Laser islands: Researcher shows how to fully integrate VCSELs on silicon

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Espenhahn in an HMNTL cleanroom holding a wafer with VCSELs fully integrated on silicon. Credit: The Grainger College of Engineering at University of Illinois Urbana-Champaign

How does your phone know it's you when you use facial recognition to unlock it? An array of tiny lasers light up your face, and your phone uses the reflection to construct a 3D model—not unlike a topographical map of your face. The phone's software then uses this to decide whether to unlock.

Those tiny lasers, called VCSELs (pronounced "vixels"), are what make this possible. Traditionally, they are used in short-range data transfer, laser printers, and even computer mice. However, since they began to appear in mainstream facial recognition and 3D imaging technologies, there has been an explosion in demand and a push to make them more efficient and compact.

Leah Espenhahn, a graduate student in the research group of electrical and computer engineering professor John Dallesasse, has demonstrated a new process for directly integrating VCSELs into electronic chips. As she described in a recent issue of *Compound Semiconductor* magazine, it is possible to create VCSELs directly on silicon microelectronics using a method called epitaxial transfer, like creating tiny islands for the lasers in the silicon.

"When compared to standard devices where independently constructed VCSELs are attached to the microelectronics," Espenhahn said, "epitaxially transferred VCSELs are more compact, perform better, and are less prone to overheating."

She has also been invited to speak on the method at the 2023 CS International Conference in Brussels.

Vertical, not sideways

VCSELs, or vertical-cavity surface-emitting lasers, belong to a class of devices called semiconductor lasers. They create intense, focused beams of light like other kinds of lasers, but they are made entirely of semiconducting materials. This means that manufacturing techniques developed for electronic microchips, which are also made with semiconducting materials, can be adapted to lasers.

Many kinds of semiconductor lasers are side-emitting, which means the beam of light is parallel to the electrical contacts. Such devices require additional manufacturing steps to ensure there is a smooth surface for the light to leave the material. In contrast, VCSELs create light that is perpendicular to the electrical contacts and vertically exits through the top layer, simplifying the manufacturing process opening the door for far more compact devices.

"Since VCSELs emit light out of the top surface," said Kevin Pikul, another graduate student in Dallesasse's group, "that makes it so much easier to create arrays. You can have thousands of VCSELs in just one sample."

Islands of fully integrated lasers

The standard approach to creating VCSEL arrays is manually soldering pre-made lasers onto electronic chips in "flip-chip bonding," a time-consuming process that has limited precision. Making them even smaller and more efficient will eventually require directly integrating them with electronic devices on microchips.

Espenhahn achieved this by taking unprocessed VCSEL device structures and attaching them to a temporary platform. After etching distinct "islands" of material for the individual lasers, a layer of bonding material was placed on top. The temporary platform was then turned over and placed on a main silicon platform, causing the islands to stick. After removing the temporary platform, what remained was an array of epitaxially transferred islands ready to be processed into VCSEL devices.

Because the VCSELs are fabricated after the transfer process, they can be far more precisely placed on the electronic circuit than flip-chip bonded devices. Moreover, the resulting devices have better thermal properties that lead to more controllability.

"Since we just have a thin layer of epitaxial material on top of silicon," Espenhahn explained, "the silicon more quickly wicks the heat away as we supply more power. This allows us to better control the wavelength [color] of the light and to create devices with longer performance ranges."

Epitaxial transfer beyond VCSELs

Facial recognition is just one example of a technology called LiDAR in which reflected laser light is used to create images or models on computers. Another use for VCSEL-based LiDAR that is gaining prominence is vision and sensing in autonomous vehicles.

But Dallesasse imagines that epitaxial transfer can go beyond just VCSELs.

"As we start talking about complex electronic-photonic systems for things like self-driving cars," he noted, "we can also start to use these techniques to put non-silicon functions onto silicon platforms to make things more compact. Silicon is also speed limited. If we wanted to integrate higher speed electronic devices or power devices, we could do that as well using an epitaxial transfer method."

Provided by University of Illinois Grainger College of Engineering

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