Holst Centre
Powered by imec & TNO

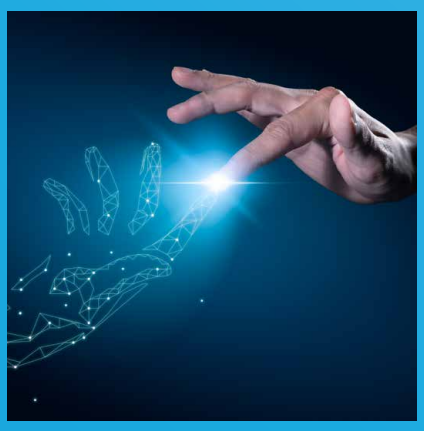
Accelerating innovation for a resilient society

Executive report 2019/2020

Holst Centre
Powered by imec & TNO

The current Covid-19 pandemic shows just how vulnerable we are as a society, impacting our basic human needs and freedom. At the same time, the crisis gives a huge boost to the adoption of technologies that support the way we communicate and collaborate, making us more resilient in the long run.

Holst Centre Themes



Health & vitality

Energy & climate

Enabling technologies

Contents

We are determined to keep developing technology that responds to the **global societal challenges** of tomorrow.

Introduction

Accelerating innovation for a resilient society

The current Covid-19 pandemic shows just how vulnerable we are as a society, impacting our basic human needs and freedom. At the same time, the crisis gives a huge boost to the adoption of technologies that support the way we communicate and collaborate, making us more resilient in the long run.

Holst Centre's innovations for health tracking, unobtrusive monitoring of vital signs, batteries, wireless distance estimation and air quality monitoring are contributing to a more resilient society. At Holst Centre, we are determined to keep developing technology that responds to the global societal challenges of tomorrow.

A perfect example is the Vitality programme that Holst Centre launched this year. The goal is to research how health care and personal care technology can improve the wellbeing of our work force. In this crisis the vitality topic is, of course, more relevant than ever. We need to completely rethink the concept and purpose of an office as a place that supports you to stay healthy.

At Holst Centre, we are launching new research roadmaps to support people in a healthy lifestyle with maximum fulfilment, from MedTech for health diagnosis and disease prevention to innovations that augment people's capabilities in a world where technology evolves at an exponential pace. Moreover, we are very proud that we could launch LionVolt BV in 2020 to commercialise our revolutionary battery concept and help the energy transition by offering safe, Cobalt-free, high-capacity, high-charging-speed batteries.

Despite the virus outbreak and thorough safety measures, work in our research facilities continued without significant delays. And we are very proud of our team that showed great flexibility and optimism in these challenging times. Together with our partners, we have brought many innovations to a higher technology-readiness level. Similarly, our application partners constantly feed us with new research challenges. At Holst Centre we are really looking forward to keep working with you, and hopefully meet each other again, in person, in 2021! Together we can accelerate innovation today to create a more resilient society tomorrow.

Kathleen Philips
General Manager imec at Holst Centre

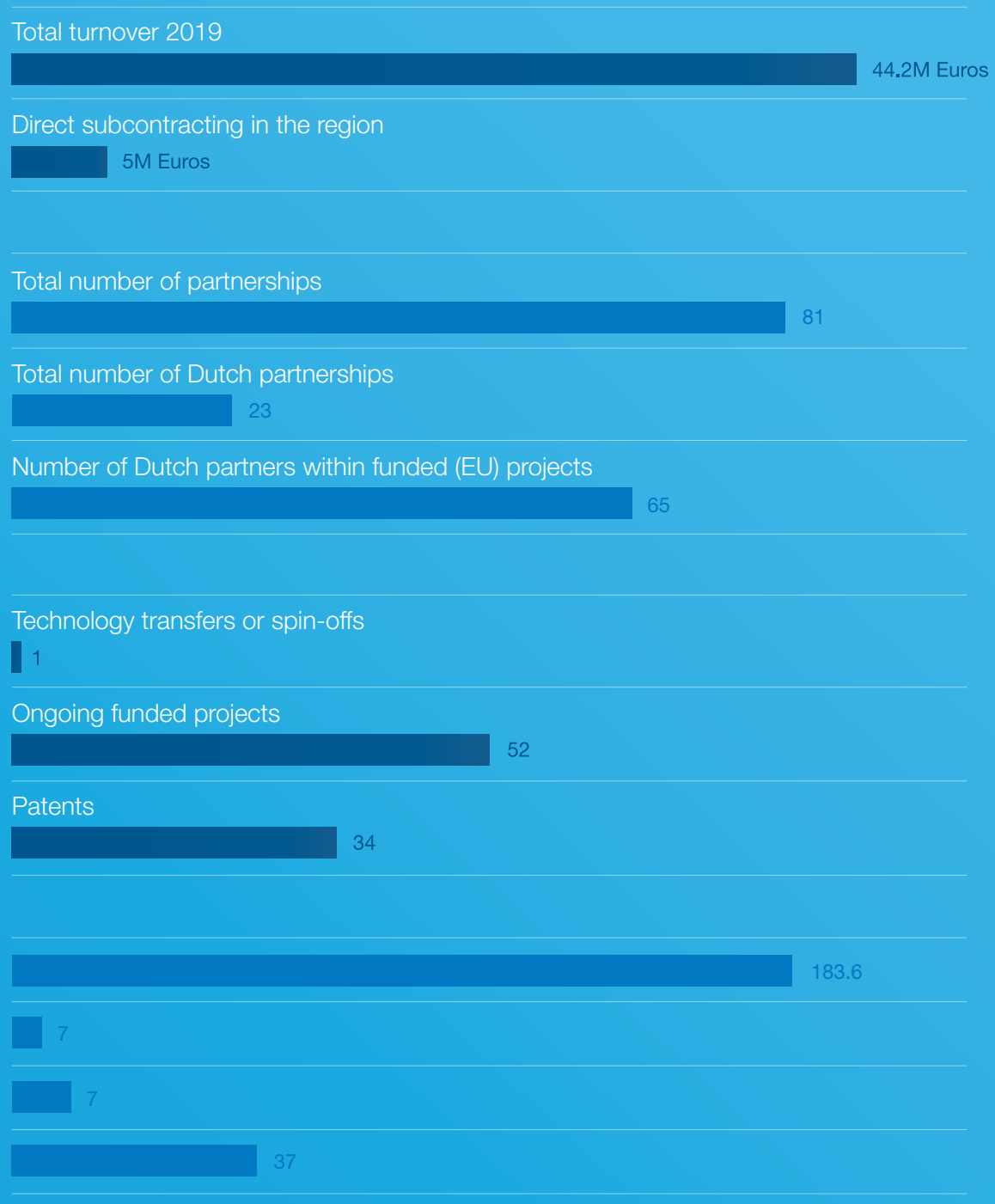
Ton van Mol
Managing Director TNO at Holst Centre

Holst Centre in a nutshell

At Holst Centre we **develop, innovate and connect**. We are an independent research and innovation centre, jointly operated by imec and TNO. We develop technology that responds to the **global societal challenges of tomorrow** and contributes to a healthier and more sustainable world.

Facts & Figures

The Holst Centre organization is built to bridge the gap between industry and academia. The current employee base is a blend of over 180 people coming from industry, academia, our mother organizations and other research institutes. There is a good mix between senior/experienced team members and more junior talent. Next to the payroll employees the Holst Centre teams consist of important other groups that add to the open innovation platform, like residents from the industry, PhD and Master-students.



Highlights

How can technology enable a **healthier and smarter future**? We have highlighted five examples of society-driven innovations.

Improving the vitality of people and society with intuitive technology

The Vitality projectthat was launched this year demonstrates how intuitive technology can contribute to a healthy society. The first objective is to address vitality at work. Brainport partners Fontys, imec, TNO, and TUe have created a new partnership (FITT) aimed at making this region not only the smartest, but also the most vital in the world.

Technology explained

The challenge of keeping people vital and resilient is, of course, more relevant than ever in the current pandemic – and it shows that a working environment is not confined to the office space. Holst Centre brings over 15 years of experience in the health domain to this programme. Technology has already helped increase people's health with wearables, but these are devices for health-conscious users. With our technology, we are able to intuitively embed preventive technology into people's daily routines. We are applying our expertise in body-monitoring solutions to deliver high-quality, multi-sensor data to create invisible, unobtrusive technology that we can integrate into the workplace.

Environmental quality at work is more important than ever. Air quality, including aspects like particles, temperature and humidity, is constantly measured in real-time so that the smart climate control system based on algorithms can create an optimal, but still generic, working climate. Even the colour and intensity of the lighting can be adjusted to the tasks and biorhythm. The challenge is to tailor the environment to a specific person. Therefore, we need reliable data of someone's physical state with sensors mounted close to the body, instead of on the skin. The final step is to close the loop and improve someone's wellbeing and productivity by adjusting the working environment.

To put this technology to the test in a real-life working environment, the FITT partners are jointly creating office spaces at the Hightech Campus where Brainport employees can share their experience and Brainport partners benefit directly from this research project.

Societal benefits

Vitality and resilience are very relevant topics for Eindhoven's Brainport region where so many high-tech companies depend on highly specialised knowledge workers. Attracting, retaining and taking good care of your employees is a big challenge.

Healthy and happy employees are better at their jobs; they are more productive and less inclined to leave the company. By supporting people in their daily life environment, you can improve workflows and increase efficiency. So, on top of the physical and mental benefits of increased vitality there are significant economical advantages. Not just for office workers in the Brainport region, of course, but for all working environments. We intend on using the results of this local project to create effective preventive technology that invisibly and unconsciously becomes part of our daily routine, so that we can all add healthy years to our lives.

Grow!

High-tech farming helps to feed the world

The earth's population is expected to reach 10 billion people in the year 2050. One of the biggest challenges is to provide sufficient food in a sustainable and efficient way. GROW! explores advanced sensor technology that significantly boosts indoor farming crop yield.

GROW! is an Interreg project for the border region of The Netherlands and Belgium, in which Holst Centre teamed up with different partners including HAS and the University of Antwerp to make greenhouse farming more efficient. With the right types of sensors and plant models, plant diseases can be nipped in the bud and abiotic stress can be measured and prevented. This is done, among other things, by regulating climate, light and nutrients. Ion-selective sensors were developed in the project that are specifically suitable for horticulture. The ion-selective sensors provide measurements of pH, conductivity and specific nutrients in water. This makes it possible to measure which nutrients are absorbed by plants. In addition, climatic sensors measure temperature, humidity and light intensities, among other things.

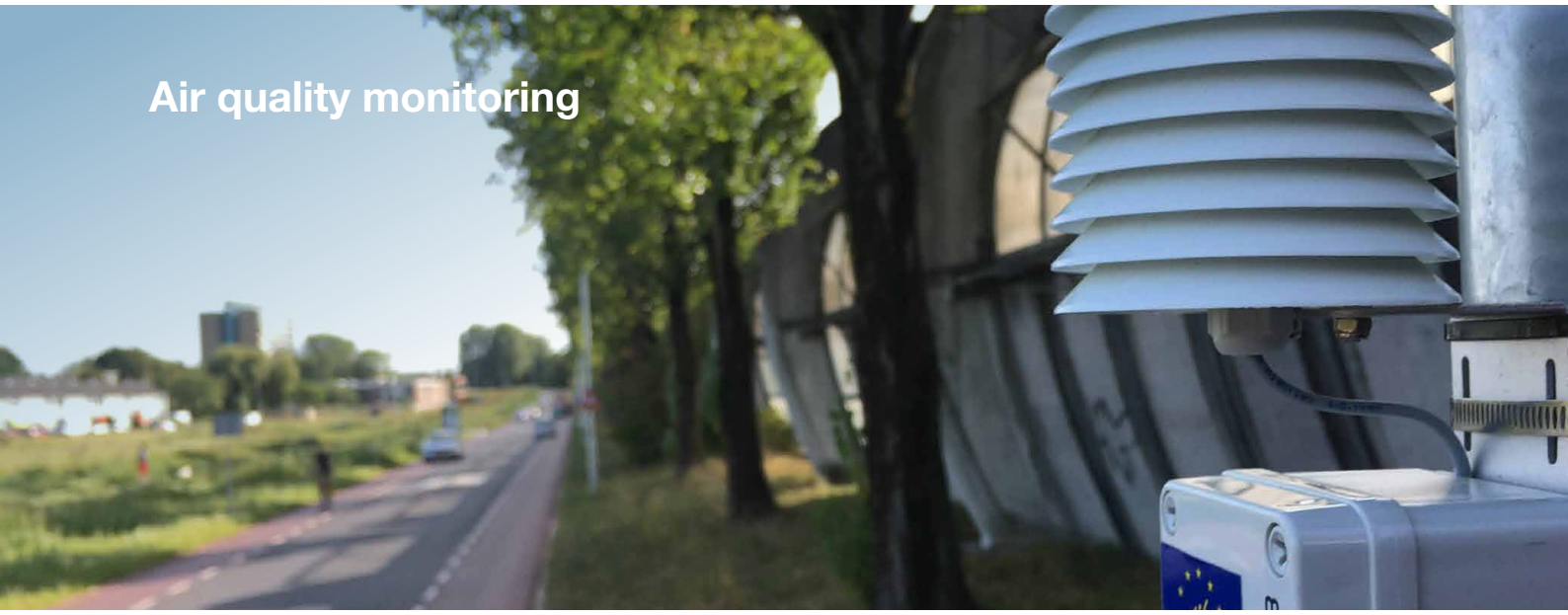
Printed electronics is key

Horticulture sensors for this project must be compact, robust, preferably inexpensive, and use little power. This is where the printed electronics technology of TNO at Holst Centre excels. As printing allows you to cover large areas in greenhouses and vertical gardens, sensors can be rolled out like LED-strips ensuring easy distribution. Having sensors all over the greenhouse generates large amounts of data. Based on smart algorithms and artificial intelligence, the observed patterns provide valuable insights into the crops' growth and nutrient intake.

In addition, printed sensors provide a cheap and disposable solution for nutrient measurements. In this way growers can easily run tests to explore effective ways to optimise crop yield. The knowledge and sensor modalities from GROW! will be taken to the next level in imec's OnePlanet programme, which is aimed at optimising the plants physiology using direct sensory feedback.

Smarter, healthier cities with fine-grained, real-time air quality maps

Air pollution is one of the biggest problems and causes of death for our urbanised society. With a dense network of low-cost sensors and smart algorithms and analytics, imec at Holst Centre creates a fine-grained real-time air quality map to support smart city policies.



Technology explained

Air quality varies wildly according to location or time of day. So, you need to be able to take targeted actions instantly to ensure that everyone breathes healthy air, all of the time. Imec's real-time cloud-based air quality monitoring approach raises the quality of low-cost off-the-shelf sensors for accurate measurements of NO2 or particulate matter levels. In this large-scale set-up, data is collected from a wide array of sources: from reference stations to citizen science sensors, and mobile sensors mounted on postal trucks, for example.

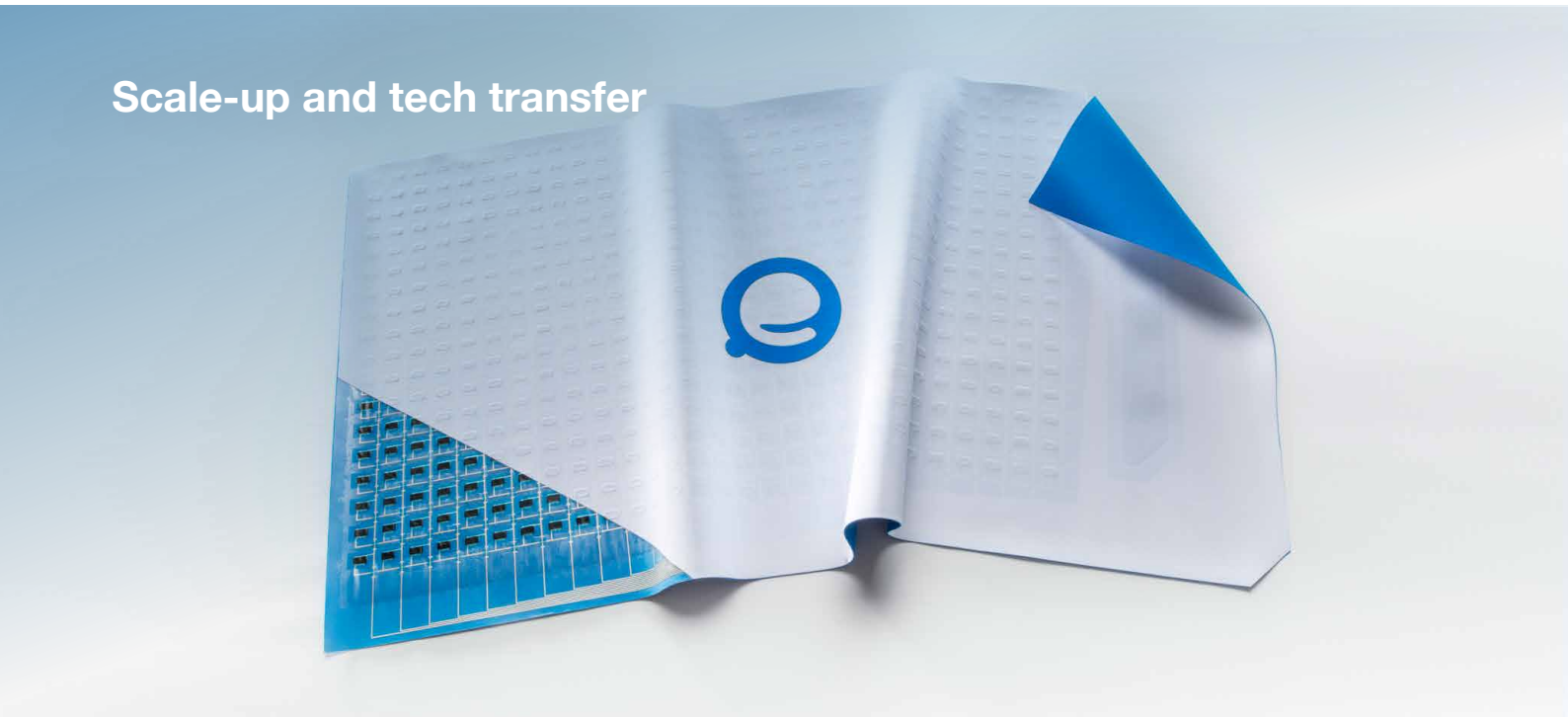
After automatic calibration and AI-based interpolation, this data can be used to make deep analyses and draw a fine-grained real-time air quality map that allows users or systems to take appropriate actions, with adaptive speed limits and dynamic traffic control.

Societal benefits

You cannot manage what you cannot measure. With this highly localised air quality data, imec at Holst Centre facilitates the creation of a digital twin: a tool designed to aid policymakers in their complex decisions about liveability in the city. Fine-grained air quality maps can also be used to measure your individual pollution exposure and suggest healthier routes for you to walk or cycle. They can also provide solid evidence of the impact of urban interventions, as in the EU LIFE Critical project in Dordrecht, such as road and building constructions for healthier and liveable public spaces.

Effective health case for printed electronics

The TNO at Holst Centre's strong local partnership with The Sleep Company and Metafas has resulted in a breakthrough sensory device that effectively and unobtrusively prevents sleep apnoea symptoms.



Technology explained

Founder of The Sleep Company, Ronald Horvers, suffered from severe sleep apnoea for years. Position therapy proved to be an effective remedy but required wearing a visible and uncomfortable chest strap. Horvers began the search for an unobtrusive but effective sleep-apnoea-prevention device and ended up at TNO at Holst Centre. The result is Sleep Assist: a thin and flexible sensor mat that is placed underneath the bed sheets. An innovative sensor network and AI-based algorithms determine the position of the user. The mat gives off small vibrations when the user turns to the more apnoea-sensitive supine position. After completion of the development, the prototype device was successfully transferred to printed electronics manufacturing company Metafas for upscaling.

Societal benefits

With its printed electronics technology, TNO at Holst Centre is at the forefront of the development of conformable electronics that can be embedded directly into fabrics, plastics and construction materials. This means we can all benefit from unobtrusive, comfortable and reliable devices that adapt to our bodies and daily life, such as the ultra-slim and flexible Sleep Assist device.

Keiron and LionVolt

Technology spin-offs with great economic potential

2020 marks two successful spin-offs of key technologies developed by TNO at Holst Centre and its business partners. Both Keiron and LionVolt show great potential to boost the future economy of the Eindhoven region.

Keiron

Following years of research, TNO at Holst Centre has brought the printing of microelectronics to a higher level. Laser-based printing technology is a contactless, digital and laser-controlled technique for depositing both solid and liquid materials on any desired surface, including bio-materials, conductive adhesives, electronics, metals, and more. Laser printing enables complex functionalities to be added to chips, and the production processes within microelectronics is much faster and more precise. All in all, this is a technology that provides great opportunities for the mass production of flexible electronics.

Together with HighTechXL, TNO at Holst Centre was able to turn this technology into a solid business case and a promising venture: Keiron. This deep-tech start-up provides a new direct-write manufacturing machine for high-volume micro-manufacturing for microfluids and microelectromechanical systems (MEMS). The global market for laser printed electronics is estimated to be worth some ten billion euros by 2025.

LionVolt

With a combined investment of 4.5 million euros by the Province of Noord-Brabant and the Ministry of Economic Affairs and Climate Policy, TNO at Holst Centre has taken a significant next step in the development of its revolutionary 3D solid-state lithium-ion batteries. These batteries are created using the patented spatial Atomic Layer Deposition (sALD) technique. They are intrinsically safe and lightweight, recharge quickly and have a long service life. Large car manufacturers are watching closely as these batteries represent the ideal solution for electric vehicles in the long term. The subsidies will be used to build a demonstration line to show that this promising technology is suitable for large-scale battery production. The Dutch government acknowledges the importance to retain this technology for The Netherlands in order to maintain its strong competitive position in Europe. To further accelerate the development of this technology in the fast-growing battery market, TNO at Holst Centre has created the spin-off company, LionVolt BV, to further develop and commercialise 3D solid-state batteries.

Innovation updates

What innovations accelerate a **resilient society**? We listed our innovations for health & vitality, energy and enabling technologies.

Health & vitality

We want to transform healthcare and make health management a natural and unobtrusive part of life.

Using smart clothing **to conquer societal challenges**

As TNO at Holst Centre we use our expertise in hybrid printed electronics to create smart clothing that improves human health and wellbeing with highly personalised solutions that blend unobtrusively into everyday life. This human-centred technology could well be the answer to a multitude of societal challenges.

Technology explained

From a shirt with haptic breathing guidance that helps regulate stress, to a pregnancy belt for monitoring foetal health at home. Hybrid printed electronics developed by TNO at Holst Centre pave the way for a new generation of electronic applications that contribute to solutions for a whole range of societal issues. Smart clothing measures biometric data almost instinctively and is barely noticeable, while the wearer feels comfortable and secure. It is worn so close to the body that it delivers data of exceptional accuracy. Printed electronics are thin, stretchable, flexible and mouldable, which is ideal for the design and manufacturing of smart clothing. Fashion design is the key to incorporate tech in comfortable garments that look 'smart', as well. To help partners build smart clothing and smart textile applications, TNO at Holst Centre has developed a 'mix and match' platform of thin, stretchable and washable printed electronic technologies. The platform allows a wide range of sensors and actuators – including ECG and bioimpedance electrodes, LEDs, solar cells and temperature, oxygen saturation, strain and motion sensors – to be combined and manufactured together. From a garment-manufacturing point of view, the printed electronics can be thought of as a trim that can easily be integrated into the garment through commonly used heat-bonding processes. This offers complete design freedom and facilitates recycling through delamination. The platform has been developed and thoroughly validated (on electrical and mechanical performance, as well as washability and wearability) in a number of our own and client applications.

Societal benefits

The global health care system is under strain and our society is confronted with an increasingly older population and a shortage of health care professionals. At the same time, people experience more stress caused by demanding working environments, and a growing sense of loneliness in this digital age. Smart clothing is a good example of technology that has the potential to alleviate the burden of our caregivers and pose a solution to the social issue of stress. As the interface between our bodies and the world around us, clothing is the perfect platform to make solutions personal and part of normal life, helping people to be more resilient, supported and protected during work, sports and leisure activities.

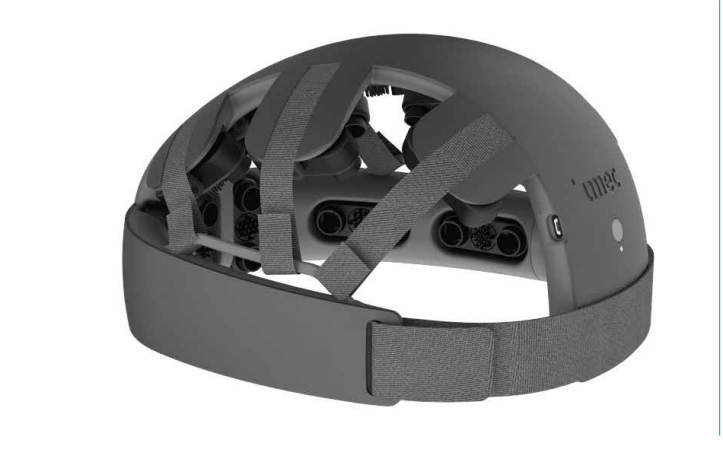
EEG/DAE and closed-loop stimulation

Closing the loop for neurotechnology

Conditions such as pain and stress do not only reside in people's minds. They manifest themselves through physiological signals. Using wearable technologies, we can leverage these signals not only to make people aware but also to improve treatments by adequate neural stimulation.

Technology explained

An electroencephalography, or EEG, no longer needs to be a complicated affair of patches and wires. Imec at Holst Centre has developed a number of EEG headset prototypes that combine user comfort with low-power technology, which opens doors to new therapeutic possibilities. This platform ensures excellent signal properties, because it uses the in-house developed DAE (digital active electrode) technology – where each dry EEG electrode is accompanied by an integrated circuit that immediately digitises the signal.



The DAE concept enables us to make a modular and expandable system that facilitates not only capturing electrical activity of the brain but also blood oxygenation level-dependent (BOLD) using optical sensors. This was demonstrated convincingly with the EU-funded ASTONISH project, where a multimodal brain-monitoring platform was developed that combines EEG and functional near-infrared spectroscopy (fNIRS).

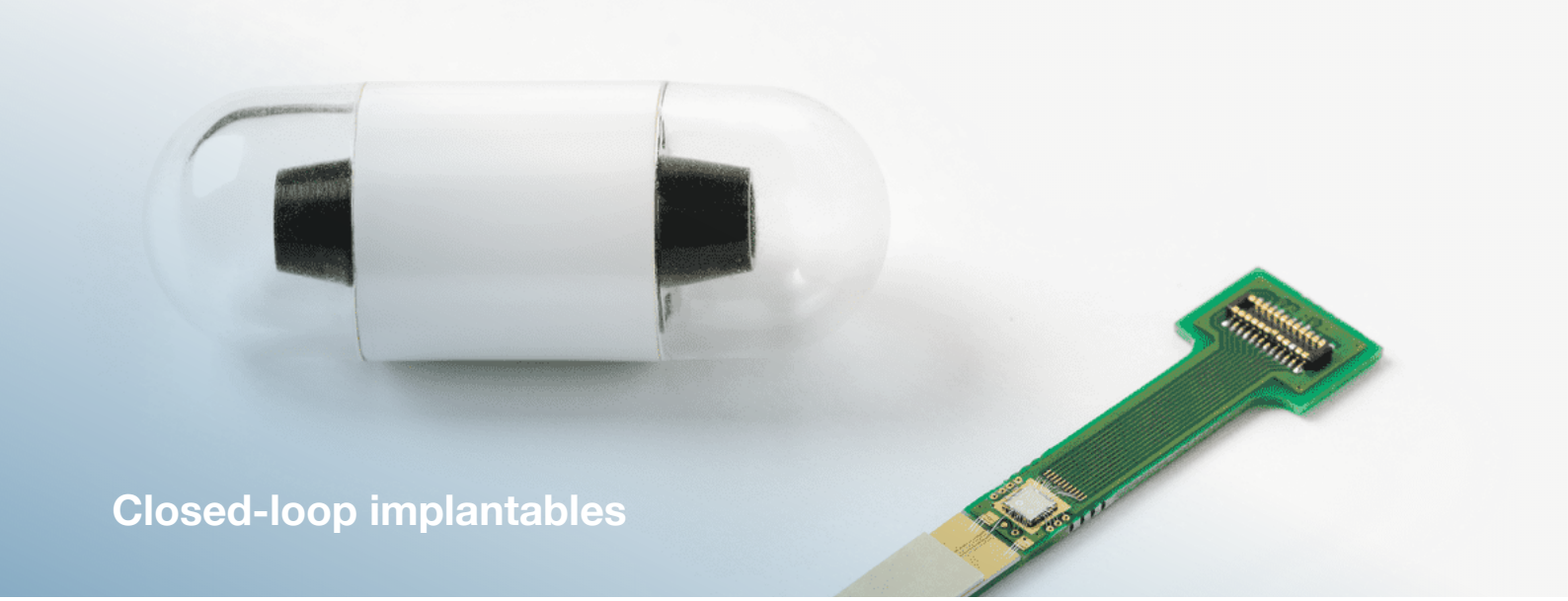
From sensing to stimulation

Being able to monitor brain activity with a smart and compact device enables the assessment of a relevant mental state and its evolution; hence it opens the door for altering or modulating this state. As a result, closed-loop monitoring and actuation systems can be designed to actively stimulate specific neural tissue to target undesirable conditions, such as pain and stress. Imec at Holst Centre is working on a flexible framework for vagus nerve stimulation in a closed-loop framework that combines wearable sensors for physiological monitoring and implantable or non-invasive stimulation modules. Given the role of the vagus nerve in the body, such a closed loop can be used to ensure the body maintains the homeostatic state. Signals acquired by the EEG headset and a wearable device, such as a wristband, can be interpreted by complex algorithms to sense the condition of a person. When it detects pain or discomfort the system triggers the stimulation through low-power implanted stimulation nodes. This closed-loop platform offers endless possibilities in the drug-free treatment of a wide variety of conditions, from epilepsy and depression to Parkinson's disease and other movement disorders.

Societal benefits

Through improvements in neuroscience technology, imec at Holst Centre is developing platforms for wearable brain monitoring and closed-loop stimulation devices that are affordable, convenient and relevant for clinical applications.

Whilst still in the prototype phase, these platforms are a major step towards personalised medicine and offer great potential for proactive stress management, drug-free pain treatment for a wide variety of chronic conditions.



Closed-loop implantables

Shifting towards **remote, preventive and patient-specific** healthcare

Imec at Holst Centre combined its extensive expertise in nano-electronics, sensor technology and AI to develop implantable and insertable medical devices with the potential to revolutionise healthcare.

Technology explained

Sensing. Acting. Healing. What if we could combine vital sign sensing capabilities with smart algorithms and actuation features in order to not only diagnose but also ‘fix’ a problem in the body? Just like a pacemaker does today, a multitude of closed-loop systems will help us in the future to keep an eye on a patient’s health. These closed-loop therapy systems can have many different form factors: wearables, invisibles, implantables and insertable devices (like a smart pill). These will help to improve diagnostics and treatments while the patient is in his home environment. Implantables are miniaturised, wireless, reliable sensor and actuator systems. Each device is customised for specific diagnostics, offering multi-sensor data harvesting with minimum power requirements. Smart algorithms translate this data into actionable insights and therapeutic interventions using wireless technologies to share this knowledge with caregivers.

Imec at Holst Centre developed implantable chips with extremely high electrode density that allows for the fine-grained recording and stimulation of nerves. The ultra-thin implants are biocompatible and flexible. They are extremely well suited for minimally invasive implantation of future-generation haptic prosthetics.

Societal benefits

The current healthcare system shifts towards wearables and careables for diagnostics and therapeutic care. The Covid-19 crisis has accelerated both the urgency and public acceptance of remote care. Continuous monitoring from home offers more reliable data than stressful snapshot diagnostics at the hospital. It allows specialists to focus on the patient and relieves them of repetitive, automatable tasks. But the biggest advantage of closed-loop systems like implantables is that they offer more effective patient-specific treatments, resulting in a higher care quality and lower healthcare costs.

A breath of fresh air in respiratory care

Breathing can be a constant struggle for someone with chronic respiratory diseases. Bio-impedance measuring is a non-obtrusive way for continuous respiratory monitoring.

Technology explained

Respiratory diseases are diagnosed and monitored by measuring the patient's pulmonary function. Currently spirometry is the main test for assessing many respiratory diseases such as asthma or chronic obstructive pulmonary disease (COPD). But because they are so obtrusive, they offer no more than a spot check. They are not suitable for continuous respiratory monitoring – for instance during sleep – or for ambulatory measurement. Over the past few years we have investigated the use of bio-impedance as a non-invasive technique for measuring respiration. Several studies have shown a linear relationship between bio-impedance and respiratory volume. This correlation was explored in a large-scale clinical study among patients with COPD. Bio-impedance combined with non-invasive muscle-activity monitoring provides complementary monitoring to spirometry in respiratory patients and can be combined into a single wearable device.

Imec at Holst Centre combines its innovative biomedical systems-on-chip technology with extensive knowledge of at-home and on-the-go wearables to develop unobtrusive bio-impedance measuring devices.

Societal benefits

Chronic respiratory diseases are among the most widespread medical conditions. Worldwide, 235 million people suffer from asthma and 251 million from COPD. All these patients stand to benefit from adequate assessment and management of their condition. Here, technologies for cost-efficient and unobtrusive respiratory care can make a real difference. In addition, this technology is useful for general vital-sign monitoring, since difficult breathing is one of the first signs of general medical deterioration.

Breakthrough in hands-free, at-home ultrasound monitoring

By combining its extensive knowledge on ultrasound technology, printed electronics, and health patches, TNO at Holst Centre has taken solid first steps in a next generation hands-free, low-cost, at-home ultrasound monitoring solution.

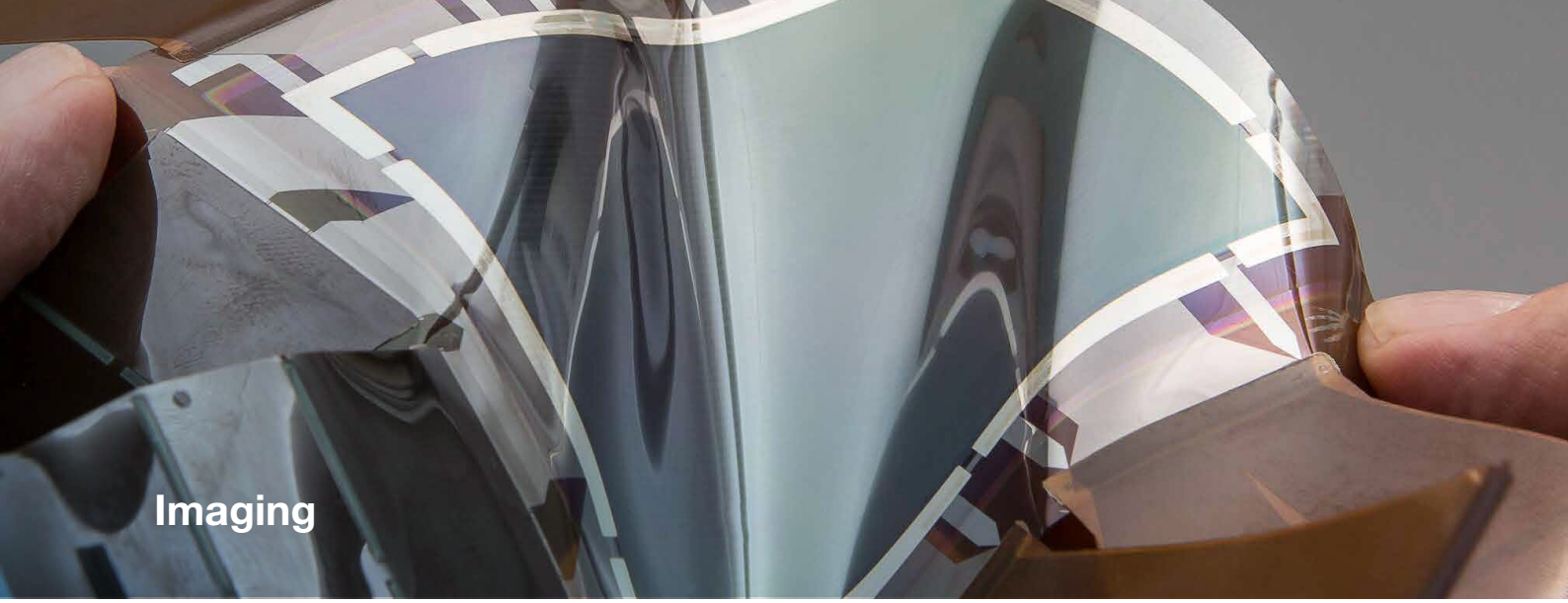
Technology explained

Ultrasound offers safe, radiation-free medical imaging. However, current ultrasound systems require manual manipulation by a highly skilled operator and offer a small field of view. Through a unique, printed architecture, TNO at Holst Centre has made it possible to create large-area, flexible transducer arrays that reduce operator variability and open the door to hands-free ultrasound systems. These systems use AI-technology to compare and interpret data sets over time, and this requires reproducible images taken from the same position and area of the body. Therefore, our ultrasound-on-foil technology potentially allows millions of individual transducers to be integrated into an adhesive patch, enabling higher resolution and improved image quality, as well as a wider field of view. Optimised polymers and adhesives in the patch potentially provide better acoustic impedance matching the human body, eliminating the need for the gels used in a traditional ultrasound scan. Such patches can be used, for example, for at-home monitoring of high-risk pregnancies and arterial plaque build-up. Extensive lab tests with this hands-free ultrasound patch created the first high-quality images proving that this technology is very promising indeed.

Ultrasound imaging

Societal benefits

Instead of going to the hospital for a snapshot impression with the current ultrasound equipment, this hands-free patch solution enables comfortable continuous and safe at-home monitoring. By producing these patches in high quantities at low costs, ultrasound monitoring becomes available for developing countries, especially because this technology does not require trained medical staff, which adds to the democratisation of healthcare.



Imaging

Thin-film technology for safe, non-invasive medical imaging

High-quality medical imaging is the cornerstone of diagnostics and an increasing suite of image-guided therapies. Using thin-film technologies, TNO at Holst Centre is opening up new possibilities for various medical imaging modalities by offering detection over larger areas.

Technology explained

Medical imaging is evolving rapidly with the rise of new large-area optical and near-infrared sensors. Based on technologies similar to those already used widely in the semiconductor and display industries, TNO at Holst Centre is developing large-area sensors for visible and near-infrared light. These can be used in applications ranging from unobtrusive pregnancy monitoring to pulse oximetry for monitoring skin grafts or arterial disease due to diabetes. In addition, our flexible, large-area ultrasound-on-foil technology enables handheld or hands-free imagers, as well as wearable patches for safe, non-invasive monitoring of even hard-to-image body parts in hospitals, at home and on the go.

A very promising innovation in the field of near-infrared technology from TNO at Holst Centre is continuous blood-pressure measuring. These long waves of light penetrate deep into the skin making it possible to register a person's Pulse Wave Velocity (PWV). This measure for arterial stiffness relates directly to blood pressure. Instead of the traditional snapshot measuring with a blood pressure cuff, this infrared monitoring could be integrated into a comfortable wearable, such as a patch or even in clothing. This allows for continuous monitoring and a far more reliable diagnosis.

Societal benefits

With the current shift in healthcare from treatment to prevention it is expected that continuous at-home and on-the-go monitoring of patients will largely replace hospitalised diagnostics. This means abnormalities and diseases can be detected at a much earlier stage, so treatment is more effective and less expensive. With fewer monitoring activities being done at hospitals, valuable expertise and resources become available for treating patients.

Patch technology for **long-term monitoring** comfort and accuracy

Effective health management relies on accurate, long-term monitoring. With the ultra-thin, fully disposable, multi-sensor health patch, Holst Centre has developed a medical device that is comfortable and reliable enough to be worn on the body for long periods of time. To accelerate new health-patch applications, our researchers have successfully launched the Nightingale V2 investigational device.

Technology explained

At Holst Centre we are combining TNO's expertise in printed electronics and bio-compatible materials, with imec's low-power miniaturised readout electronics to create body-monitoring solutions that are comfortable to wear while still delivering reliable, high-quality and multi-sensor data. With these technologies we can create devices, such as bandages, clothing or dedicated patches for use in hospitals, at-home care and telehealth programmes for remote communities.
Many years of research and development with the health-patch technology at Holst Centre now result in a reliable, waterproof, power-efficient patch with seven-days wear comfort.

The disposable health patch is built around MUSEIC v3: an all-in-one chip that measures vital health signs like heart rate (ECG), breathing rate (bio-impedance) and blood oxygen saturation. The collected information is pre-processed on chip. That significantly reduces the amount of data, which is then safely transmitted to a mobile phone, base station or the cloud. Combined with smart algorithms and data analysis, this makes it possible to develop tailored applications, such as pre- and postoperative monitoring of patients undergoing transaortic valve replacement, and the monitoring of patients suffering from chronic obstructive pulmonary disease (COPD).

Health patch

Nightingale V2

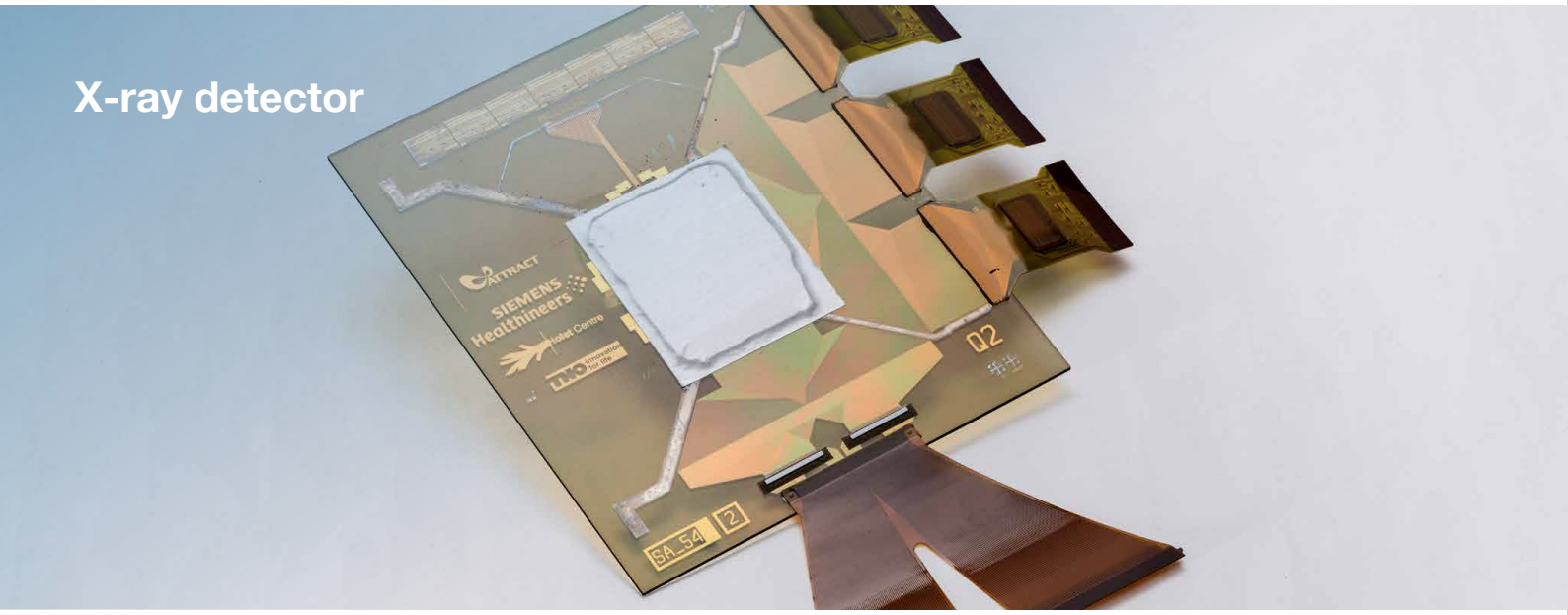
To unlock the full potential of the health patch and develop new custom-designed applications, Holst Centre has created the Nightingale V2 investigational device. This customisable multi-sensor platform allows researchers to determine the technical requirements and necessary measurements at an early stage of development. Offering the flexibility of a Swiss army-knife, Nightingale V2 can be configured to measure various bio-signals, including ECG, BioZ, PPG, motion and heart sounds simultaneously at very low power consumption. This year, Nightingale V2 was successfully deployed in a clinical study involving monitoring of tissue health. In this study, Nightingale V2 has proven to be an effective tool for clinical research with great potential to accelerate the development of health-patch applications. Other clinical studies are in preparation, in which a variety of vital signs will be measured.

Societal benefits

Continuous health monitoring has a promising future. It will enable us to find new diagnostic methods, improve therapies and reduce hospital readmissions. This health patch is an ideal solution for long-term ambulatory monitoring with huge benefits for chronic patients or people recovering from surgery; they can be checked continuously at home without having to come to the hospital every day, making their lives easier and their treatments more effective.

The perovskite revolution in X-ray detectors

Improving resolution while simultaneously reducing the X-ray dose is the biggest challenge with X-ray detectors. TNO at Holst Centre is leading the way with a new generation of direct conversion X-ray detectors that use ultra-sensitive perovskite materials.



Technology explained

As TNO at Holst Centre, we are working on a new generation of direct-conversion X-ray detectors that will revolutionise the process of taking X-rays. Direct conversion, used for example in mammography, means that X-rays are directly transferred into an electrical signal, which is then converted into an X-ray image. Perovskite, best known for its use in the fastest-advancing solar cell technology to date, is also promising in the area of direct-conversion X-ray materials that can be applied over large surfaces at low costs. In a first demonstration of this technology, TNO at Holst Centre and Siemens Healthineers have created a perovskite-based direct X-ray detector that is 100 times more sensitive than currently used mammography detectors. This means we can reduce the X-ray dose by a factor of 100, which clearly has great health benefits. At the same time, the image resolution is better than the world's finest CMOS indirect detector by a factor of 2, which will help to detect diseases at an early stage.

Societal benefits

The future trend in health care is to bring care to the patient instead of bringing the patient to a hospital. With the use of direct perovskite-based detectors, taking X-rays becomes easier, cheaper and safer. By turning it into a routine procedure, more people will benefit from this low-dose X-ray technology. And thanks to the improved image quality, diseases can be detected at an earlier stage, which will significantly reduce health care costs.

We want to create innovations that improve people's lives. **Now and in the future.**

Energy & climate

Helping an energy-craving world move towards zero-carbon emissions. With our expertise in thin-film technologies we provide the building blocks for green energy solutions to help reduce carbon emissions and improve people's lifestyles.

Advanced battery technology to **power the future**

TNO at Holst Centre deploys its expertise in thin-film technologies to create more advanced batteries with improved safety, charging density, charging times and lifespan. We explore ways to improve existing lithium-ion batteries and create innovative new 3D solid-state battery architectures.

3D and sALD enabled next gen batteries

Technology explained

Whether it's mobility, communication or health care: the future is electric. And TNO at Holst Centre is developing new technology to overcome the drawbacks of the current batteries. Rechargeable lithium-based batteries have huge potential: from enabling new generations of wearable and implantable devices to powering electric vehicles or balancing renewable energy supply and demand.

TNO at Holst Centre uses its thin-film expertise to enhance lithium battery performance in two ways. Firstly, our interfacial engineering improves the safety and lifespan of existing lithium-ion technologies. We can use spatial Atomic Layer Deposition (sALD) to optimise the interface between the electrodes and the electrolyte materials in many different battery designs and cell chemistries.

Secondly, we are pioneering a novel 3D solid-state architecture that combines safety, short charging times, high charge density and a longer lifespan. Here, too, the atomic-scale control of sALD allows us to create coatings on extremely high aspect-ratio 3D structures (100:1) that maximise the internal surface area while ensuring excellent layer thickness and homogeneity.

Societal benefits

Electrification is the way of the future, and with our improved battery technology we can accelerate this development to help reduce carbon emissions. The higher energy density and increased lifespan also mean batteries become more sustainable, supporting a greener, cleaner future.

Enabling technologies

Combining expertise in wireless sensor technologies and flexible electronics under one roof puts us in a unique position, in both domains as well as in the synergy between them.

Adding energy-efficiency and AI to **neuromorphic computing**

Spiking neural networks (SNNs) technology has the potential to become a game changer for robotics, AI and IoT. Chips using SNNs meet the industry's demand for extremely low-power neural networks that are truly self-learning.

Technology explained

Neuromorphic computing has been around since the late 1980s when Carver Mead designed a system containing electronic analogue circuits to mimic neuro-biological architectures present in the nervous system. Artificial neural networks (ANNs) have already proven their worth in a wide range of application domains, like the radar-based autopilot system in the automotive industry. But ANNs consume too much power and decision-making is too slow. Imec at Holst Centre has overcome these drawbacks with SNNs technology.

SNNs operate very similarly to biological neural networks, in which neurons fire electrical pulses sparsely over time, and only when the sensory input changes. As such, energy consumption can significantly be reduced. Chips featuring SNNs emulate the neural structure and operation of the human brain, its probabilistic nature and are capable of dealing with the uncertainty and ambiguity of the natural world – enabling almost instantaneous decision-making. What's more, the spiking neurons can be connected recurrently – turning the SNN into a dynamic system that learns and remembers temporal patterns. While the chip's architecture and algorithms can easily be tuned to process a variety of sensor data (including electrocardiogram, speech, sonar, radar and lidar streams), its first use-case will encompass the creation of a low-power, highly intelligent anti-collision radar system for drones that can react far more effectively to approaching objects.

Societal benefits

There is great potential for extremely low-power neural networks that truly learn from data and enable personalised AI. This technology could be used in robotics scenarios in the deployment of automatic guided vehicles (AGVs) and even in health monitoring, since SNNs and our nervous system speak the same language. Therefore the development and application of SNNs marks a significant breakthrough in the biggest tech trends of our time: AI, robotics and IoT.

Unlocking the full potential of ultra-wideband technology

Imec at Holst Centre has succeeded in combining machine-learning algorithms and innovations in chip design to achieve cm accuracy and low-power ultra-wideband (UWB) localisation. The technology marks a breakthrough in a wide range of domains, from secure keyless access and AR/VR gaming to industrial asset-tracking robotics and digital health.

Technology explained

With a track record of over 15 years in ultra-wideband research, imec at Holst Centre is at the forefront of UQV technology, which is perfectly suited to support a variety of high accuracy and secure wireless ranging use-cases. Think of the 'smart lock' solutions commonly used in automotive – automatically unlocking a car's doors as its owner approaches, while locking the car when the owner moves away. While UWB is inherently more difficult to compromise than some alternatives, its potential has largely remained untapped because of its high power consumption and larger device footprint. The breakthrough innovation that imec at Holst Centre has introduced this year marks an important step to unlocking the technology's full potential. Imec's brand new UWB radio chip consumes 10 times less power and fits an entire radio transceiver with three receive chains in an extremely compact 1mm^2. Complementing these hardware developments, we have come up with algorithmic enhancements that significantly improve UWB's wireless ranging performance in challenging environments, such as factories or warehouses. We have already demonstrated a factor-two improvement compared to existing approaches.

Societal benefits

The recent hardware and software breakthroughs mean that there is a great potential for these next-generation, low-power and high-accuracy UWB chips, from secure (keyless) access and AR/VR gaming to asset tracking robotics and digital health. But UWB chips can also be utilised in a wide range of other use cases such as improved digital contact tracing and safe distancing during pandemics, such as Covid-19, using small and privacy-preserving devices.

Bluetooth Secure Proximity

Enabling secure micro-location on Bluetooth devices

Next generation Bluetooth devices capable of accurately measuring distances between devices will empower diverse micro-location applications, such as secure keyless entry, contactless payments and medical asset tracking. However, the popularity of Bluetooth also makes it vulnerable to attack. We, imec at Holst Centre, are overcoming this flaw by teaching Bluetooth devices to securely detect physical proximity and mitigate wireless relay attacks and location spoofing.

Technology explained

The widespread deployment of Bluetooth makes it vulnerable to attack. In micro-location use cases, attackers who can decrease the measured proximity by manipulating the communications between two legitimate entities, for instance, your car key and your car, pose the biggest security threat. More accurate positioning capabilities based on phase measurements would make this technology safer, but future relay attacks need to be considered as well. The solution is to combine high-accuracy distance measurement techniques with countermeasures against relay attacks and cryptographic methods. That is the essence of our Bluetooth secure distance-bounding protocol. Furthermore, standardisation is a prerequisite to be able to unleash the full potential of secure positioning technologies within a large ecosystem of companies and application domains. Together with the Bluetooth Special Interest Group (Bluetooth SIG) that oversees the development of Bluetooth standards, imec at Holst Centre is focusing its efforts on creating an industrial standardisation for next-generation secure and high-accuracy positioning.

Over the past few years, imec at Holst Centre has taken big steps in developing the algorithms and chip technology that enable these new Bluetooth secure proximity capabilities. At this year's International Solid-State Circuits Conference (ISSCC) in San Francisco, we demonstrated a new chip prototype that further speeds up these phase-based distance measurements. Up to ten times faster than today's approach, they enable the tracking of more devices and reduce energy consumption.

Societal benefits

Next to ultra-wideband (UWB) radio technology and radar, the next generation of Bluetooth micro-location capabilities will create a wide array of new possibilities; particularly in logistics, which requires high-precision tracking of assets in warehouses or even individual packages and letters. But, also in the digital domain of medical applications, Bluetooth could offload routine tasks, such as locating equipment or navigating patients to the right place in the hospital, allowing staff to focus on the patient. The power of localisation with new levels of accuracy and safety will fundamentally change the way in which we interact with the world around us.

An electrifying solution that will boost the high-tech industry

With its innovative spatial Atomic Layer Deposition (sALD) technology TNO at Holst Centre enables the fast and low-cost production of applications that generate, store and convert energy.

Technology explained

The spatial Atomic Layer Deposition (sALD) technology developed by TNO at Holst Centre is a ground-breaking innovation for the large-scale production of flexible solar cells, batteries, OLED lighting, sensors and displays. It offers the same precise control and uniformity of film composition and thickness as traditional atomic layer deposition (ALD), but at much higher deposition rates – around 1 nm/s. Moreover, sALD is an atmospheric pressure process and does not require costly vacuum equipment. The possibility to produce uniform, ultra-thin layers of materials on large surfaces is of great importance to the global high-tech industry. The long-term cooperation between knowledge institutes and businesses in the Eindhoven region made it possible to transfer this innovative technology from the lab to the manufacturer.

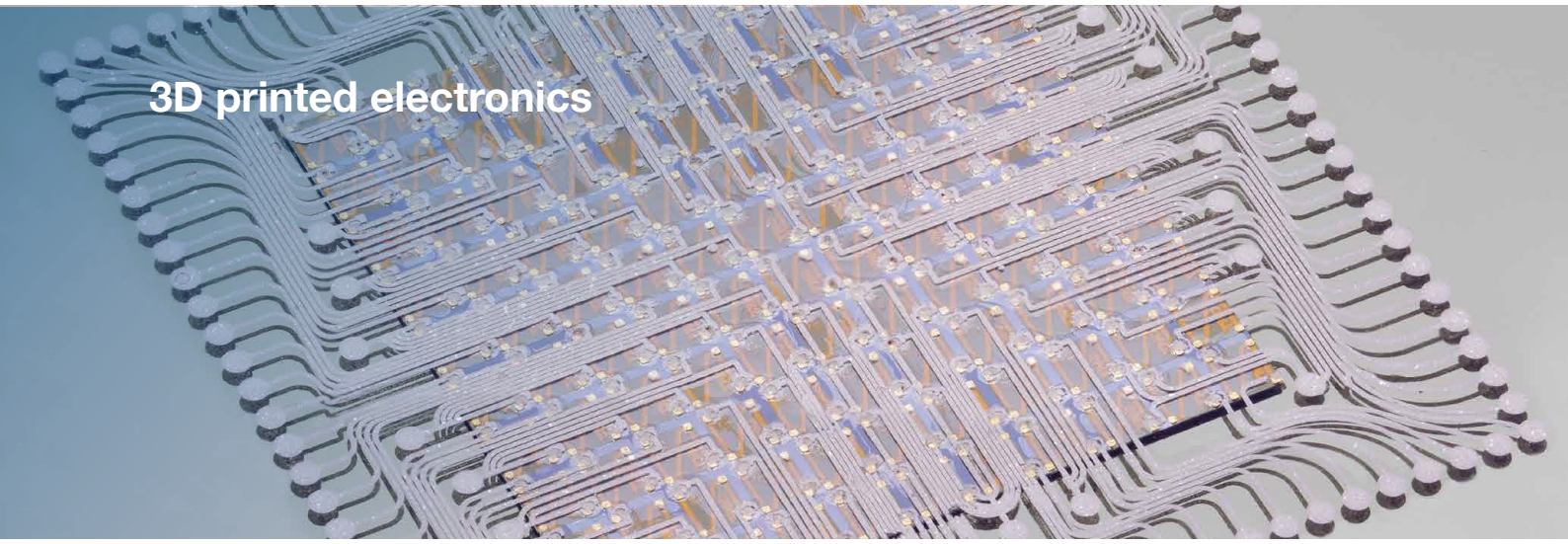
TNO at Holst Centre has successfully upscaled sALD to large areas in sheet-to-sheet and roll-to-roll equipment and can achieve highly uniform layers even for structures with an extreme aspect ratio. The technology is ready to be integrated into commercial production of, for example, thin-film solid-state batteries, optical stacks, thin-film photovoltaics and semiconductor and dielectric layer stacks for a host of large-area applications.

Societal benefits

Global manufacturers of solar panels and batteries, as well as their customers, such as the automotive industry, aim for higher returns on energy conversion, more efficient power consumption, higher energy storage capacity combined with shorter charging times, and a longer product lifespan. In all these growth markets, short production times against the lowest possible costs are essential for success. Scientific testing has shown that sALD can play a decisive role in achieving this success. Therefore this TNO at Holst Centre invention has the potential to accelerate electrification and boost the Dutch high-tech industry.

Entering the future of printed electronics

As a pioneer of flexible and printed electronics, TNO at Holst Centre is at the forefront of new printed electronics developments and it offers an extensive portfolio of technologies. A very promising one is 3D printed electronics, which could boost the design and development process of wearables, medical instruments and chip packaging.



Technology explained

3D printed electronics is an emerging technology at the intersection of 3D printing and printed electronics. It combines structural and electronic manufacturing into a single manufacturing step. The electronic circuits are created using printed electronics technologies as part of the 3D printing production process, embedding them directly into structural components. This means there is no longer a need for separate circuit boards or electronics layers, giving complete design freedom and inherent protection from dust and dirt. The complete product can be printed in one go, which reduces waste and streamlines system integration.

The latest breakthrough from TNO at Holst Centre is the successful implementation of high-resolution printing, which allows for more complex electronic circuits. TNO at Holst Centre is currently building a proof-of-concept machine to create customer prototypes as a stepping-stone for potential end-users to validate the 3D printing process for their products.

Societal benefits

3D printed electronics is currently in the early stages of development, but already there is great potential for advanced applications. The size, weight and design advantages are beneficial for multiple fields. There is strong interest from the medical industry, where 3D printed electronics could be used for the production of surgical instruments. And this method could also replace current wiring technologies in semiconductor chip packaging and display use cases.

Highlights
Funded projects

Silense

Humans communicate mainly with speech and body language. The technologies SILENSE is to develop, take the way we naturally communicate one step further: from communication between humans, to communication between humans and objects. This will become increasingly important in an IoT-dominated world. The application of the developed technologies in numerous areas will bring lots of benefits to the general public, ranging from an enhanced user experience to improved health and safety.

www.silense.eu

InSCOPE

Leading research and technological development centers from across Europe came together in 2017 to develop an open-access pilot line for hybrid printed electronics. Initiated and coordinated by TNO at Holst Centre, the EU-funded InSCOPE project was set up with the aim of boosting industrial and commercial adoption of hybrid printed electronics (HPE) and maintain Europe's leading position in a rapidly growing market. Today, TNO at Holst Centre is proud to announce that it has succeeded in setting up a consortium that hosts an open-access HPE pilot manufacturing line.

Vitality Living Lab

The group of people with an inactive lifestyle is growing. Obesity in combination with other related diseases leads to an enormous increase in healthcare costs and loss of productivity. How can you tempt people to be healthy and active? The Vitality Living Lab will devise solutions for this over a period of four years.

www.sportsandtechnology.com/vitality-living-lab

LIFE Critical

Life Critical shows an innovative approach to adapting old city neighbourhoods to the effects of climate change. It addresses the problems that these neighbourhoods face by exploiting the potential of nearby parks for climate adaption. Crucial for this approach is the proactive involvement of citizens and co-ownership, because without their support the changes to the parks are difficult to realize. This is demonstrated in two cities: Wielwijk in Dordrecht and Greater Horton in Bradford. Seven other EU cities showed direct interest in this project, of which Ghent (B) and Bergen (N) will participate in the transferability action.

www.lifecritical.eu

Overview
Funded projects

Nano4Sport
www.nano4sports.eu

Astonish
www.ecsel.eu/projects/astonish

Partner
itea3.org/project/partner.html

Enables
www.enables-project.eu

Vitality Living Lab
sportsandtechnology.com/vitality-living-lab/

Flexlines
www.flexlines.be

DMCoach2
https://www.dmcoach.eu/

TWB 2
www.eitdigital.eu/fileadmin/files/2019/factsheets/digital-wellbeing/TWB_Factsheet.pdf

MSP
www.multisensorplatform.eu

Prime
www.ecsel.eu/projects/prime

SCOTT
www.ecsel.eu/projects/scott

NexGen

Ideal IoT
ideal.iot.vlaanderen

Perses

EsAirQ
penta-eureka.eu/project-overview/penta-call-2/esairq

Mnemosene
www.mnemosene.eu

Secredas
www.ecsel.eu/projects/secredas

Quasimodo
forumvirium.fi/en/quasimodo

SunRise
penta-eureka.eu/project-overview/penta-call-3/sunrise

Amanda
amanda-project.eu/about

5E
5e-project.eu

Grow!
www.has.nl/nl/has-onderzoek/has-in-onderzoeksprogrammas/project-grow

Critical Chains
research.reading.ac.uk/critical-chains

Tempo
tempo-ecsel.eu

Comp4Drones
www.comp4drones.eu/

BFM

Internet of Water
www.internetofwater.be

CRITICAL
www.lifecritical.eu

Partners voor Water
www.partnersvoorwater.nl

SUBLIME
sublime-project.eu

MADRAS
madras-project.eu

5E
5e-project.eu

SmartEEs2
smartees.eu

LEE-BED
lee-bed.eu

BOWI
bowi-network.eu

Peroxis
peroxis-project.eu

CAPID
www.capid.eu

EnSO
www.enso-ecsel.eu

A-Patch
apatch.technion.ac.il

PYCSEL
www.pycsel-project.eu

SILENSE
silense.eu

NEXIS
www.nexis-project.eu

PI-Scale
pi-scale.eu

HiperLAM
www.hiperlam.eu

InSCOPE
inscope-project.eu

ULIMPIA
ulimpia-project.eu

HYBMAN
hybman.eu

HYCOAT
www.hycoat.eu

ESSENCE
attract-eu.com

LaGemPix
attract-eu.com

Interreg iCOAT
www.rocket-innovations.eu

Partnerships


MITSUBISHI
CHEMICAL

Panasonic

SHINKO

nanogate

PHILIPS

SILEX
Inside

NeuroPro

PragmatIC

SMART FLOOR
Innovatieve nauwkeurige bewegingsanalyse

NEW COSMOS ELECTRIC CO.,LTD.

RENESAS

SONY

niko

Rexroth
Bosch Group

spgprints

niraxx

ROHM
SEMICONDUCTOR

SUNPLUS

NOVACENTRIX

ROYOLE

technospark
наноцентр

onera

سابك
sabic

TEN FLECS
Flexible Electronics Contract Services

orange

SALDtech

touch
biometrix

orbotech

SAMSUNG

VDL

OSRAM

SEKISUI

WATER
FUTURE
when every drop counts.

PACKETCRAFT

ShinEtsu

water-link

Holst Centre
Powered by imec & TNO

Holst Centre
High Tech Campus 31
5656 AE Eindhoven
The Netherlands

T +31 40 40 20 400
info@holstcentre.com

holstcentre.com