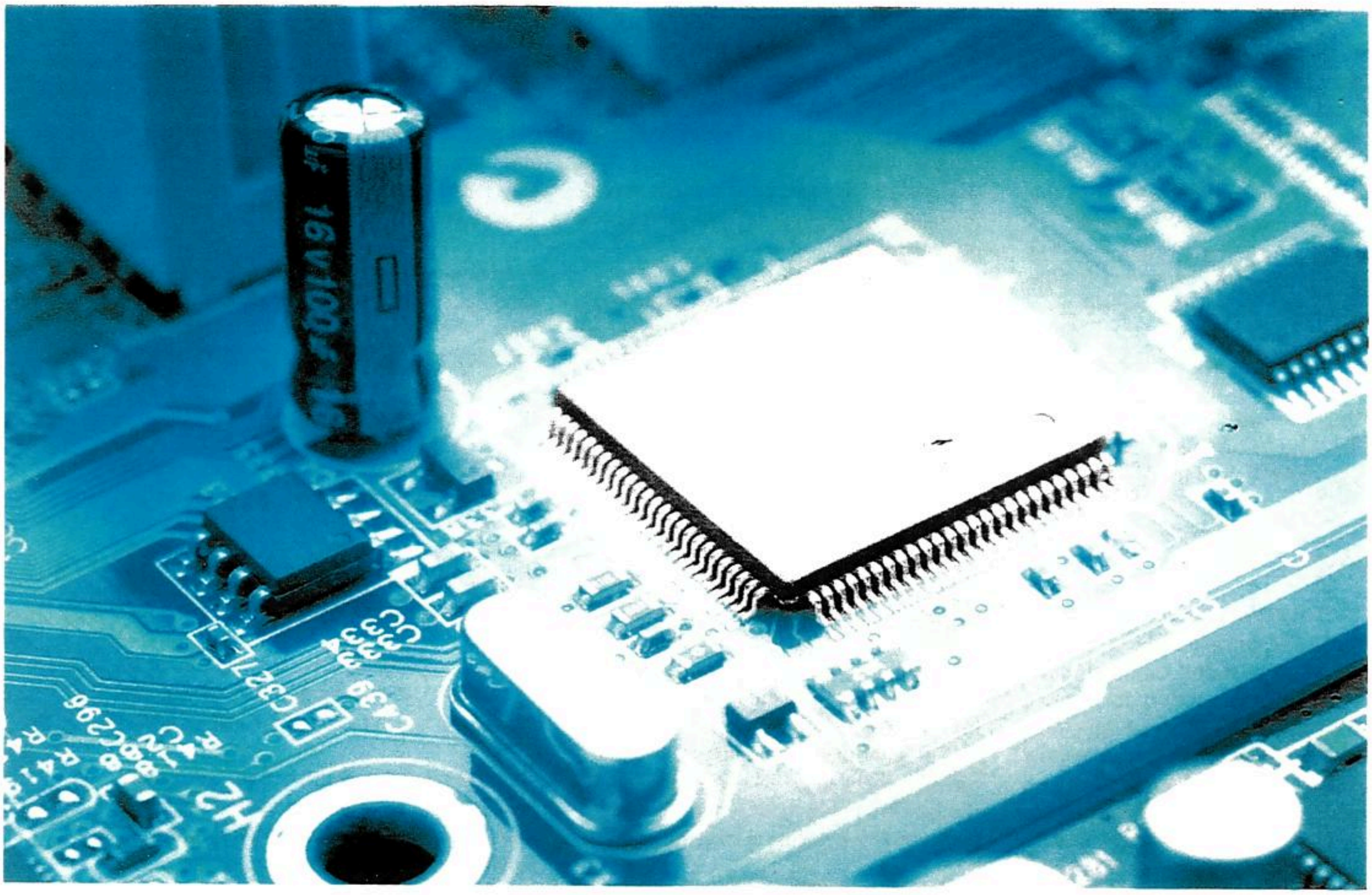
INDUSTRIAL TECHNOLOGIES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Nanodevices for a 'More than Moore' world

Since Intel co-founder Gordon E. Moore described his theory in 1965, circuit designers have counted on the steady increase in transistor density to provide greater chip performance in ever-smaller packages. Now, however, some of the physical constraints to transistor scaling — such as overheating, energy dissipation and resistance — mean that conventional semiconductor design approaches are unlikely to produce the same rate of progress.

And that is not the only challenge in achieving more powerful and smaller electronic devices. Moore's Law only deals with integrated circuits, such as the 'Complementary metal-oxide-semiconductor' (CMOS) chips that live inside your PC, mobile phone or digital camera. A bulky array of additional discrete passive components — such as resistors, capacitors, inductors, antennas, filters and switches — interconnected over a printed-circuit board or two are still needed for your phone to make a call or your camera to take a photo.

For real miniaturisation, a different approach is required: one based on advanced nanotechnology that promises seemingly infinite possibilities and unlimited potential applications. By integrating new functionality using tiny nanostructures such as nanowires and nanomaterials (each tens of thousands of times thinner than a human hair) into CMOS chips, the 'More than Moore' approach means electronics can keep getting smaller, more powerful and more efficient. So small in fact that a computer in pill form could monitor health and deliver drugs inside the human body, or a complete smart home-control system could be combined into a package about the size of a credit card.

'In recent years, nanostructures and nanowires have received much attention for future CMOS. Nowadays, activities devoted to using nanostructures, especially nanowires, to create innovative "More than Moore" products are very promising,' says Dr Francis Balestra, Director of the Sinano Institute of France's Centre National de la Recherche Scientifique (CNRS) and a researcher at INP-Minatec in Grenoble.

Devices on the nanoscale

In the NANOFUNCTION[1] Network of Excellence, Dr Balestra and a team of researchers from 15 academic and industrial partners in 10 European countries investigated how nanostructures can be integrated with CMOS chips to add a vast array of new functionalities on a tiny scale. Supported by EUR 2.8 million in research funding from the European Commission, the consortium focused in particular on ultra-sensitive nanosensors capable of detecting signals in molecules; nanostructures for harvesting energy for the development of autonomous nanosystems; nanodevices for spot cooling of integrated circuits; and nanodevices for radio-frequency (RF) communication.

'These nanodevices will be needed in the future for very-low-power or autonomous nanosystems for many applications, including health and environmental monitoring and the "Internet of Things",' Dr Balestra explains.

Nanoscale systems-in-package (SiP) or system-on-chip (SoC) devices, integrating processing power with sensors, RF communication and a range of other functionalities, for example, could be used to detect all manner of substances, toxic or benign, including chemicals in the environment, in food, and in the human body.

In the NANOFUNCTION project, the researchers advanced the current state of the art, developing a low-cost and highly efficient nanowire sensor array, which contains more than 1000 silicon nanowires and integrates different sensing elements to simultaneously detect various molecules. To test the array, the team designed effective functionalisation techniques for DNA grafting — a cutting-edge and highly experimental process in which a segment of DNA is removed and replaced by another form of the DNA structure.

The team further showed how nanostructures, as well as acting as sensors, can also provide critical improvements to existing sensor technology and other electronic applications. Working in an area known as 'cooltronics', the team proved that huge performance enhancements or new operation regimes are enabled when critical components in an electronic circuit are cooled to ultra-low temperatures. Their approach relies on a new type of 'electron cooler' that uses strained silicon (sSi) in combination with a superconductor, and which has so far been tested on terahertz (THz) radiation sensors. This is an emerging technology operating in the frequency range between microwaves and infra-red light waves, which has many potential uses, including medical imaging, security and space applications.

Similarly, the consortium took a cutting-edge approach to using nanostructures for RF communications, exploring the potential for nanowires to be used as highly efficient RF interconnects and antennas — technology that could lead to much smaller communication devices.

Nano-power

But where would such a tiny device draw its power from? Conventional batteries are still a long way from reaching the nanoscale. The NANOFUNCTION researchers therefore investigated innovative ways to power nanoscale devices from their immediate environment, drawing energy from vibrations, movement, heat or solar power and storing it in active materials that can act as nano-batteries. The development paves the way for fully autonomous nano-devices able to power themselves.

'These nanotechnologies will be combined and integrated in future autonomous nanosystems, which will be needed for many applications. The main challenges include the development of CMOS-compatible technologies and the reduction of sensors' energy consumption, computing and RF communication, as well as increasing the energy harvested from the environment,' Dr Balestra says.

He notes that many challenges have been overcome in the NANOFUNCTION project, and that the team's work is helping open the door to further miniaturisation of devices.

'Miniaturisation remains a major enabler for price reduction, functionality multiplication, and integration with other electronics. In addition, nanoscale structures can improve devices' intrinsic performance or enable new functionality, such as ultra-high-sensitivity detection,' he explains.

In advancing the current state of the art and carrying out extensive dissemination activities among the European and international nanotechnology community, NANOFUNCTION's work constitutes an important benchmark in the field.

'It will benefit European industry and society by preparing long-term integration, which Europe can rely on to underpin research on advanced technology development in this strategic "More than Moore" field — in which Europe already has a strong position,' Dr Balestra says.

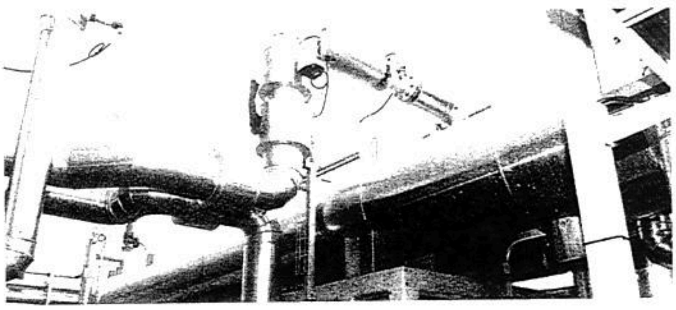
He notes, nonetheless, that it is likely to be 10 to 20 years before such advanced nanodevices make their way into commercial applications.

'For commercial exploitation, additional research will be needed in order to optimise these nanocomponents for very important applications for the European economy and society,' he says.

The project was coordinated by the Grenoble Institute of Technology in France.

1. 'Beyond CMOS nano-devices for adding functionalities to CMOS'

Beer brewing comes clean



Enter Union Engineering, an enterprising Danish company that has developed an ingenious and much more environmentally friendly brewing solution called ECO2Brew. Based on advanced CO_2 recovery technology, the initiative was launched under the EU-funded project FICOB[1].

The innovative technology enables breweries to effectively capture the CO_2 in its fermentation tanks. It can then be used to make carbonated soft drinks in other beverage lines or factories. ECO2Brew is designed to operate water-free and to use significantly less power — whilst recovering CO_2 at a higher rate than other technologies.

Embarking on a joint venture with Danish brewer Carlsberg, the team at Union introduced the novel technology in 2012.

'We spent the first six to eight months running tests at the CO_2 production at Carlsberg,' says Union's chief sales officer Michael Mortensen. 'The test