The Shrinking Transistor

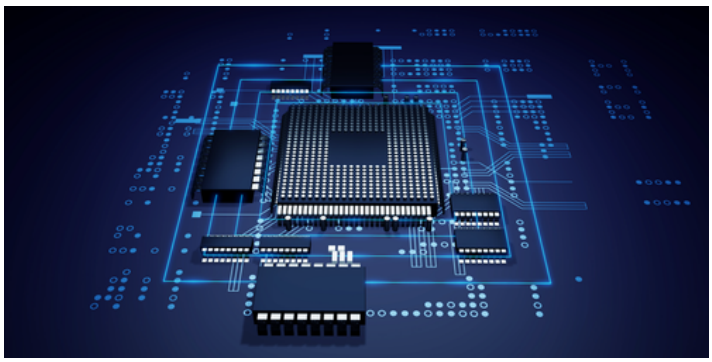
Researchers have identified the best silicon and silicon dioxide materials for the next generation of transistors, which are expected to be just a nanometer long.

By **Monica Bobra**

In 1965, Gordon Moore famously predicted that the number of transistors on an integrated circuit would double about every two years. While the increase still roughly follows that prediction, this trend will eventually slow because shrinking transistors any further will introduce quantum-mechanical effects, such as tunneling, which can degrade performance. Now, Ye-Fei Li and Zhi-Pan Liu of Fudan University, China, have identified two semiconductor materials that should be robust to tunneling when formed into a transistor structure that has lateral dimensions as small as one nanometer [**1**].

In their study, Li and Liu used a machine-learning method to simulate thousands of so-called field-effect transistors. These transistors combine a semiconducting layer, usually silicon (Si), together with an insulating layer, usually silicon dioxide (SiO_2), to modulate current flow. The duo used a different combination of lattice orientations for Si and SiO_2 to figure out which performed the best on nanometer scales.

Of the 2497 simulated lattice structures of Si and SiO_2 that they considered, the duo found that only 40 contained a pattern that repeated itself every nanometer. Of those 40, only 10 were stable—their interfacial structure had a similar energy to their bulk structure—a requirement for a robust transistor. They also found that the orientation of the two materials relative to each other was key to effective device operation. Ultimately, they identified two systems, $\mathrm{Si}(210)/\mathrm{SiO_2}(102)$ and $\mathrm{Si}(211)/\mathrm{SiO_2}(112)$, that minimized quantum tunneling effects.



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The researchers now plan to use their technique to study other transistor materials, such as gallium nitride and silicon carbide. Transistors built from those materials can withstand higher temperatures and handle higher voltages than silicon ones, making them ideal for use in technologies such as electric cars and trains.

Monica Bobra is a research scientist and a contributing editor for *Sky & Telescope* magazine.

REFERENCES

1. Y. F. Li and Z. P. Liu, "Smallest stable Si/SiO_2 interface that suppresses quantum tunneling from machine-learning-based global search," **Phys. Rev. Lett. 128, 226102 (2022).**