleanroom laboratories. Most important during 2020 was EuroNanoLab's submission of a design study to the ESFRI road-map update. Other important activities were joint programming with the quantum technology community (QT Flagship), star and initial operation of international technology expert groups (dry etching & lithography), long-term work on standardization of FAIR Nanofabrication process descriptions . Furthermore, EuroNanoLab is in charge of the European Nanofabrication Research Infrastructure Symposium (ENRIS), arranged every second year.

NODE ACTIVITIES

Myfab Chalmers

Myfab Chalmers experienced a significant drop in academic usage of -19% during 2020 due to the COVID pandemic, while the commercial activities increased with 2%. We have had the lab open 24/7 as usual but with a somewhat lower service level during some time periods due to pandemic restrictions.

We have commissioned two new tools during the year. An automated optical microscope with an extremely high-performing camera, autofocus and programmable motorized xyz-stage. The software support automatic image capture, stitching, and analysis. We have also commissioned a simple maskless lithography unit (Microlight 3D SmartPrint). This is a digital projector that can expose pixel image. This is for example used for pattern needed for process development where you not always need the resolution of the high-end direct write lithography tools.

During the year we have also updated the investment plan, now to include almost 30 tools and a total investment cost of approximately 150 MSEK during the time period 2020-2024. In addition, we have identified a number of investments needed in the now 20 year old infrastructure which sums up to around 10 MSEK.

We have for the first time done a more thorough investigation on the project volume using Myfab Chalmers every year. In 2020 we had 44 academic PIs within total more than 79 external contracts/projects using the facility. The annual budget for these projects is around 255 MSEK, corresponding to 13% of the external grants volume at Chalmers.

Myfab KTH

Myfab KTH consists of two cleanroom facilities. The Electrum Lab in Kista is operated in collaboration with the industrial research institute RISE, and the Albanova Nano Lab in collaboration with Stockholm University. Both laboratories are recognized as "KTH Infrastructures".

The Albanova Nano Lab has started significant upgrades of the facility, procuring new equipment. A Heidelberg MLA150 litho-system is scheduled for installation in April 2021 and an Oxford Instruments PlamaLab Pro 100 Cobra etcher is to be delivered in the fall of 2021. We have also identified a major development area toward QT-metrology. A platform with the base of type Quantum-Design PPMS, equipped with electrical (incl. rf/microwave), optical (incl. spectroscopy), magnetic, thermal, and mechanical options, designed for variable temperatures will offer quick-turnaround test and characterization, thereby significantly shortening our fabrication loops and process iteration times for the many QT-related research projects, such as q-materials/sensors/communications/computing devices, used primarily at low-T.

Two older tools (a dry etcher and a sputter) have also been transferred to Albanova from Electrum in connection with the move of some of the academic user groups from Kista to Albano. Simultaneously, many of the commercial users at Electrum are expanding their activities and inquire for increased lab space, both in the cleanroom and in non-cleanroom labs.

A new process at Electrum is Micro Transfer Printing, supported by a KTH infrastructure grant. For the lab operations, the aging ventilation system - with many components remaining from the first installation in 1987 - has been partly restored.

Electrum Lab is covered by the Swedish regulations on potentially dangerous operation. In accordance with the Act on Protection Against Accidents, an in-depth risk analysis with regard to the handling of potentially hazardous gases has been undertaken.

A major revision of the ISO9001:2015 certified quality management system, with respect to the administrative processes, for increased efficiency and improved control has also been made. This will facilitate the follow-up carried out in the annual audits.

Myfab Lund

During 2020, Myfab Lund was used by 136 active users from Engineering, Natural Science and Medical Faculties of Lund University, as well as from other universities and seven commercial companies. In total there were 119 active academic users, 2 from an institute (RISE), and 15 users from 7 different companies. There were 30 new users in 2020 who attended the introductory training that is needed for access.

In 2020, extra ordinary efforts made to ensure the lab remained open 24/7 throughout the Covid-19 pandemic for all users to be able to conduct their important research and educational programs. This is only possible by support from highly educated lab personnel, which includes 15 persons, 4 of which have a PhD-degree. The lab staff provides cleanroom and safety education for all new lab users, are responsible for the equipment "hands-on" training, give qualified advice regarding processing and characterization and maintain and operate the cleanroom facility.

Despite the lab being open and available, the number of booked hours in 2020 reduced by 20% to 43 864, compared to 51 254 in 2019. It is likely that users have been deferring, delaying or cancelling their lab work over this period due to the pandemic. There were in addition many workflows disrupted during early 2020 when the Voyager Electron Beam Lithography tool, a key instrument in many workflows, was inoperable for almost half a year due travel restriction affecting the service engineer's ability to travel to Sweden from Germany.

In the time that staff have not been able to be on site during 2020, their time was focused on developing a web-based information system for Myfab Lund using the 'Confluence' platform. The time invested will enable users to access important information that is relevant to equipment and processes in the lab, e-learning material, access FAQ, user forums and other functionality aimed at improving the user experience and access to information.

The planning and preparations for the new Nanolab at Science Village has been a major and important task during 2019-2020. The current lab was designed originally for 40-50 users, but Myfab Lund reached its capacity limit already since several years ago, with the user base tripling since 2007. In 2020, the Dean of LTH initiated a market survey, followed by a procurement for a new Nano Lab at Science Village, Brunnshög.

The planning for the new clean-room takes a lot of effort and requires time, including systematic work to specify parameters and layout of the new Myfab Lund. Preparing our staff and all the current and new equipment to be able to handle the increased demands in competence and available time is critical and will significantly impact the work of our users. It will also enable high-impact research and publications from researchers at different faculties, as well as many outside users both within the local area, Sweden and beyond.

Myfab Uppsala

The Covid-19 pandemic certainly made 2020 a very special year, with restrictions and recommendations limiting the lab activities. Nevertheless, the number of active users reached 96 % of the corresponding value for 2019 and tool usage only dropped with 8 %. On the other hand, we only received 59 new users, which was 27 % less than the year before. Most academic users are affiliated with some of the departments of Materials Science, Electrical Engineering, Physics or Chemistry. The lab remained open, with special procedures for e.g., gowning and tool training.

Due to some technical issues, but more importantly the pandemic travel restrictions, the new FIB (delivered late 2019) did not pass acceptance testing until fall 2020. We started procurement of a 3D printer cluster, which is the first investment made possible by the new

SRC grant. In this case the Covid-19 situation prevented a proper market survey and delayed the procedure.

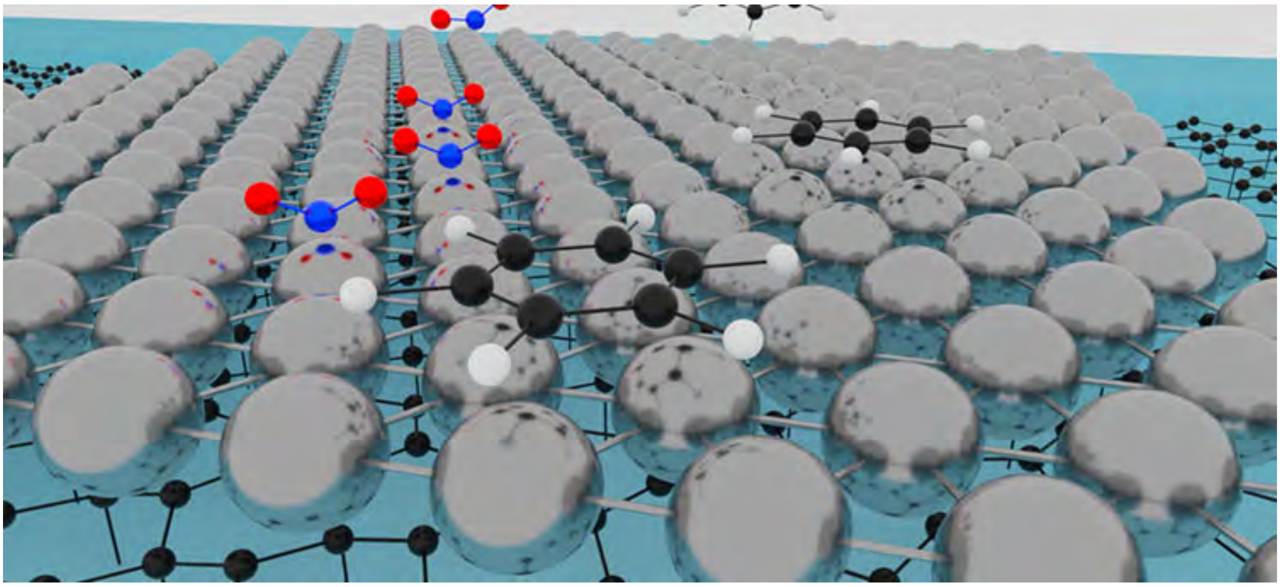
Investment planning has been a continuous development area during the last few years. Expert groups are now being established to cover specific technology areas and propose strategic priorities in their respective field.

The service track of the SciLifeLab pilot facility Customized Microfluidics has now become an integrated part of the Myfab Uppsala operation. A new staff member was hired for this purpose and efforts will be made to expand the process service activities beyond life science and microfluidics.

SELECTED USER SUCCESS STORIES

One atom thin platinum makes a great chemical sensor

Researchers at Chalmers University of Technology in Sweden, with collaborators, have reported the possibility to prepare one-atom thin platinum and use it as chemical sensors. The results were recently published in the scientific journal Advanced Material Interfaces. "In a nutshell, we managed to make a one-atom thin metal layer, a sort of a new material. We found that this atomically-thin metal is super sensitive to its chemical environment: its electrical resistance changes significantly when it interacts with gases", explains Kyung Ho Kim (to the right), postdoc at the Quantum Device Physics Laboratory at the Department of Microtechnology and Nanoscience – MC2, and lead author of the article.

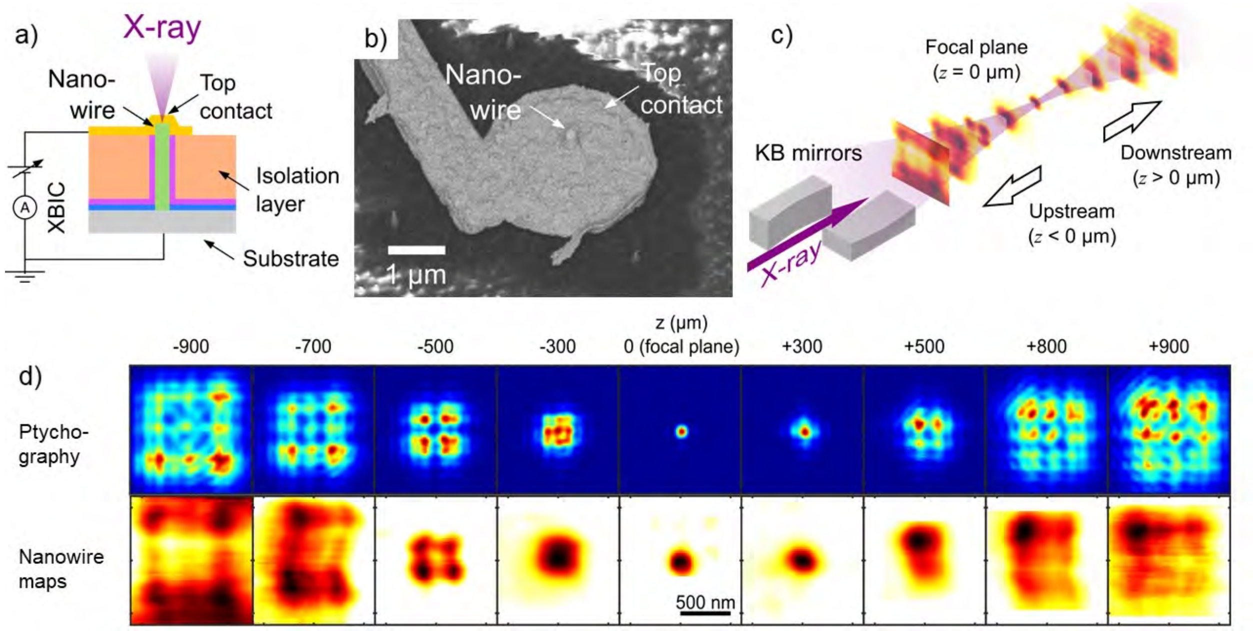


The researchers used the sensitive chemical-to-electrical transduction capability of atomically thin platinum to detect part-per-billion contents of toxic gases. They demonstrate this for detection of benzene, a compound that is cancerogenic to very small concentrations in ambient, and for which no low-cost detection apparatus exists. "This new material approach, atomically thin metals, is very promising for future air-quality monitoring applications", says Jens Eriksson, Head of the Applied sensor science unit at Linköping University and co-author of the paper.

Reference: *Kim KH, He H, Rodner M, Yakimova R, Larsson K, Piantek M, et al. Chemical Sensing with Atomically Thin Platinum Templated by a 2D Insulator. Advanced Materials Interfaces. 2020;7(12).*

3D imaging of the X-ray focus at NanoMAX using a single 60 nm diameter nanowire device

Nanoscale X-ray detectors could allow higher resolution in imaging and diffraction experiments than available systems. We have demonstrated X-ray detection in a single nanowire, in which the nanowire axis is parallel to the optical axis and the resolution is defined by the 60 nm diameter. After growth using MOCVD, the as-grown p-i-n doped InP nanowires were processed into devices at the Myfab Lund using atomic layer deposition, reactive ion etching and both UV and electron beam lithography. The devices were used to make a high-resolution 3D image of the 88 nm diameter X-ray nanofocus at the NanoMAX beamline, MAX IV, by scanning the single pixel device in different planes along the optical axis. The images reveal fine details of the beam that are unattainable with established detectors.

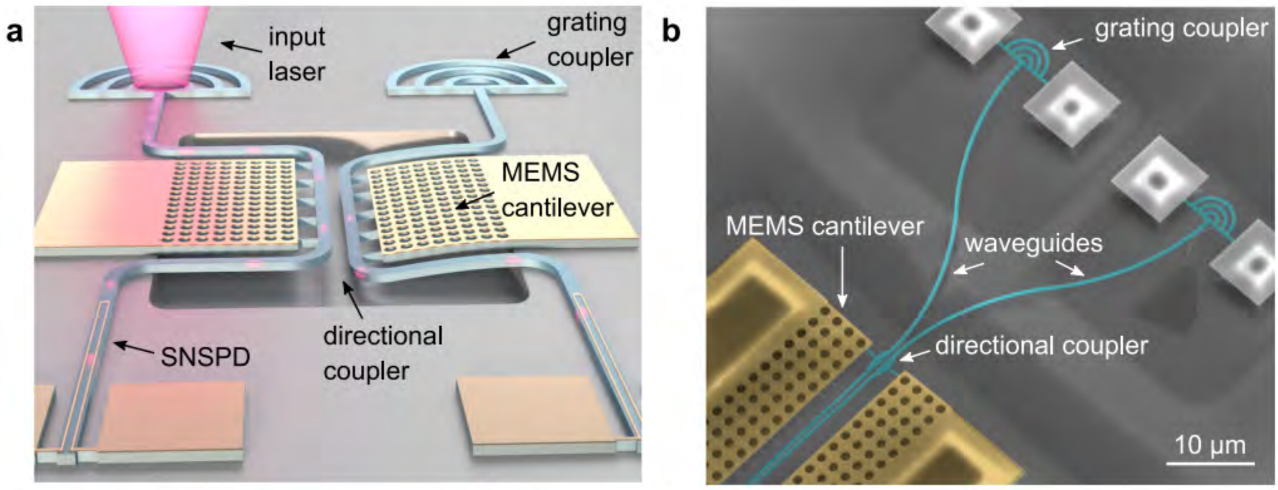


Single nanowire device for X-ray detection. a) Schematic of the vertical nanowire device, b) SEM, c) Schematic of the experiment, where the nanowire device was 2D scanned at different planes around the X-ray nanofocus at the NanoMAX beamline, MAX IV. d) 3D imaging results. The top row (jet colour scale) shows the calculated intensities from ptychography. The bottom row (hot colour scale) shows the X-ray beam induced current in the nanowire.

Reference: *L. Chayanun, L. Hrachowina, A. Björling, M. T. Borgström, and J. Wallentin, "Direct Three-Dimensional Imaging of an X-ray Nanofocus Using a Single 60 nm Diameter Nanowire Device" Nano Letters 20 (11), 8326 (2020).* http://dx.doi.org/10.1021/acs.nanolett.0c03477

Nanoscale quantum devices

The research group of Val Zwiller develops devices to generate, manipulate and detect single photons. Hence, advanced quantum circuits, where quantum dots, waveguides, filters and detectors are combined to form complex systems to explore new schemes in quantum sensing, communication and computing. The aim is to demonstrate new quantum sensing techniques and explore all facets from fundamental to technological implementations including applications to life and environmental sciences. The group explores hybrid and scalable approaches, where single III–V quantum emitters are positioned and integrated in a metal–oxide– semiconductor-compatible photonic circuit. They have demonstrated on-chip single-photon filtering and wavelength division multiplexing with a footprint one million times smaller than similar table-top approaches, marking an important step to harvest quantum optical technologies' full potential [Ref.]. The quantum detectors are made using advanced nanofabrication tools available at Myfab KTH and offer excellent single photon detection over an unprecedented spectral range. Currently the possibility of starting a company to make the quantum sensing instruments widely available is investigated.



Reconfigurable photonics with on-chip single-photon detectors. a) Artist view of the demonstrated device, composed of grating couplers for light input and a MEMS reconfigurable beam splitter connected to two superconducting single-photon detectors. b) False-coloured SEM of the input section of the device, showing the waveguides and grating couplers, and the MEMS actuator and electrodes.

Reference: *Samuel Gyger, Julien Zichi, Lucas Schweickert, Ali W. Elshaari, Stephan Steinhauer, Saimon F. Covre da Silva, Armando Rastelli, Val Zwiller, Klaus D. Jöns & Carlos Errando-Herranz, "Reconfigurable photonics with on-chip single-photon detectors". Nature Communications, volume 12, (2021) Article number: 1408.* https://doi.org/10.1038/s41467-021-21624-3

Tiny quantum computer solves real optimisation problem

Quantum computers have already managed to surpass ordinary computers in solving certain tasks – unfortunately, totally useless ones. The next milestone is to get them to do useful things. Researchers at Chalmers University of Technology, Sweden, have now shown that they can solve a small part of a real logistics problem with their small, but well-functioning quantum computer.

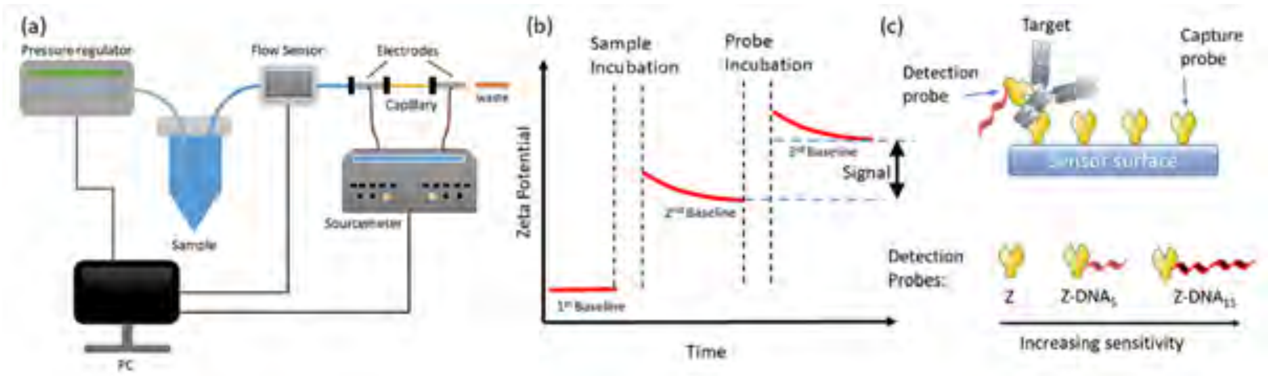
All airlines are faced with scheduling problems. For example, assigning individual aircraft to different routes represents an optimisation problem, one that grows very rapidly in size and complexity as the number of routes and aircraft increases. Researchers hope that quantum computers will eventually be better at handling such problems than today's computers. The basic building block of the quantum computer – the qubit – is based on completely different principles than the building blocks of today's computers, allowing them to handle enormous amounts of information with relatively few qubits.

However, due to their different structure and function, quantum computers must be programmed in other ways than conventional computers. One proposed algorithm that is believed to be useful on early quantum computers is the so-called Quantum Approximate Optimization Algorithm (QAOA).The Chalmers research team has now successfully executed said algorithm on their quantum computer – a processor with two qubits – and they showed that it can successfully solve the problem of assigning aircraft to routes. In this first demonstration, the result could be easily verified as the scale was very small – it involved only two airplanes.

Reference: *Bengtsson A, Vikstål P, Warren C, Svensson M, Gu X, Frisk Kockum A, et al. Improved Success Probability with Greater Circuit Depth for the Quantum Approximate Optimization Algorithm. Physical Review Applied. 2020;14(3).*

Using nanotechnology for monitoring cancer

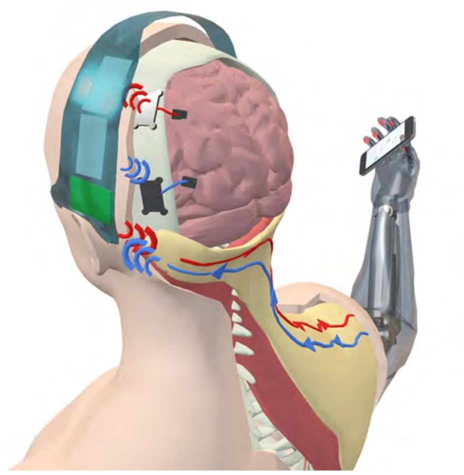
Despite major progress in tumour detection and in targeted therapy approaches, cancer continues to be a major cause of death. This is largely due to the metastatic spread, often occurring already at the time of the initial diagnosis, resulting in a poor prognosis for the patient as illustrated in lung- and pancreatic cancer. Reliable and sensitive methods to analyse cancer markers in an easily accessible patient sample, e.g., a blood sample, are highly needed. Given that the methods would be inexpensive and fast they could also serve to monitor therapy on a frequent basis during tumour progression. The "liquid biopsy concept", i.e., a direct measure of tumour in blood/plasma has therefore attracted a large interest as a way for non-invasive diagnostics but also for treatment monitoring. During the last few years, methods to detect and monitor cancer have therefore shifted to blood-borne entities such as circulating DNA and small Extracellular Vesicles (EVs) or exosomes. In particular exosomes, being 30 – 150 nm in size, are released both by ordinary and cancer cells in large numbers and are used for communication and transporting cargo between cells. They carry surface proteins that uniquely identify them with their parent cells. Thus, by detecting and monitoring exosomes with a specific protein surface expression, one may monitor cancer progression and the response of the tumour to targeted therapies. At the KTH Department of Applied Physics, the group of Prof Linnros and Dr Apurba Dev has developed an electrical sensor technology using capillaries, functionalized with antibodies for specific proteins, to detect exosomes related to cancer tumours. The sensing is multiplexed to analyse a palette of different proteins to accurately attribute the origin of the exosomes to a specific cancer form.



Schematic representation of (a) the experimental setup and (b) the sequence of a multistep measurement, starting with the recording of the 1st baseline, followed by the injection of the target until an equilibrium is reached. Thereafter, the 2nd baseline is recorded for a fixed duration. After the injection of the detection probe, the recording of the 3rd baseline follows. The signal is the difference indicated by the double-arrow. Panel (c) shows (top) a schematic, depicting the target, along with the capture and detection probes (not drawn to scale) and (bottom) the detection probe and its charge modification with the conjugation of DNA oligonucleotide of different lengths.

Reference: *SS Sahu, C Stiller, EP Gomero, Á Nagy, AE Karlström, J Linnros, A Dev, Electrokinetic sandwich assay and DNA mediated charge amplification for enhanced sensitivity and specificity, Biosensors and Bioelectronics 176, 112917 (2021). https://doi.org/10.1016/j.bios.2020.112917*

Neuromorphic Tactile Systems

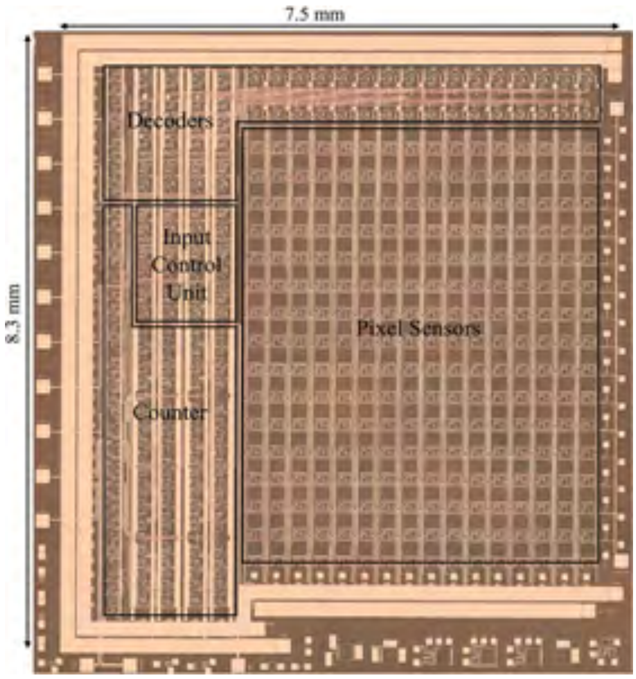


Tactile peripheral nervous system is essential to human's haptic exploration and dexterous object manipulation. Inspired by the working and organization principles that the tactile peripheral nervous system uses, a research team at Uppsala University has demonstrated a neuromorphic tactile system that features self-powered tactile sensing process, ultrasensitive response to mechanical stimulation, adaptive behaviour that emulates slowly adaptive type I receptors, and enhanced spatial resolution of tactile imaging. By combining the artificial skin, and wireless communication through fat, Robin Augustine (PI) and Zhi-Bin Zhang (Co-PI), together with their EU partners, have been granted a FET Open project to develop a comprehensive neuromorphic system for prosthetic applications.

Reference: *Chen L., Wen C., Zhang S-L., Wang Z-L., Zhang Z-B., Artificial Tactile Nervous System Supported by Self-Powered Transducers, Nano Energy 82, 105680, (2021).*

UV sensitive image sensor for high temperature operation

An image sensor based on wide band gap silicon carbide (SiC) has the merits of high temperature operation and ultraviolet (UV) detection. To realize a SiC-based image sensor the challenge of opto-electronic on-chip integration of SiC photodetectors and digital electronic circuits must be addressed. Prof. Carl-Mikael Zertterling and his group at KTH have demonstrated a novel SiC image sensor based on an in-house bipolar technology. The sensing part has 256 (16×16) pixels. The digital circuit part for row and column selection contains two 4-to-16 decoders and one 8-bit counter. The digital circuits are designed in transistor-transistor logic (TTL). The entire circuit has 1959 transistors. It is the first demonstration of SiC opto-electronic on-chip integration. The function of the image sensor up to 400 °C has been verified by taking photos of the spatial patterns masked from UV light. The image sensor would play a significant role in UV photography, which has important applications in astronomy, clinics, combustion detection and art.

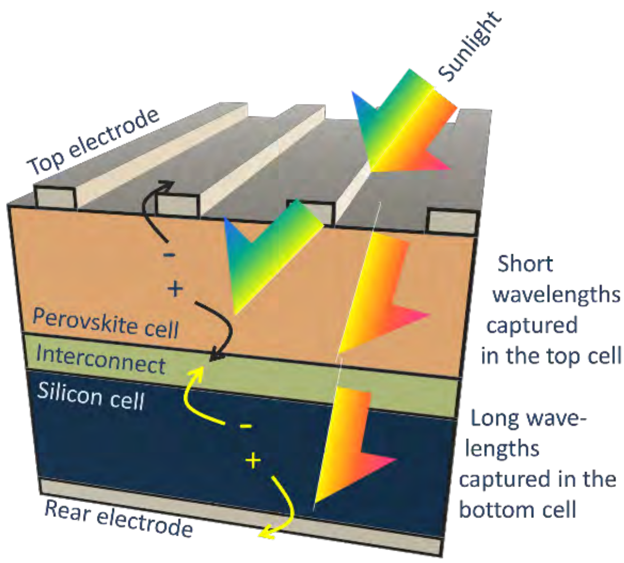


Microscope image of the entire image sensor circuit. It has a total area of 62.3 mm^2. The four main building blocks are 4-to-16 decoder, 8-bit counter, input control unit (2×4 tri-state buffer array) and 16×16-pixel sensors.

Reference: *Hou, S., Shakir, M., Hellström, P.-E., Malm, B.G., Zetterling, C.-M., and Östling, M., A Silicon Carbide 256 Pixel UV Image Sensor Array Operating at 400 °C, IEEE Journal of the Electron Devices Society, vol. 8, p. 116, 2020.* https://doi.org/10.1109/JEDS.2020.2966680

Photovoltaics

Several material systems and solar cell architectures are studied in the new division for Solar Cell Technology at Uppsala University. The full solar cell comprises several thin film materials in a range from nanometre to micrometre, all fabricated in the Myfab cleanroom.



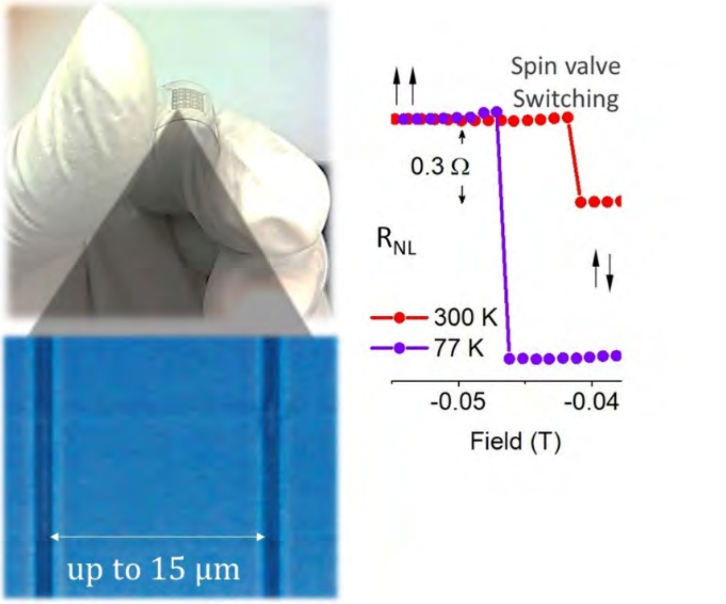
The working principle of a tandem junction solar cell. In this example perovskite and silicon are used for high-bandgap and low bandgap partners, but also kesterites and high bandgap chalcopyrites can be used as topcells and low bandgap chalcopyrites can be used as bottom cells.

Among the materials used to absorb sunlight are the chalcopyrite system, I-III-VI2, e.g. (Ag,Cu)(In,Ga)Se2 and the kesterites I2-II-IV-IV4, e.g., Cu2ZnSnS4, but also inorganic chalcogenide perovskites based on BaZrS3. Buffer layers forming the junction as well as passivation layers and contact layers are other essential components. The electro-optical properties are improved with feedback from materials characterization and opto-electronic characterization available at Myfab, as well as data from large facilities like Max IV, where Natalia Martin got an SRC starting grant 2020. A large EU-funded project on novel architectures for ultrathin solar absorbers (ARCIGS:M), coordinated by the division, was recently finished, and the work continues in a SRC-Energy funded project during 2021-2025. Tandem solar cells are considered to be the next leap-frog technology to bring the efficiency of state-of-the-art solar cells to new record levels. The division recently got funding from the Energy Agency to continue the work on high bandgap materials for use as top cells in tandem solar cells. So far, these efforts have resulted in several break-through results.

Reference*: Keller J., Sopiha K.V., Stolt O., Stolt L., Persson C., Scragg J.J.S., Törndahl T., Edoff M.,* Wide-Gap (Ag,Cu)(In,Ga)Se2 Solar Cells with Different Buffer Materials – a Path to a Better Heterojunction, *Progress in Photovoltaics, DOI:10.1002/pip.3232, (2020).*

Quantum Material Spin Components

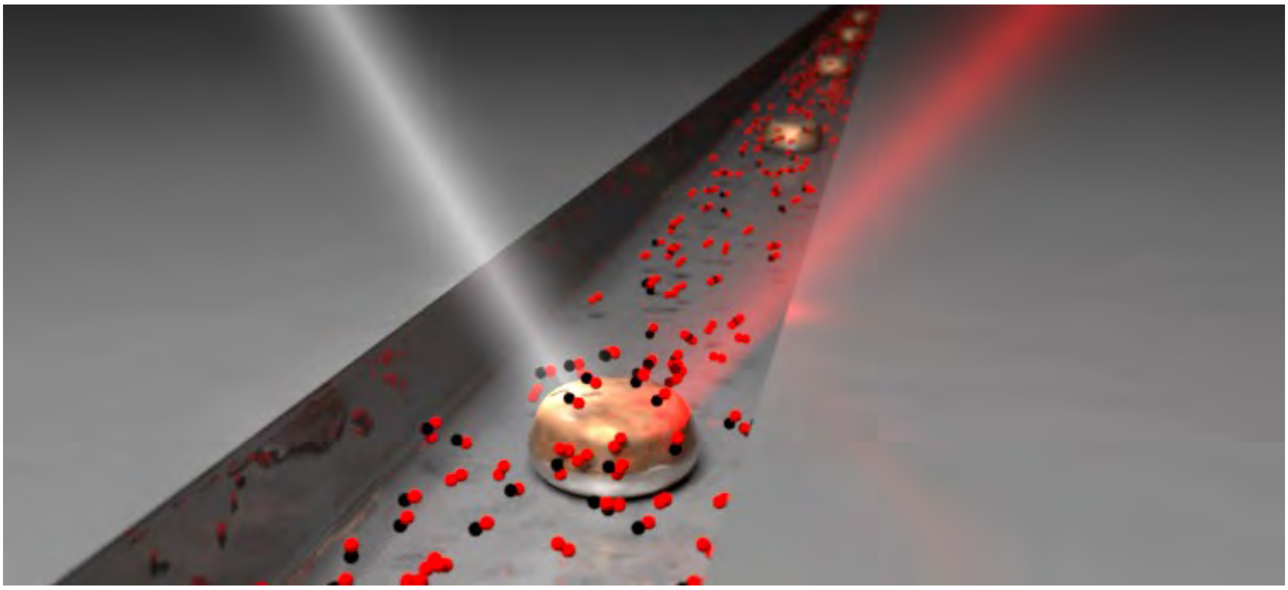
Venkata Kamalakar Mutta received ERC consolidator Grant 2020 for spin engineering in flexible and functional two-dimensional quantum material devices. His team focuses on exploring the capabilities of cutting-edge 2d materials systems, for example unique spinterfaces and flexible 2D heterostructures. They were the first to realize two-dimensional flexible spin circuits, which opened up a new avenue of flexible 2D spintronics with possibilities for developing strained 2D spintronics. In 2020, the team achieved the highest spintronic performance of ultimate spin currents in the 2D material graphene. They showed conclusive evidence of specific sources of spin current relaxation in the material, providing a fresh understanding of the phenomena. Magnetism is a quantum phenomenon that can be observed at room temperature. The very recent advent of magnetic order in atomically thin magnets or 2D magnets provides exciting new opportunities to address electric field-induced switching challenges, manipulating spin order and spin waves. Simultaneously, the unique relativistic-quantum effects of low dimensional materials, like graphene, provide new opportunities for transporting individual electron magnetic moments or spin currents. The 2D quantum magnets and the record capabilities in spin current communication and tuning interatomic distances will enable new spin components and spin-integrated circuits with implications for low-power computing and novel hardware for advancing artificial intelligence.



Reference: *Panda J., Ramu M., Karis O., Sarkar T., Venkata Kamalakar M.,* Ultimate Spin Currents in Commercial Chemical Vapor Deposited Graphene, *ACS Nano 14 (10), 12771–12780, (2020).*

The importance of good neighbours in catalysis

Are you affected by your neighbours? So are nanoparticles in catalysts. New research from Chalmers, published in the journals Science Advances and Nature Communications, reveals how the nearest neighbours determine how well nanoparticles work in a catalyst. "The long-term goal of the research is to be able to identify 'super-particles', to contribute to more efficient catalysts in the future.

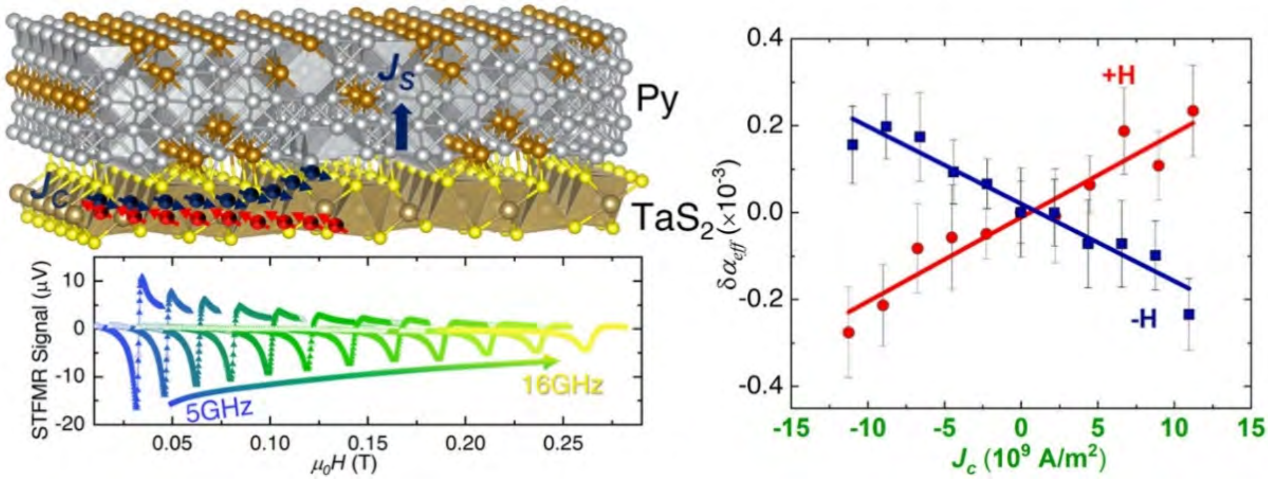


To utilise the resources better than today, we also want as many particles as possible to be actively participating in the catalytic reaction at the same time," says research leader Christoph Langhammer at the Department of Physics at Chalmers University of Technology. Inside a catalyst several particles affect how effective the reactions are. Some of the particles in the crowd are effective, while others are inactive. But the particles are often hidden within different 'pores', much like in a sponge, and are therefore difficult to study. To be able to see what is really happening inside a catalyst pore, the researchers from Chalmers University of Technology isolated a handful of copper particles in a transparent glass nanotube. When several are gathered together in the small gas-filled pipe, it becomes possible to study which particles do what, and when, in real conditions. What happens in the tube is that the particles come into contact with an inflowing gas mixture of oxygen and carbon monoxide. When these substances react with each other on the surface of the copper particles, carbon dioxide is formed. It is the same reaction that happens when exhaust gases are purified in a car's catalytic converter, except there particles of platinum, palladium and rhodium are often used to break down toxic carbon monoxide, instead of copper. But these metals are expensive and scarce, so researchers are looking for more resource-efficient alternatives.

Reference: *Albinsson D, Boje A, Nilsson S, Tiburski C, Hellman A, Ström H, et al. Copper catalysis at operando conditions - bridging the gap between single nanoparticle probing and catalyst-bed-averaging. Nature Communications. 2020;11(1).*

Spintronics Technology

The rapid growth of digitalization has made the information and communication technology (ICT) sector one of the largest energy consumers and new technologies, beyond the existing complementary metal-oxide-semiconductor based logic circuits, are required to reduce the energy footprint of the ICT sector.



Spintronics technology, using economically viable non-traditional magnetic and nonmagnetic high spin-orbit coupling (SOC) thin films for spin-logic devices, can provide energy efficient processing of data. Peter Svedlindh and collaborators at the Ångström Laboratory, Uppsala University, are exploring novel combinations of magnetic thin films and non-traditional nonmagnetic high SOC thin films, like 2D transition metal dichalcogenides, in heterostructures, with the objective to further increase the spin-orbit torque efficiency. This work has immediate relevance for the realization of energy efficient spin-logic devices.

Reference: *Husain S., Chen X., Gupta R., Kumar P., Edvinsson T., García-Sanchez F., Brucas R., Chaudhary S., Sanyal B., Svedlindh P., Kumar A., Large Damping-Like Spin-Orbit Torque in a 2D Conductive 1T-TaS2 Monolayer, Nano Letters 20, 6372-6380, (2020).*

ECONOMY

Myfab's financial report for 1 January – 31 December 2020, submitted separately and undersigned by Chalmers financial controller, has been delivered to the Swedish Research Council. The report presents how the Myfab operations grant has been distributed, in accordance with the decisions taken by Myfab's steering group. The table below present the total economy of the Myfab laboratories and sets the Myfab operation grant in perspective to each laboratory's total economy. The Myfab grant in this table represents the full-year 2020.

Income [kSEK]	Myfab Chalmers	Myfab KTH	Myfab Lund	Myfab Uppsala	Myfab all four labs
Faculty grants	29 449	17 274	22 199	8 071	**76 993**
Fees, academic	14 854	12 743	8 196	7 489	**43 282**
Fees companies incl. RISE	15 129	19 459	3 437	1 917	**39 942**
Myfab SRC grant	3 200	3 200	3 203	3 200	**12 803**
Financed depr.	5 411	939	1 113	5 588	**13 051**
Projects SSF, EU	0	4 931	0	0	**4 931**
Services	0	2 441	3 515	0	**3 515**
Income Total	**68 043**	**60 986**	**41 663**	**26 265**	135 971
Costs [kSEK]					
Personnel	14 803	15 869	11 966	7 085	**33 854**
Rent premises	16 913	10 416	9 550	8 537	**45 416**
Operation	13 692	23 279	9 125	4 878	**50 974**
Overhead	4 742	7 610	6 804	1 094	**20 250**
Financed depr.	5 411	939	1 113	5 588	**13 051**
Depreciations	3 184	3 445	6 438	2 434	**15 501**
Costs Total	**58 733**	**62 497**	**44 997**	**29 616**	133 346
Result	**9 298**	**-1 510**	**-3 334**	**-3 351**	4 454

MYFAB STANDARD REPORT 2020 – KEY NUMBERS FROM MYFAB LIMS

	Chalmers	KTH	Lund	Uppsala	2020 Myfab	2019 Myfab	2018 Myfab	2017 Myfab	2016 Myfab
Users with access	394	527	300	411	**1632**	1648	1658	1611	1592
Active users	189	201	136	258	**784**	836	855	804	847
Female active users	37	48	35	82	**202**	210	224	198	211
Gender balance, active users	20%	24%	26%	32%	**26%**	25%	26%	25%	25%
University active users	157	146	114	229	**646**	714	723	669	716
Institutes active users	2	9	5	2	**18**	14	11	11	12
Commercial active users	30	46	17	27	**120**	108	121	124	119
Companies with own personnel	10	20	9	20	**59**	51	56	56	59
Number of booked hours	58930	34219	43864	28290	**165304**	187017	191280	195615	199303
-from universities	51778	23542	39413	26684	**141418**	165979	168885	170101	170980
-from institutes	31	2374	966	60	**3432**	2233	2323	3220	3630
-from commercial users	7121	8303	3484	1545	**20454**	18804	20072	22293	24694
Number of tools	201	270	98	190	**759**	738	706	709	697
Booked tools	146	98	73	86	**403**	405	408	404	399

ANNEXES

Annex A: Myfab Key Numbers 2020
Annex B: Organisation 2020
Annex C: Myfab Accounting of Procuerments 2020
Annex D: Plan for the Myfab 5 Investment Grant
Annex E: Myfab Publications and Doctoral Theses 2020

ANNEX A - MYFAB KEY NUMBERS 2020

Key numbers as specified in Appendix 1 (Bilaga 1) to Myfab's contract (Dnr: 2019-00207)

Infrastrukturens namn: Myfab 5

Diarienummer: **2019-00207**
Respondent (namn): Thomas Swahn
Respondent (epost): thomas.swahn@chalmers.se
Respondent (telefon): 0730-744676

Avser år: 2020

Katergorier av nyckeltal

1	Anställda (enskilda individer (eller FTE))	73
2	Projekt (fakturerade)	530
3	Användare (enskilda individer)	784
4	Kvantitet av användning [timmar]	165304
5	Output	

1	Anställda vid infrastrukturen	
1.1	*Enskilda individer*	
	Totalt	73
	Ledning (labchefer ingår)	5
	Vid Myfab Chalmers	22
	Vid Myfab KTH	21
	Vid Myfab Lund	16
	Vid Myfab Uppsala	13
1.2	*FTE*	
	Totalt	57,35
	Ledning	1,8
	Vid Myfab Chalmers	17,3
	Vid Myfab KTH	15
	Vid Myfab Lund	14,8
	Vid Myfab Uppsala	9,25

		a. Alla projekt			b. Typ av hemvist för alla projekt						c. Typ av akademisk hemvist för projekt (endast akademiska hemvister)			
					Akademisk			Kommersiell	Offentlig	Övriga				
2	Projekt	Totalt	Män	Kvinnor	Totalt	Män	Kvinnor	Totalt	Totalt	Totalt	Värdorganisation	Inom konsortiet, ej värd	Annat svenskt lärosäte	Internationell
2.2	*Genomförda projekt*													
	Totalt	530			*425*			*88*	*19*	*0*		86	37	
	Vid Myfab Chalmers	149	52	5	130	40	4	16	3	0	119	0	11	0
	Vid Myfab KTH	188	170	18	142	128	14	34	12	0	115	5	22	0
	Vid Myfab Lund	83	73	10	70	60	10	13	2	0	68	0	2	0
	Vid Myfab Uppsala	110			83			25	2	0		81	2	0

		d. Alla användare			e. Typ av hemvist för alla användare						f. Typ av akademisk hemvist för användare (endast akademiska hemvister)			
					Akademisk			Kommersiell	Offentlig	Övriga				
3	Användare	Totalt	Män	Kvinnor	Totalt	Män	Kvinnor	Totalt	Totalt	Totalt	Värdorganisation	Inom konsortiet, ej värd	Annat svenskt lärosäte	Internationell
3.2	*Genomförda projekt*													
	Totalt	784	612	183	*661*			121	17		615	12	34	
	Vid Myfab Chalmers	189	152	37	158	127	31	29	2	0	139	0	19	0
	Vid Myfab KTH	201	153	48	146	111	35	46	9		127	10	9	
	Vid Myfab Lund	147	131	16	128	112	16	19	4	0	124	0	4	0
	Vid Myfab Uppsala	258	176	82	229			27	2	0	225	2	2	0

		g. Total kvantitet per typ av tillgång till		h. Kvantitet av tillgång för akademiska projekt		
		Alla användare		Fysisk tillgång till infrastruktur		
4	Typ och kvantitet av tillgång	Fysisk [antal anv.]	timmar	Totalt (timmar)	Män (andel, %)	Kvinnor (andel, %)
4.1	*Användning under året*					
	Totalt	784	165304	141418	74%	26%
	Vid Myfab Chalmers	189	58930	51778	80%	20%
	Vid Myfab KTH	201	34219	23542	76%	24%
	Vid Myfab Lund	136	43864	39413	74%	26%
	Vid Myfab Uppsala	258	28290	26684	68%	32%

5	Output		
5.1	Publikationer	Bifoga lista enl specifikation	736
5.2	Antal examinerade doktorer	Som haft en väsentlig verksamhet i Myfab	45

ANNEX B – ORGANISATION 2020

General Assembly members (Stämma)

Chairman:
Lars Börjesson, Senior Advisor to the President, Chalmers
Annika Stensson Trigell, Vice Rector KTH
Stacey Ristinmaa Sörensen, Vice Rector Lund University
Johan Tysk, Vice Rector Uppsala University

Steering Group members

Chairman:
Mikael Östling, Deputy President KTH
Marcus Aldén, Professor, Lund University
Anne Borg, Rector NTNU Trondheim
Mikael Jonsson, Professor, Uppsala University
Ellen Moons, Professor, Karlstad University
Anna Stenstam, CEO CR Competence, Lund
Henrik Thunman, Professor Chalmers

Operational management

Director:
Thomas Swahn, Docent

Laboratory Managers:
Myfab Chalmers: Peter Modh, Ph.D.
Myfab KTH: Nils Nordell, PhD.
Myfab Lund: Luke Hankin, PhD.
Myfab Uppsala: Stefan Nygren, PhD.

Support systems and project manager:
Cristina Andersson, Ph.D.

ANNEX C – MYFAB ACCOUNTING OF PROCUREMEN 2020

Accounting of procurements during 2020.

Several procurements were initiated during 2020 but since we have not yet got any deliveries we do not have any cost to report using the the template: "Mall för redovisning upphandling samt för slutredovisning av vetenskaplig utrustning.xlsx".

Currently only investment number 7 is ordered, and we expect delivery during spring 2021.

Myfab 5 Investment Progress

Pos.	Investment	Node	Needs and requirements	**Investment decision**	Market survey / Procurement doc.	**Tender invitation**	Tender submission	**Tender deadline**	Tender evaluation	**Order contract**	Lead time	**Delivery**	Installation / Acceptance test	**Delivery acceptance**	Test and preparation	**Final acceptance**	**Released to users**	Comments
1	LPCVD: poly-Si / TEOS / SiN	Chalmers		(1)														
2	Automated SEM	Chalmers		(2)														
3	ICP-RIE / CVD: two chamber system	Chalmers		(3)														
4	ICP-RIE: deep Si etch	KTH			(4)													
5	HVPE reactor upgrade	KTH		(5)														
6	UHV evaporator: therm. / e-gun / ion mill	KTH		(6)														
7	3D microfabrication cluster	Uppsala																
	a) High resolution printer										(7)							To be delivered in August 2021.
	b) Interface printer				(7)													
	c) Extruder						(7)											Tender submission deadline 2021-05-03.
8	UHV sputter: high temp.	Chalmers		(8)														
9	ALE	Chalmers		(9)														
10	CD / overlay / defect inspection	KTH			(10)													
11	Thin film strain measurement	KTH			(11)													
12	4-point sheet resistance mapping	KTH			(12)													
13	TEM energy filter / spectrometer	Uppsala		(13)														
14	E-beam lithography	Uppsala		(14)														
15	III-V MOVPE: high temp. Option	Lund		(15)														

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ANNEX D – PLAN FOR THE MYFAB 5 INVESTMENT GRANT

The attached plan for investments was decided by Myfabs Steering Group 27 January 2021. The plan will be reviewed and if necessary updated annually by the Steering Group.

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Plan for the Myfab period 5 investment grant:
105 000 000 SEK

The fifteen investments below were decided by the steering group

For each tool we have the following motivations:

1). Local Motivation

2). In relation to the application (refer to the five research areas)

3). Relative to the Gantt chart in the application (red/yellow/green)

4). National relevance (profile area, unique features, …) Unique, base tool, which material systems etc.

5). How this support scientific excellence

Cost (in parenthesis) is the estimated cost. All estimated costs are funded partially. The funded share is found by multiplication by a factor 105000/112300 = 0,934996.

2021

1. LPCVD SiN, polySi, TEOS   8 414960 SEK (9000 kSEK)   Myfab Chalmers

1). Critical tool for several excellent research environments (High speed electronics/Microwave and Photonics), workhorse for many others

2). Generic tool, relevant to all research areas but extremely important for ICT

3). Thin film deposition generic platform replacement

4). This kind of technology is needed at all nodes. Local research profiles determine the needed film varieties and set the quality requirements. At Myfab Chalmers the focus is on ICT with very high-quality films for optical waveguides and as dielectric barriers in microwave electronics.

5). Absolute necessity for the large research communities in ICT with focus on photonics and microwave and terahertz electronics. Several large framework programs within this fields are dependent upon this technology. In addition, it is a base technology for many other areas (films for microfluidics, mems and so on).

2. Automated SEM 3 272 484 SEK (3500 kSEK) Myfab Chalmers

1). Automated analysis for process development, especially for e-beam exposure, broad use

2). Nano, ICT, Life science, Energy

3). Metrology -replacement

4). This replaces an old SEM but with an interferometric stage it will enable automated analysis and measurement of absolute positions for ex. New capability at Chalmers. Is this available anywhere else in Myfab?

5). This will support the nano and ICT in particular but also Energy and Life science in enabling high precision and automated analysis of the fabricated devices (position and shape).

3. ICP Rie/CVD two chamber system 7 479 964 SEK (8000 kSEK) Myfab Chalmers

1). Critical tool for 60-70% of all projects running in the lab

2). Generic tool relevant to all research areas

3). Dry etch generic platform

4). A dry etch system with two chambers, one for Chlorine based chemistry and one for Fluorine based chemistry with vacuum transfer between chambers. It's a unique tool in Myfab although it is a generic dry etch tool for a multitude of projects for etch of III-V materials and dielectrics. Laser interferometric end point detection handles the unavoidable process variations in a generic dry etch tool.

This tool supports approximately half of all projects run at Myfab Chalmers. The existing tool 5). (20 years old) that this system will replace is used around 1100 times per year.

4. ICP-RIE, Deep Si etch 13 089 938 SEK (14000 kSEK) Myfab KTH

1. Local Motivation:
The investment replaces two tools, 10 and 20 years old, respectively, with one new tool with considerably higher performance.

2). In relation to the application (refer to the five research areas):
Material
Nano
ICT
Life Science

3). Relative to the Gantt chart in the application (red/yellow/green)
Dry etch Generic Platform

4). National relevance (profile area, unique features, …)

Unique, base tool, which material systems, …

Myfab KTH is leading in deep-Si etching since 1997. The tool has advanced features such as sub-second gas switching, low-temperature chuck cooling, multi-coil plasma control, multiple end-point detection mechanisms and is able to handle different substrate and chip sizes up to 200 mm. The tool will be the most advanced deep-silicon etcher in a public clean-room in Europe, and it would be the first tool world-wide delivered with sub-0.5 second gas switching capability.

5). How this support scientific excellence

The deep silicon etching enables devices for biotechnology (DNA sequencing), biomedical applications (microneedles for transdermal drug delivery), microwave and terahertz frequencies, photonics, sensors and actuators, 2D-material integration (graphene enabled sensors). Examples of current cutting-edge research, relying on deep-silicon nano and micromachining, include for instance single-photon microwave radiation detection at room temperature enabled by nanometer surface-roughness multi-domain waveguides (for radio-astronomy applications), or ultra-high Q-factor terahertz-frequency resonators requiring sub-micrometer precision deep-silicon etched cavities.

5. HVPE reactor upgrade 3 272 484 SEK (3500 kSEK) Myfab KTH

1). Upgrade of existing tool used in several projects

2). Generic tool, with applications in 4 of 5 research areas: Materials science, Nanoscience and nanotechnology, Information and communication technologies, Energy

3). Epitaxial growth of III-V materials

4). Upgrade of a process unique for Myfab, and even in Europe. HVPE is either boosting the performance of advanced photonic devices whose structures were fabricated by MOVPE or MBE or used to create novel devices.

5). Developing III-V/Si heterojunction solar cells, High Speed QCLs for free space communication, orientation patterned GaP for quasi phase matched non-linear optical frequency generation of entangled photons and very recently by a collaborative project funded by AFOSR (Air Force Office of Scientific Research, USA). Also, a project on THz laser generation.

6. UHV evap. with e-gun/thermal/ion-milling 4 674 998 SEK (5000 kSEK) Myfab KTH

1). A new tool at ANL, expanding the Labs' functionality and efficiency, via an integrating upgrade of three heavily used tools.

2). Generic tool relevant to all research areas

3). Albanova processing platform

4). The tool allows optimization where e-gun, thermal evaporation, and in-situ ion milling could be combined in one, substantially more capable system with a much smaller footprint and maintenance. Such versatile e-gun/thermal/ion-milling UHV system (e.g., by AJA Inc.) would be a significant improvement for most of the process lines at ANL, cover current material deposition needs and allow us to expand into new material systems and patterning processes.

5). Support to projects in nano electronics and photonics, quantum optics, quantum computing, nanomaterials. ANL has about 70-80 unique LIMS users and up to 100 projects funded by EU, VR, SSF, KAW etc., at an estimated volume of 300 to 500 MSEK. In the longer term, this lab enhancement will undoubtedly help attract new research groups, projects, and funding to the nano-environment in Stockholm and hopefully the region as a whole.

7. 3D Microfabrication 10 565 450 SEK (11300 kSEK) Myfab Uppsala

1). New technology to advance fabrication capabilities. Obvious complement to existing 3D efforts (AM@Å / AddLife / U-PRINT) at Uppsala University.

2). A great number of application areas, primarily in life science but also in materials science and energy storage.

3). New emerging techniques.

4). New capability, not yet provided by Myfab. Focus on life science consistent with profile of Myfab Uppsala.

5). The added flexibility with 3D printing will greatly enhance the possibilities and reduce the limitations in our fabrication processes.

- High precision 3D printer (sub-μm resolution) 4.0 MSEK
- Low resolution 3D printer 3.0 MSEK
- Extruder 2.0 MSEK

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2022

8. UHV sputter high temp 4 674 998 SEK (5000 kSEK) Myfab Chalmers

1). Base technology but quality improving for metal films

2). Generic tool, relevant to all research areas

3). Thin Film Deposition 'Generic platform' - replacement

4). Thin Film Deposition 'Generic platform' - replacement

5). The high temperature option is especially important for fundamental research (e.g., material research) but also in applied fields such as catalysis.

9. ALE 4 207 480 (4500 kSEK) Myfab Chalmers

1). New technology at Chalmers, will enable high precision etching for the majority of user groups

2). Generic tool, relevant to all research areas

3). New emerging techniques - new capabilities

4). New emerging techniques - new capabilities

5). Such a generic technique will help all environments, but we see that especially the large activity in quantum device in WACQT and the photonics and high speed electronics research areas will directly benefit the most.

10. CD, overlay, defect inspection 2 804 987 SEK (3000 MSEK) Myfab KTH

1). Tool to acquire critical dimension (CD) and overlay information in process line for fabrication of complex components and circuits demands automatic metrology of CD, overlay and defect densities. ISO9001 quality system.

2). Generic tool, relevant to all research areas

3). New emerging techniques - new capabilities (alt. Metrology replacement)

4). Enabling the Si and SiC based circuits are complex, rising the research demands on fast and reproducible feedback on the processing results, from state of-the-art in-line metrology.

5). Enabling the Si and SiC based circuits are complex, rising the research demands on fast and reproducible feedback on the processing results, from state of-the-art in-line metrology.

11. Thin film strain measurement 1 869 991 SEK (2000 kSEK) Myfab KTH

1). Replacement of old stylus profilometer that do not have mapping nor strain measurement capabilities, to: (1) measure strain in thin films and (2) mapping of step height measurements over a wafer

2). Generic tool, relevant to all research areas

3). Generic tool, relevant to all research areas

4). Control of thin film strain is important in MEMS as well in device fabrication. Collecting step height data over a wafer enables optimization of dep/etch processes leading to increased yield.

5). For wide application areas. Step height measurements over a wafer is essential for all complex process flows in Si, SiC and III-V device/circuit technologies. Strain metrology allows researchers to exploit strain in a beneficial way in devices.

12. Sheet resistance 4-point mapping 467 498 SEK (500 kSEK) Myfab KTH

1). Metrology replacement of old tool and new tool enables wide sheet resistance range and also dense automatic mapping of sheet resistance over a wafer.

2). Generic tool, relevant to all research areas

3). Metrology replacement

4). Sheet resistance mapping is an excellent metrology for advance metallization and for characterization of epitaxial growth of semiconductor materials.

5). Sheet resistance mapping is an excellent metrology for advance metallization and for characterization of epitaxial growth of semiconductor materials.

13. TEM energy filter / spectrometer 5 609 973 (6000 kSEK) Myfab Uppsala

1). Required to do electron energy loss spectroscopy (EELS) in the TEM.

2). Generic tool. Relevant to most areas, but most significantly to materials science and nanoscience / nanotechnology.

3). Materials characterization – replacement and upgrade.

4). Based on research tradition and available competence, Myfab Uppsala has a profile in materials science and is the most well equipped node for materials characterization. With EELS the information available from a TEM analysis can be greatly enhanced.

5). Transmission electron microscopy (TEM) is a very powerful tool in micro- / nanotechnology, providing information about crystal structure / defects, interfaces and device structures. EELS will add the capability to measure e.g. atomic composition, chemical bonding and electronic properties in connection with the TEM imaging.

14. E-beam lithography 9 349 955 SEK (10000 kSEK) Myfab Uppsala

1). Replacement to secure fundamental capacity.

2). Lithography is a generic capability relevant to all five areas.

3). Nanolithography - replacement.

4). E-beam lithography has become a standard technology for nanofabrication and should be available at any site with an ambition in this field. A high and continuously growing usage adds a capacity issue that in itself motivates a number of tools, most efficiently distributed among the Myfab nodes.

5). Critical tool for a number of projects and research groups in nanoscience / nanotechnology, ICT and life science. Many of the most advanced projects rely on the availability of e-beam lithography. Some of the PI:s were recently awarded prestigious grants from KAW and ERC.

15. MOVPE III-V with high T option 25 244 880 SEK (27000 kSEK) Myfab Lund

1). Local Motivation

2). In relation to the application (refer to the five research areas)

3). Relative to the Gantt chart in the application (red/yellow/green)

4). National relevance (profile area, unique features, …) Unique, base tool, which material systems, …

5). How this support scientific excellence

Addressed in this order: 2, 4, 1, 5

Material synthesis with atomic level control is a very strong area within Myfab Lund. Such a system will support research in the areas of ICT, Nanotechnology and Materials Science.

The current III/V epitaxy machine (Aixtron 200) used for fundamental materials science, electronics and optoelectronics at Myfab Lund is approaching 20 years old (2001) and it has been a high priority for a long time to replace it, but it is a very large investment that is difficult to find investment for. Investment in a new high temperature MOVPE will provide a more stable and reliable platform to enable the 'growth of III/V semiconductor nanowires with very high precision and control'.

The Metal-Organic Vapor Phase Epitaxy (MOVPE) tools are critical to enable our progress in science as well as in technology development in the growth and synthesis of III/V films and nanowires in GaAs and InP. By investing in a high temperature MOVPE heating setup we expect to enable in-situ cleaning of silicon wafers for efficient integration of high performing III-V materials with novel functionality on silicon: until now a show stopper for large scale are integration of III-V materials on silicon. This is critical for development of materials, both for materials science purposes and for applications in many different areas: to reach the higher Technical Readiness Levels (TRL) for many epitaxially grown nanowire devices and applications, improved MOVPE process control at higher temperatures are needed as well as a more stable and reliable platform to enable the 'growth of III/V semiconductor nanowires with very high precision and control'. Supporting continued scientific excellence in nanowire photovoltaics, photodetectors, light emitting diodes, thermoelectrics, low power electronics as well as fundamental biology research enabled by electro optical nanowire-based devices.

ANNEX E – MYFAB PUBLICATIONS AND DOCTORAL THESES 2020

Peer-reviewed publication lists Doctoral Theses from Myfab Chalmers (144 publications, 14 doctoral theses), Myfab KTH (126 publications, 9 doctoral theses) , Myfab Lund (190 publications, 5 doctoral theses) and Myfab Uppsala (276 publications, 17 doctoral theses). In total 736 peer-reviewed publications and 45 doctoral theses during 2020.

Myfab Chalmers Peer Reviewed Journal and Conference Papers

1. Alam AS, Girardi M, Caut A, Larsson A, Torres Company V, Galili M, et al. $LiNbO_3/Si_3N_4$-Bilayer Vertical Coupler for Integrated Photonics. In: Conference Proceedings - Lasers and Electro-Optics Society Annual Meeting-LEOS. 2020.
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