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How short the silicon and 2D MoS2 MOSFET conduction channel can be?

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The scaling of the traditional silicon MOSFETs, which are the basic devices of modern electronics, had resulted already in the channel length of 5 nm order. However, its further miniaturization faces the obstacles of fundamental nature: electrons in the ultra-short channels are tunneling freely through the barrier, and the current in the source-drain circuit is no longer governed by the gate voltage, making a transistor to lose its functionality .
The work estimates the minimum channel length of the silicon MOSFET transistor. Taking into account the real shape of potential barrier in the channel shows that the electron tunnels through a region significantly shorter than the physical length of the channel L in the presence of drain voltage, and so the available estimate of the minimum quantum constraint channel length in silicon MOSFET, Lmin ~ 1.2 nm, is significantly underestimated. The fact makes it clear why after reaching 5 nm working lengths of the channel it was impossible to reach the long-declared values of 3 nm under maintaining the proper level of functionality of the transistor. The estimates made in this work confirm that the fundamental scaling limits of silicon MOSFETs have almost been reached.
Therefore the new possibilities for MOSFETs miniaturization are studied intensively now, including the use of the novel 2D transition metal dichalcogenides for conduction channel materials. We propose in [3] a theoretical model for describing the operation of a transistor with a MoS2 monolayer channel, which allows to obtain an analytical approximation of the potential in the channel, that depends on the drain and gate voltages. On this basis we make estimates for the minimum channel lengths due to the fundamental restriction of quantum tunneling through the barrier. It is shown that the relatively large effective mass of electrons in the MoS2 monolayer allows to predict the creation of devices with channels of a significantly shorter (2.5 - 3 nm) length than in traditional silicon MOSFETs. The ultra-short channel and high enough (of the order of silicon one) mobility of electrons in MoS2 monolayer on the hafnium oxide substrate, makes this transistor promising for the ultra-fast electronics of new generation, and, in particular potentially suitable for 5G devices.

Topics

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