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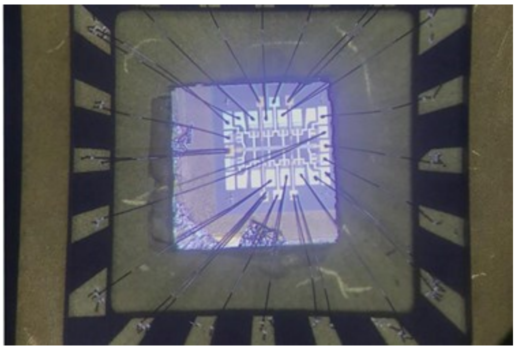
Growing components onto a semiconductor block

A new study from UNSW Sydney has shown that by growing electronic components directly onto a semiconductor block it is possible to avoid messy, noisy oxidation scattering that slows and impedes electronic operation.



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With the need for ever-smaller transistors the channel that the electrons flow through has to be very close to the interface between the semiconductor and the metallic gate used to turn the transistor on and off.

Unavoidable surface oxidation and other surface contaminants tend to cause unwanted scattering of electrons flowing through the channel, and can also lead to instabilities and noise that are particularly problematic for quantum devices.

Collaborating with wafer growers at Cambridge University, the research team at UNSW Sydney have been able to create transistors in which an ultra-thin metal gate is grown as part of the semiconductor crystal, preventing problems associated with oxidation of the semiconductor surface and reducing unwanted effects from surface imperfections.

“This new all single-crystal design will be ideal for making ultra-small electronic devices, quantum dots, and for qubit applications,” commented group leader Prof Alex Hamilton.

Field-effect transistors (FETs) and high electron-mobility transistors (HEMTs) could be further optimised to have high conductivity to provide lower device noise and enable higher frequency operations. Improving electron conduction within these devices should directly improve device performance in critical applications.

The research has sort to address a key challenge that is when electrons travel in solids, the electrostatic force due to unavoidable impurities/charge in the environment causes the electron trajectory to deviate from the original path, which is described as the ‘electron scattering’ process. The more scattering events, the more difficult it is for electrons to travel in the solid, and thus the lower the conductivity.

The surface of semiconductors often has high levels of unwanted charge trapped by the unsatisfied chemical bonds– or ‘dangling’ bonds – of the

surface atoms. This surface charge causes scattering of electrons in the channel and reduces the device conductivity. As a consequence, when the conducting channel is brought close to the surface, the performance and conductivity of the HEMT plunges rapidly.

In addition, a surface charge can create local potential fluctuations which, apart from lowering the conductivity, result in charge-noise in sensitive devices such as quantum point contacts and quantum dots.

The team at UNSW Sydney have been able to show that the problem associated with surface charge can be eliminated by growing an epitaxial aluminium gate before removing the wafer from the growth chamber.

“We confirmed the performance improvement via characterisation measurements in the lab at UNSW,” said Dr Daisy Wang.

The team compared shallow HEMTs fabricated on two wafers with nearly-identical structures and growth conditions – one with an epitaxial aluminium gate, and a second with an ex-situ metal gate deposited on an aluminium oxide dielectric.

They characterised the devices using low-temperature transport measurements and showed the epitaxial gate design greatly reduced surface-charge scattering, with up to 2.5× increase in conductivity.

The team’s research also showed that the epitaxial aluminium gate could be patterned to make nanostructures. A quantum-point contact fabricated using the proposed structure demonstrated robust and reproducible 1D conductance quantisation, with extremely low charge noise.

The high conductivity in ultra-shallow wafers, and the compatibility of the structure with reproducible nano-device fabrication, suggests that MBE-grown aluminium gated wafers could be suitable candidates for making ultra-small electronic devices, quantum dots, and for qubit applications.

- *“High electron mobility and low noise quantum point contacts in an ultra-shallow all-epitaxial metal gate GaAs / AlxGa1–xAs heterostructure” was published in Applied Physics Letters in August 2021.*

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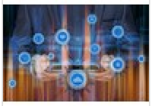

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