



Digital Healthcare Powered By Chemistry



Challenges to understand and treat certain diseases and improve people's well-being have pushed the boundaries of chemistry as both a science and an industry. Digital and electronic technologies can fill these gaps, transforming the application of chemistry well beyond medication. Chemical processes are needed to produce microchips and nanotechnology that can assist the chemistry (drug therapy) traditionally used in healthcare. On the other hand, artificial intelligence (AI) enhances the development and efficacy of drugs to improve and extend human life.

Imagine getting just the right amount of insulin you need as a diabetic or having your blood pressure monitored with perfect accuracy due to a microchip inside you. Or getting faster access to new medications at affordable prices because AI reduces their cost and time of development. Or cures for Parkinson's and Alzheimer's diseases arriving at last. These advancements are not an extension of Aldous Huxley's book "Brave New World," rather gateways to the amazing future of medicine.



"AI is fast becoming integral to medical research," says [Geert Langereis](#), Ph.D., program manager of health research at [imec](#), a world-class research and innovation center in nanoelectronics and digital technologies. "It is critical to discovering and validating new drugs and therapies. In addition, nano- and microchips have amazing potential to complement or even replace medicines in treating medical conditions."

Imec is creating microchips for remote patient monitoring, in- and out-of-body sensing and electronic stimulation in a new generation of implantable, ingestible, wearable and non-contact medical devices. Based in Eindhoven, Netherlands, Langereis is leading imec's development of implants inside the human body to address chronic conditions. They include deep implants and "organ-on-chip" technology where cells of an organ like the brain grow on top of a microchip to record information or stimulate activity.

Drug Screening and Validation

AI significantly speeds up the time to screen molecules for drug discovery and validation. Electronics can test the efficacy of drug delivery systems like diabetes or pain management pumps as well as deliver the correct dose around the clock inside the body.

"Diseases are becoming more complex, so drugs have to be more specific, and it takes a longer time and more money to develop them," notes Langereis. "Electronics and AI can help."

He explains that AI is about decorrelation like an electronic bookstore that sorts books on a generic level based on a virtual copy of a person. Drug screening is similarly based on human profiles, protecting individual identities while targeting their medical conditions.

"We can do multiple screenings of drugs via organ-on chip-technology," he says. "For society, this means more targeted drugs and for individuals, less side effects."

Eventually, apps and wireless devices will be able to gather real-world evidence of drug effectiveness and drive virtual clinical trials. They will be used for phase 4 chemical trials to evaluate what happens to drugs once they enter a market, an area that's largely unexplored, notes Langereis. "Digital medicine has huge potential for long-term monitoring of drugs. This is the lowest hanging fruit."

Chip technology will also be used to decipher degenerative brain diseases like Parkinson's and Alzheimer's, which cause the death of specific brain areas or progressive brain cell (neuron) loss. To date, these diseases are incurable and neuron loss is irreversible. That's largely because they are difficult to study so their causes are unknown. Multi-electrode arrays (MEAs) from imec are poised to change this situation. These 1-square-millimeter chips have thousands of electrodes that can interrogate and interact with networks of neurons grown on top of them, recording information that AI deciphers or stimulating the cells. Combined with stem cell technology that can reprogramme cells, MEAs can create and alter brain circuits to study disease mechanisms and the effects of drugs on these circuits.

For example, a 10-year project called [Mission Lucidity](#) will use brain-on-chip technology to combat Parkinson's and Alzheimer's diseases as well as other neurodegenerative disorders. This technology will enable researchers to study brain regions before damage occurs to understand disease onset and progression. It will also allow for drug studies on a global patient population, dividing people into groups based on molecular and electrophysiological profiles. This could lead to targeted therapies that slow down or stop devastating brain disorders.

Inside the Body

In addition to helping create and evaluate drugs, digital technologies can complement drug therapy and, in some cases, even replace it. They can monitor vital bodily functions with pinpoint accuracy and treat or control medical conditions in a reversible way with less side effects.

"Insulin delivery in a closed loop system via a pump was a breakthrough but imec is looking beyond that to measure how much insulin is in the body real time," Langereis points out as an example. "In addition, small sensing chips can be ingested by people to reveal the chemistry of their gut. In the future, why not for monitoring chemotherapy as well?"

Pacemakers and hearing aids have already become so small that they are insertable into the body. Other electronic medical devices will transform to fit inside the body as well. For example, the dialysis system will become an artificial kidney and blood pressure will be continuously and accurately measured by a microchip. "Medical solutions not yet available will also enter the market," Langereis predicts. "With electronics, you can address the nervous system or brain directly or stimulate organs."

Electronic stimulation can sometimes assist drug therapies or replace them altogether. For example, with rheumatoid arthritis and epilepsy, [vagus nerve stimulation](#) in the neck can lessen pain and prevent seizures, respectively, reducing reliance on medication. With epilepsy, a microchip acts like a pacemaker for the brain. Of course, chemistry in the form of silicon, graphene or other material is essential in the production of microchips and electrodes.

Electrical stimulation can also be used instead of drugs as a stand-alone solution to problems like pelvic nerve disorders. In fact, [imec and NeuroGyn AG](#) of Switzerland are collaborating on an implantable device for such disorders, using micro-electrodes that deliver pulses to change nerve activity.

"If you take drugs, it takes a day or longer for them to be removed from your

body,” notes Langereis. “If you use electrical stimulation, you simply stop the stimulation and it [the impact on the body] stops. It’s reversible.”

This bodes well for treating depression and other chronic conditions, where drugs take time to work as well as to flush out of the body. Moreover, when life-saving drugs are not accessible or taken, mechanical solutions can be game changers, according to Langereis.

Outside the Body

Wearable devices like smart watches are the first generation of electronics to measure heart rate. Soon will be the next generation: invisible sensors placed outside of the body, such as in clothing or in a chair, to measure vital functions related to the heart, kidneys or other organs.

“If you want to do continuous monitoring, clothing is very nice material for implanting chips as it’s the closest thing to the body and you can wash it,” Langereis says.

Photonics (infrared light waves) can also measure heart rate and oxygenation of the blood as well as estimate psychological stress based on heart rate. Cardiovascular disease prevention and monitoring stands to benefit significantly from such technologies.

“We will also see more interventions outside the body to activate or inhibit the operation of chemical substances within the body,” Langereis adds. “This will allow for specific targeting of systemic drugs. An application is already available for chemotherapy: a cooling cap prevents hair loss 80 percent of the time in patients. Twenty years ago, this was not possible. We are constantly innovating.”

Good Deal for Green Deal

Digital medicine is in line with the European Green Deal’s goal of optimizing the use of drugs to essential doses needed for health remediation. Reducing the need for medicines with complementary or alternative digital technologies also decreases their residues in sewage, particularly if they are delivered in closed-loop systems within the body.

Animals stand to benefit from AI and digital technologies in medicine as well. “Organs-on-chip will provide better information from humans in an ethical, precise way and AI can determine drug efficacy and dosing instead of animals,” Langereis says.

Moreover, AI will enable the democratisation of drugs and other therapies around the world because they will be less expensive to produce. Chemistry will always have a role in medicine of the future, Langereis notes, whether as targeted drugs or adhesives in foil technology to encase microchips or to create sensors and other devices. But digital medical innovations will give consumers choice.

“For several medical issues, there are both chemical and mechanical solutions,” Langereis concludes. “Sometimes people can choose one or the other based on their needs or desires or they can combine them.

“Overall, digital technologies can extend human life by reducing the impact of chronic diseases and preventing co-morbidities as well as improving the quality of life by giving people back their mobility or functionality.”

If Huxley wrote his book today, it seems he would change the word “brave” in his book title to “bravo” as digital innovations are leading to medical miracles.

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