Study introduces new nanoscale vacuum channel transistors

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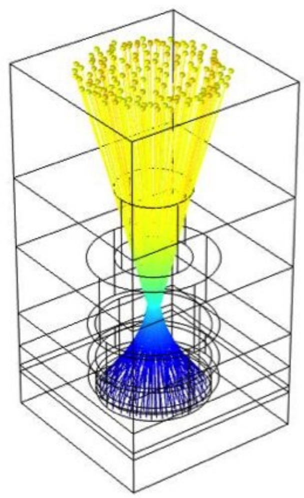

Electron emission trajectory through the vacuum transistor from the source (bottom) to the drain (top). Credit: Jin-Woo Han.

Vacuum tubes initially played a central role in the development of electronic devices. A few decades ago, however, researchers started replacing them with semiconductor transistors, small electronic components that can be used both as amplifiers and switches.

Although vacuum tubes are now rarely used in the development of electronics, they have several important advantages over transistors. For instance, they typically enable faster operation, better noise immunity and greater stability in extreme or harsh environments.

In a recent study, researchers at the NASA Ames Research Center have demonstrated that nanoscale vacuum channel transistors can be fabricated on silicon carbide wafers. Fabricating this type of transistor on the wafer scale could ultimately enable their widespread use, making them a viable alternative to solid-state electronics.

"Off-the-shelf-electronics have very little use for space missions because of the impact of radiation," Meyya Meyyappan, one of the researchers who carried out the study, told TechXplore. "Typically, radiation shielding or advanced radiation-aware circuit design would be needed, all of which are expensive, time consuming and result in hardware that is not the state-of-the-art. We have combined the best of vacuum physics and modern integrated circuit manufacturing to produce nanoscale vacuum transistors to overcome the above shortcomings."

When fabricating the nanoscale vacuum channel transistor, Jinwoo Han, the researcher responsible for the design and fabrication, followed a similar process to that employed when building conventional MOSFETs (metal oxide semiconductor field-effect transistors). The only difference was that he replaced the semiconductor channel, which in MOSFETs is placed between the source and the drain, with an empty channel.

"Unlike our earlier works on silicon surround gate nano vacuum transistors, we have flipped the orientation this time to vertical instead of a horizontal transistor," Meyyappan explained. "Since the channel has nothing, electrons can be faster than in semiconductors where they experience scattering with the lattice, and thus the operating frequency or speed can be higher."

The nanoscale vacuum channel transistor presented by the research was fabricated on 150mm silicon carbide wafers. When evaluating its performance, the researchers found that the drive current of their transistor scales linearly with the number of emitters on the source pad.

Meyyappan and his colleagues also compared its performance with that achieved by silicon vacuum channel transistors fabricated simultaneously. Their tests revealed that the silicon carbide device offers significantly superior long-term stability, which could be particularly beneficial for applications in space and in other challenging environments.

"We have fabricated our sub-100 nm feature scale vacuum channel transistors in both silicon and silicon carbide material systems," Han told TechXplore. "Their performance is encouraging and the transistors are not affected by radiation. The implication is that we can use our current manufacturing infrastructure and known material systems to make ultrasmall vacuum devices."

In the future, the findings gathered by Meyyappan, Han and their colleagues could promote the reintroduction of vacuum channel transistors for the fabrication of electronics, particularly for those designed to be used in space. Meanwhile, the researchers are planning to use the transistors they developed to build circuits, in order to apply them and test them in real-life settings.

More information: Jin-Woo Han et al. Nanoscale vacuum channel transistors fabricated on silicon carbide wafers, *Nature Electronics* (2019). DOI: 10.1038/s41928-019-0289-z

Jin-Woo Han et al. Nanoscale Vacuum Channel Transistor, *Nano Letters* (2017). DOI: 10.1021/acs.nanolett.6b04363