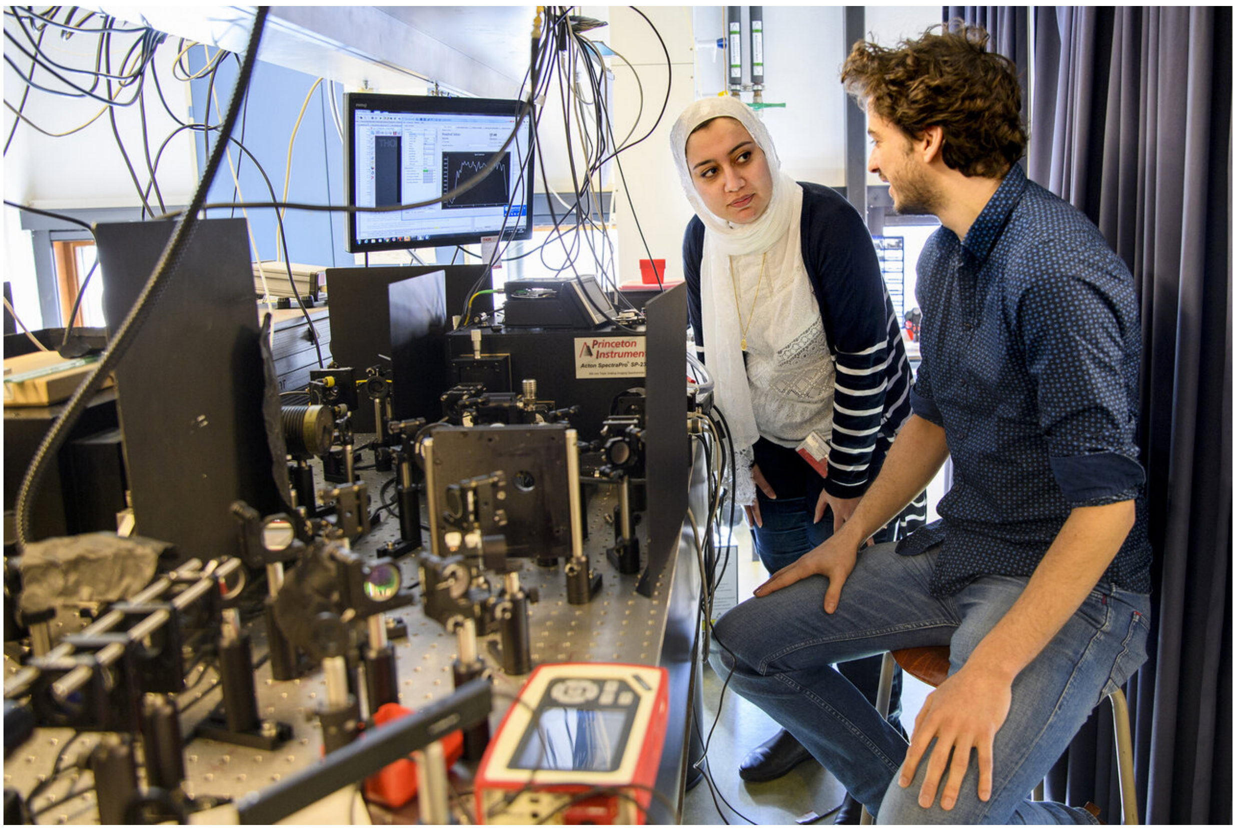
Light-emitting silicon for photonic computing

May 15 2020, by Alexander Hellemans



Eindhoven University of Technology, researchers Elham Fadaly (left) and Alain Dijkstra (right) with their setup for measuring light emission by a silicon-germanium sample with hexagonal crystalline structure. Credit: Sicco van Grieken, Eindhoven University of Technology

If computers transmitted data using photons instead of electrons, they would perform better and use less power. European researchers are now studying a new light-emitting alloy of silicon and germanium to obtain photonic chips, which can revolutionize computing

Over the last 50 years, photons, the particles that make up light, have replaced electrons for data transfer in communication networks. The high bandwidth of optical signals has driven the enormous growth of telephone systems, television broadcasting and the internet.

However, photons have not yet replaced electrons in computers. Using light for transmitting data in processor chips and their interconnections would allow a substantial increase in the speed of computers (the speed of on-chip and chip-to-chip communication could be increased by a factor of 1000) and at the same time, reduce the power required for them to operate.

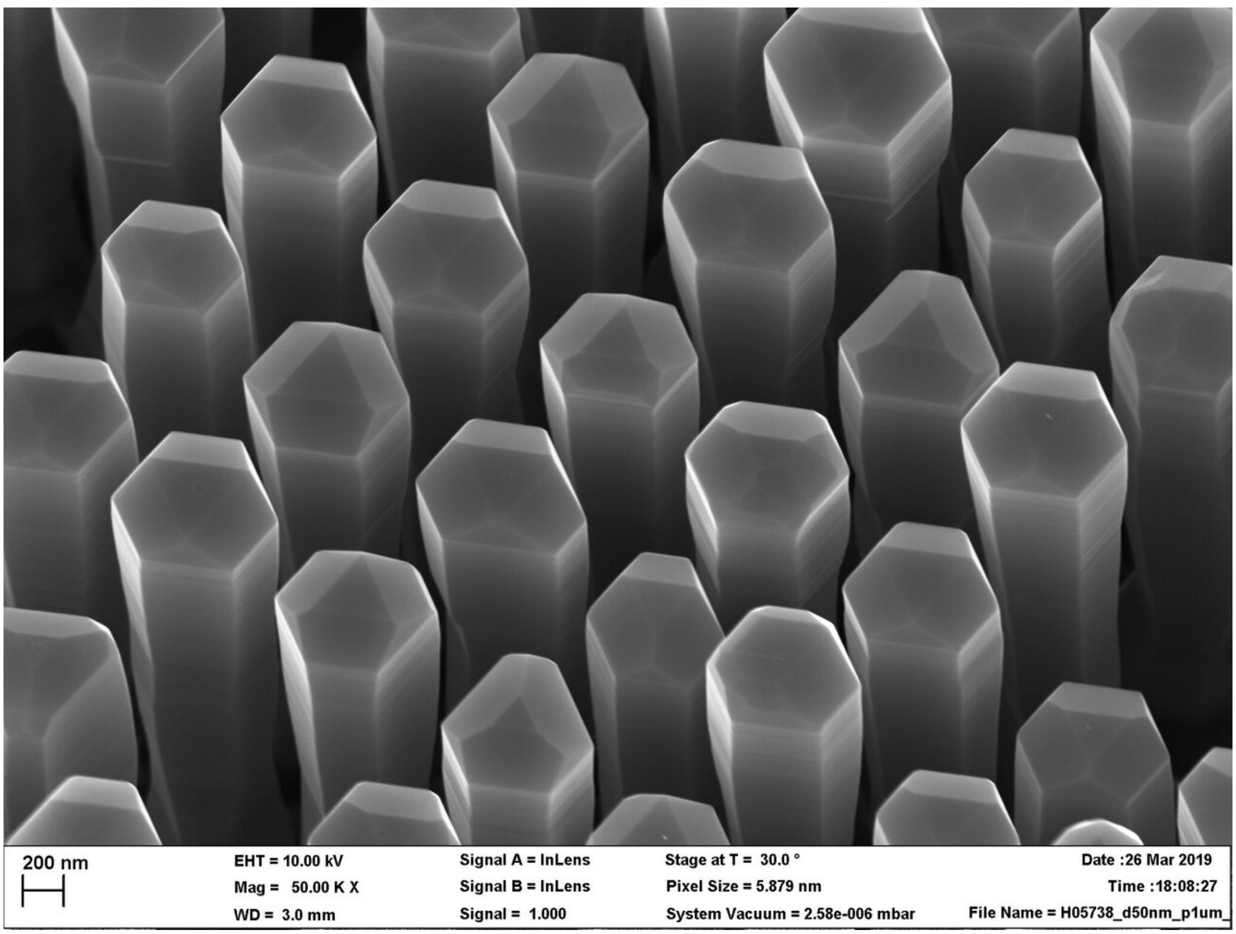
Advanced microprocessor chips can contain tens of billions of transistors, and their copper electrical interconnections produce large amounts of heat when in operation. Unlike photons, electrons have a mass and an electrical charge. When flowing through metals or semiconductor material, they are scattered by the silicon and metal atoms, causing them to vibrate and produce heat. Therefore, most of the power supplied to a microprocessor is wasted.

The challenge of emitting light from silicon

Today, the electronics industry is geared up to use silicon in computer chips because of its advantageous electronic properties and availability. It is a good semiconductor, an abundant element, and—as silicon oxide—a constituent of glass and sand.

However, silicon is not very good at dealing with light because of its crystalline structure. For example, it cannot generate photons or control their flux for data processing. Researchers have investigated light-emitting materials such as gallium arsenide and indium phosphine, but their application in computers remains limited because they don't integrate well with current silicon technology.

Shaping photonics chips: towards a revolution in the electronics industry



Nanofibers of germanium-silicon alloy with a hexagonal crystalline structure, which can emit light and are compatible with current silicon semiconductor technology. Credit: Elham Fadaly, Eindhoven University of Technology

Recently, European researchers reported in the journal *Nature* an innovative alloy of silicon and germanium that is optically active. It is a first step, says Jos Haverkort, a physicist at the Eindhoven University of Technology in the Netherlands: "We showed that this material is very suitable for light emission, and that it is compatible with silicon."

The next step is to develop a silicon-compatible laser that will be integrated into the electronic circuitry as the light source of photonics chips. This is the ultimate aim of the project SiLAS, supported by the EU program FET. The team, led by Erik Bakkers from the Eindhoven University, also includes researchers from the universities of Jena and Munich in Germany, Linz in Austria, Oxford in the UK and from IBM in Switzerland.

To create the laser, the scientists combined silicon and germanium in a hexagonal structure that is able to emit light, overcoming the drawbacks of silicon, in which the atoms are arranged in a pattern of cubes. It was a difficult project. An initial attempt to coax silicon into adopting a hexagonal structure by depositing silicon atoms on a layer of hexagonal germanium failed.

Silicon stubbornly refuses to change its cubic structure when grown on planar hexagonal germanium, explains Jonathan Finley of the Technical University of Munich, who took part in the research by measuring the optical properties of the created silicon samples. "You have to convince nature to allow the growth of this unusual form of silicon germanium. It likes to grow cubic, that is what it does," he says.

However, over the years, the research group at Eindhoven has developed expertise in growing nanotubes, and reasoned that what does not work on a planar surface of germanium might work on a curved surface of a nanotube. And this time things worked out. "What we did was to use a nanowire of gallium arsenide, which has a hexagonal structure. So we had a hexagonal stem, and we created a silicon shell around the core, which also had a hexagonal structure," says Haverkort.

By varying the amount of silicon and germanium deposited on the nanotubes, the researchers found that the hexagonal alloy was capable of emitting light when the concentration of germanium was above 65 percent.

The next step is a demonstration of lasing, in other words, determining how the silicon-germanium alloy can amplify and emit light as a laser, and measure it.

There are several open questions to resolve before silicon germanium can become fully integrated with silicon-based electronics, remarks Haverkort: "First, these devices have to be integrated with existing technologies and that is still a hurdle." He expects that future quantum computers will use applications such as low-cost silicon-based LEDs, optical fibre lasers, light sensors, and light-emitting quantum dots.

In general, the shift from electrical to optical communication will boost innovation in many sectors, from laser-based radars for autonomous driving to sensors for medical diagnosis or air pollution detection in real-time.

Provided by iCube Programme

Citation: Light-emitting silicon for photonic computing (2020, May 15) retrieved 16 June 2024 from https://phys.org/news/2020-05-light-emitting-silicon-photonic.html