Creating a new paradigm of technology

Driven by its R&D institute, Samsung is set to lead the next century of technological innovation

A non-invasive, cuffless blood pressure sensor, developed by the Samsung Advanced Institute of Technology (SAIT).

"Hundreds of PhD holders gather here with one goal — to develop groundbreaking yet commercially viable technology. I feel truly fortunate to be able to discuss new and emerging knowledge with top experts every day," says Sungwoo Hwang, president of the Samsung Advanced Institute of Technology (SAIT), a R&D arm of Samsung Electronics, established in 1987.

With a research domain covering artificial intelligence, semiconductors, and new devices and materials, SAIT has already brought a number of revolutionary technologies to market, such as quantum dot-based screens in TVs featuring vivid colours and high resolutions, and voice and face recognition software, as well as neural processing units (NPUs) on Samsung phones.

While SAIT's main mission is to develop practical innovations for Samsung's business division, Hwang says the institute is not afraid to dream big. "We hope some of our innovations will become standard technology in the future," he says.

Sustainability is a priority on SAIT's agenda — looking after the future, not just from an environmental perspective, but also in the arena of human health. A series of non-invasive, wearable sensors is being developed that could transform disease detection and management, and save lives.

At the same time, SAIT's moonshot projects include a scheme to revolutionize research by harnessing artificial intelligence and robotics for R&D.

MIMICKING THE BRAIN AT A NETWORK LEVEL

SAIT is also working on an artificial electronic brain that copies biological synaptic organization to create an unprecedented neuromorphic electronic platform that exhibits the unique capabilities of the human brain.

"The digital ANN (Artificial Neural Net) processor is a calculator — it handles big data well, unlike the brain," says Donhee Ham, a Samsung Fellow and a professor of applied physics and electrical engineering at Harvard University who is leading the project. "The brain, being a chemical machine, works very differently from the ANN. It has the advantage of low power requirements and excels at tasks such as fast learning and cognition — areas where the ANN falls short," he adds.

An artificial electronic brain that brings alive the unique network capabilities of the biological one will add a new dimension to machine intelligence. "Developing such an artificial brain, by harnessing neurobiology and memory technology, is our goal," says Ham.

Ham has worked with Hongkun Park, a professor of chemistry and physics at Harvard, to map the synaptic connectivity of the biological neuronal network. This collaboration has culminated in an array of approximately 4,000 vertical nanoelectrodes controlled by an underlying complementary metal-oxide-semiconductor (CMOS) chip. The array was able to perform a highly sensitive intracellular recording from approximately 1,700 rat neurons, from which the team developed a map of about 300 excitatory and inhibitory synapses.

"This massive parallelization of intracellular recording has been an outstanding challenge in neurobiology. The scale this new ability enables in functional synaptic connectivity mapping is unprecedented and it can still be drastically enhanced," Ham says.

Ham now seeks to use intracellular recording data to drive a non-volatile memory network to download the synaptic connectivity map.

"EVERY TIME PEOPLE TELL ME THESE STORIES I FEEL A SOCIAL RESPONSIBILITY BEYOND MY RESEARCH DUTIES."

"Certain memories can learn the time correlations of the signals that drive them. We can exploit this to wire the synaptic connectivity, hidden in time correlations of the intracellularly recorded signals, into a memory network. This may one day create a better approximation of the brain's unique traits."

AI SET FOR MATERIAL BREAKTHROUGHS

The institute is also working on autonomous R&D, concentrating on autonomous material development (AMD). SAIT is working on an AI algorithm that after learning from experimental data sets, will be capable of driving robot synthesis tools.

"In about 10 to 20 years, SAIT hopes to reach the point where all the synthesis can be done by machine and human researchers can instead focus on things that require superior creativity," Hwang says.

"It's a promising way to sift through the many possible combinations of elements in different configurations for new materials, a task that would present a huge analysis challenge for humans," says InTaek Han, SAIT senior vice president, who is leading the AMD project.

"AI can utilize enormous datasets in a very short time and search unexplored experimental spaces that humans would have never considered," Han says.

The boost from the AI platform will add to an already impressive output of materials research successes — centred around quantum

(left to right) InTaek Han, Eunjoo Jang, Jongae Park, Donhee Ham, and Sungwoo Hwang.

dots, 2D materials, and other nanostructures — from Han's team.

QUANTUM DOTS BECOME COMMERCIAL REALITY

Samsung Electronics' QLED TV, using cadmium-free quantum dot backlight hit the market in 2015, in an industry-first, featuring 'immersive colour quality' and the 'largest colour volume'. Its superb image quality stems from the extremely sharp colour spectrum through use of the quantum dot, and continues to be refined.

Samsung Fellow, Eunjoo Jang, was involved in the 20-year development of quantum dot technology and says that successfully including the technology in a commercial product was a symbolic breakthrough. "It was not just a technical advance in picture quality for TV, but proof of the realization of nanotechnology-driven consumer products."

"When commercial QD products from our research finally came out in the market, something that had never been done by others, it was a fantastic feeling," she says.

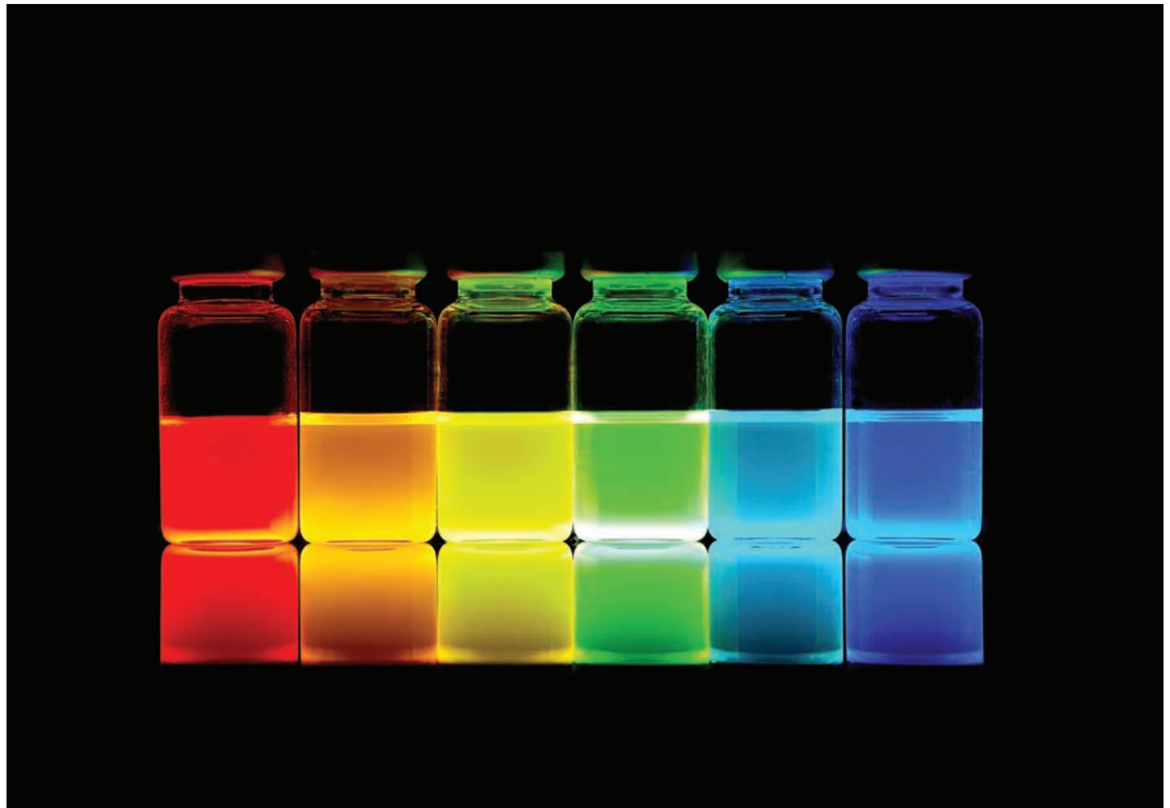
Quantum dots have wider potential, for example in optoelectronic applications such as photovoltaics and sensors, Jang says.

"We have been intensively studying electroluminescence from quantum dots, which could be another leading technology within 10 years."

BIG IMPACT THROUGH SMALL DIMENSIONS

As well as improving image quality, miniaturization is a key challenge in other growth areas, such as semiconductor performance and battery power density, says InTaek Han.

"Materials are one of the key solutions to overcome the physical limits of electronic devices. The performances of electronic components are approaching the theoretical or practical limits in dimension," Han says.



Cadmium-free quantum dots emitting light across a wide range of wavelengths.

Han's team is looking to replace traditional silicon based technology with two-dimensional materials such as graphene, which can support a higher memory density and faster processing. They have already had success extending the area of graphene layers up to the scale of computer chips, by demonstrating the fabrication of 'barristor' arrays on a silicon wafer.

A new material on Han's radar is amorphous boron nitride (a-BN). "The amorphous phase was made by chance by a SAIT and Ulsan National Institute of Science and Technology (UNIST) research team, during experiments with crystalline boron nitride. It wasn't discarded even though it didn't look good," Han says.

When measuring the a-BN's electrical properties, however, the team found it had an ultra-low dielectric constant of 1.78 with robust electrical and mechanical properties. The finding was published in *Nature* in June 2020.

SAIT material researchers are also using nanotechnology to create innovative battery technologies.

In 2017, for example, they successfully used graphene balls — a silica nanoparticle centre, with surrounding graphene layers, forming a three-dimensional (3D) popcorn-like structure — for charge storage in the active anode of lithium batteries increasing energy density by 40%.

The latest move, however, is beyond lithium batteries towards 'all solid-state batteries', which replace a separator and liquid electrolyte with solid electrolyte.

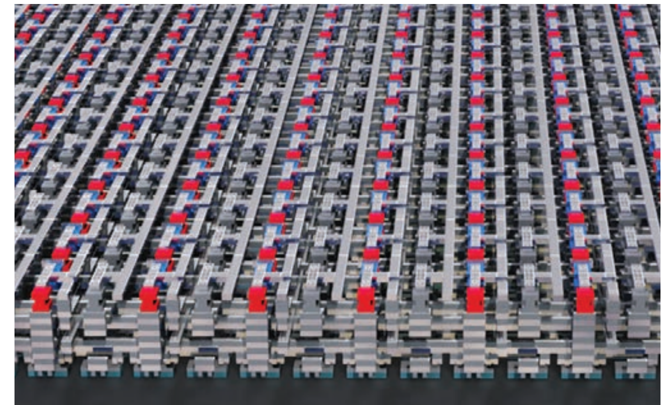
"With all solid-state batteries it is possible to eliminate anode active material, resulting in energy densities more than 30% higher than the practical limit of lithium batteries" says Han.

Recent tests of SAIT's all solid-state batteries with a sulfide electrolyte showed they could enable an electric vehicle to travel up to 800 kilometres on a single charge, and would have a lifespan of more than 1,000 charge cycles. SAIT is also expanding its research to include all solid-state batteries with oxide electrolytes, and lithium-air batteries.

ADVERTISEMENT FEATURE

Autonomous materials development (AMD) at SAIT.

A non-invasive method to measure blood glucose levels.



Schematic of a neuromorphic processor.

WEARABLE, NON-INVASIVE SENSORS

Increasing the potential of electric vehicles is just one facet of sustainability in SAIT's research. "SAIT naturally continues to engage in human sustainable technology development, believing that technological progress should coexist with humans," says Sungwoo Hwang. Alongside the batteries, the cadmium free quantum dots and low-energy electronic processors, SAIT is also working to transform healthcare.

SAIT vice-president, Jongae Park, says the institute's wearable health sensors will trigger a paradigm shift from hospital-centric diagnosis and treatment to patient-centric management and prevention. "Personalized patient-centric medical services can be realized by genetic information, 24-hour bio-signal monitoring, big data analysis, and expert diagnosis and treatment," Park says. "Wearable health sensors can provide much more information, including trend tracking during daily life, changes on a weekly/monthly basis, and intermittent symptoms without time and location constraints."

A blood pressure sensor that uses a technique called pulse waveform analysis to measure blood pressure without a cuff has been a major success for SAIT. Park points out that pulse waveform analysis through data-based artificial intelligence combined with physiological analysis has parallels with traditional Asian medicine where practitioners used their finger to sense the rhythm and strength of a patient's pulse to diagnose various diseases, non-invasively.

The non-invasive, cuffless blood pressure sensing technology has been applied to the Samsung Galaxy Watch series and was launched in South Korea in the form of the blood pressure monitor app in June 2020 in an industry-first. It also received clearance from South Korea's Ministry of Food and Drug Safety in 2020.

Park's team also has developed non-invasive blood glucose sensors. The sensors utilize an optical skin spectrum, shown to be effective in screening for diabetes. It does not require finger pricking to extract blood drops, which minimizes patient pain and discomfort — a long-standing dream in diabetes management.

"Many people are waiting for healthcare sensing technology to be commercialized. There are people who want to screen for arrhythmia, monitor daily blood pressure, or check blood glucose non-invasively, especially for kids' diabetes, because they don't want to have another painful experience," says Park.

"Every time people tell me these stories I feel a social responsibility beyond my research duties," says Park. ■

SAMSUNG

https://www.sait.samsung.co.kr/saithome/main/main.do

Advertiser retains sole responsibility for content