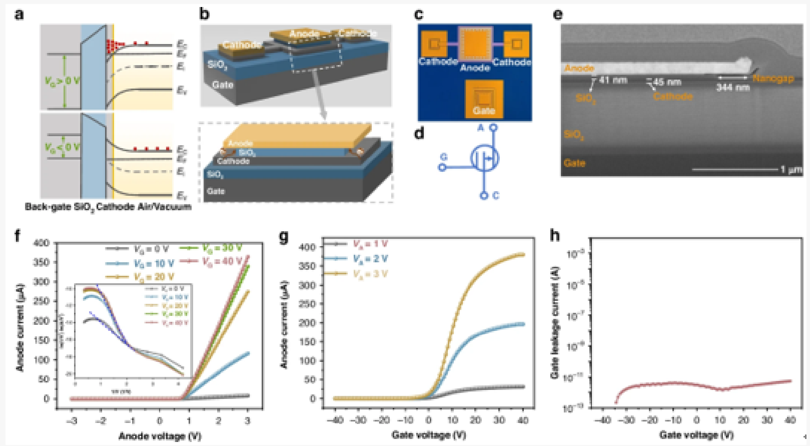
A tiny vacuum tube that could outrun today’s transistors – no gate leak, no problem

FAYETTEVILLE, GA, UNITED STATES, June 5, 2026 /EINPresswire.com/ -- For decades, the speed of transistors has been approaching its physical limit. Now, researchers have built a new type of vacuum/air channel electron tube that completely eliminates a fatal flaw that has kept such devices out of integrated circuits: gate leakage current. By modulating electron concentration at the cathode instead of intercepting electrons mid flight, the device allows all emitted electrons to reach the anode.



Working principle, device structure, chip photo, device symbols and device characteristics of CMVET.

Planar vacuum electron tubes made with microelectronics technology have been explored for over a decade as a potential successor to solid‑state transistors, because electrons in vacuum can travel near the speed of light – three orders of magnitude faster than in silicon. But all previous designs suffered from the same fundamental flaw: when the gate tries to control the current, electrons end up hitting the gate instead of the anode, creating unavoidable leakage. That leakage has made it impossible to integrate these tubes into functional circuits. Based on these challenges, there is an urgent need to develop a fundamentally different operating principle that can break this deadlock and finally bring vacuum tubes into integrated circuits.

A team led by researchers from Shanghai Jiao Tong University and Shaoxing University, China, reports the new device in the journal Microsystems & Nanoengineering, published (DOI: 10.1038/s41378-026-01234-z) on 20 April 2026. The work describes a cathode‑modulated vacuum/air‑channel electron tube (CMVET) fabricated using standard IC‑compatible processes on silicon‑on‑insulator wafers. The device has been tested in common‑source amplifiers, differential amplifiers, cascade amplifiers, and even NAND and NOR gates – marking the first time a vacuum/air‑channel electron tube has successfully entered functional integrated circuit blocks.

The CMVET solves the gate‑leakage problem through a clever reversal of roles. Instead of using the gate to block or divert electrons on their way to the anode, the gate modulates the electron concentration inside the cathode itself. A back gate, separated by an oxide layer, bends the energy band of the ultrathin silicon cathode (just 45 nm thick). A positive gate voltage pulls electrons toward the cathode surface, increasing the field‑emission current; a negative voltage repels them, reducing emission. Because every electron that leaves the cathode reaches the anode, the gate current is suppressed below 10^{-11} A – orders of magnitude lower than most previously reported tubes.

The device operates at room temperature and atmospheric pressure, and its output characteristics are distinctly non‑saturating: the current keeps rising with anode voltage, unlike MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistor) that flatten out. That difference demanded new circuit design considerations, but the team successfully demonstrated amplifiers with gains up to 1.6 and logic gates with clear high/low output levels (around 4.5 V and 1.9 V for NAND, 4 V and 1.1 V for NOR). The SEM images and electrical measurements confirm a switch current ratio of roughly 10^4 and a transconductance of about 23 μS.

“We’ve worked on this problem for years, because everyone knows that if you could make vacuum tubes work again at the chip scale, the speed advantage would be enormous,” the authors said. “The reason previous attempts failed was always the same – the gate leaked. By controlling the electron supply at the cathode instead of trying to catch electrons in mid‑air, we finally got rid of that leakage. Seeing the same device work as an amplifier, a differential pair, and even a NAND gate on the test bench was the moment we realized this approach actually has a future.”

The immediate implication is a practical path toward monolithic vacuum‑tube integrated circuits that could operate at speeds far beyond today’s transistors, particularly in high‑frequency and harsh‑environment applications where solid‑state devices struggle. Because vacuum channels are immune to radiation and operate over wide temperature ranges, CMVET‑based circuits could find uses in aerospace, defense, and satellite electronics. The fabrication process is already IC‑compatible, using standard oxidation, deposition, etching, and ion implantation. While the current device is non‑saturating – a quirk that limits gain in some configurations – the team notes that reducing this effect is the next clear engineering target. For now, a decades‑old roadblock has finally been removed.

References
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Lucy Wang
BioDesign Research
email us here
