A new transverse tunneling field-effect transistor

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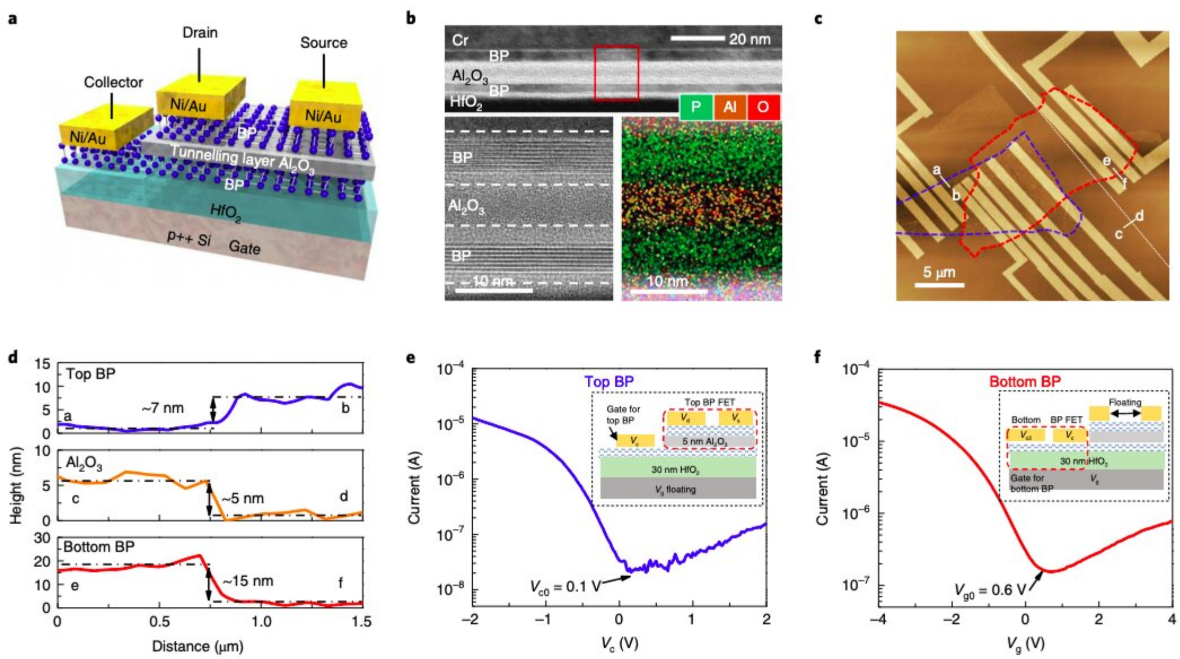

The transverse tunnelling field-effect transistor's structure and characteristics. Credit: Xiong et al.

Researchers at the Chinese Academy of Sciences have recently fabricated a transverse tunneling field-effect transistor. This is a semiconductor device that can be used to amplify or switch electrical power or signals, operating through a phenomenon known as quantum tunneling. The new transistor, introduced in a paper published in *Nature*

Electronics, was built using a van der Waals heterostructure, a material with atomically thin layers that do not mix with each other, but are instead attached via van der Waals interactions.

Tunnel field-effect transistors are an experimental type of semiconductor device that operate via a mechanism known as band-to-band tunneling (BTBT). These transistors have a wide range of applications, for instance, in the development of radiofrequency (RF) oscillators or memory components for electronic devices.

In these devices, carriers (i.e., particles carrying an electric charge) typically tunnel through a barrier, heading in the same direction as the total output current. The current in this tunnel contributes directly to the device's overall current.

To operate most effectively, these devices should ideally be built with high-quality interfaces and sharp energy band edges. Two-dimensional van der Waals heterostructures may thus be optimal candidates for their fabrication, as researchers can easily stack different materials on top of each other, resulting in high-quality interfaces and sharp band edges.

To enable high tunneling efficiency in semiconductor devices, researchers must be able to tune the density of states with Fermi-level alignment and conserve momentum from the source to end in the momentum space, without involving phonons. The researchers who carried out the recent study featured in *Nature Electronics* found that using 2-D black phosphorus (BP) allowed them to do both these things.

"Tunnel devices that exhibit negative differential resistance typically follow an operating principle in which the tunneling current contributes directly to the drive current," the researchers wrote in their paper. "Here, we report a tunneling field-effect transistor made from a black phosphorus/Al_2O_3/black phosphorus van der Waals heterostructure in which the tunneling current is in the transverse direction with respect to the drive current."

In the transverse tunneling field-transistor created by this team of researchers, the tunneling current can elicit a drastic change in the output current via an electrostatic effect. This ultimately allows the device to attain a tunable negative differential resistance with a peak-to-valley ratio (PVR) of over 100 at room temperatures.

"Our device also exhibits abrupt switching, with a body factor (the relative change in gate voltage with respect to that of the surface potential) that is one-tenth of the Boltzmann limit for conventional transistors across a wide temperature range," the researchers wrote in their paper.

This team of researchers at the Chinese Academy of Sciences demonstrated the feasibility of fabricating highly efficient tunneling field-effect transistors using a vertical van der Waals heterostructure containing BP. In the future, the new device could be integrated in a number of electronics, potentially enhancing the performance of radiofrequency oscillators or multi-valued logic applications.

More information: Xiong Xiong et al. A transverse tunnelling field-effect transistor made from a van der Waals heterostructure, *Nature Electronics* (2020). DOI: 10.1038/s41928-019-0364-5