Tiny arm shuttles electrons in a new transistor

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Using a vibrating arm less than one-millionth of an inch long and one-thousand times thinner than a human hair, a new transistor toggles on and off through the movement of a single electron.

The infinitesimal size and low power requirements of this **single electron transistor** (SET), created by UW-Madison engineering professor Robert Blick and physicist Dominik Scheible of Ludwig-Maximilians University in Munich, could eventually lead to advances such as much tinier semiconductor chips; more powerful, yet less power-hungry, cell phones; and long-lived remote sensors for monitoring everything from airborne toxins to forest fires.

And unlike earlier SETs, the device is easily manufactured in silicon and operates at room - rather than super-low - temperature, allowing its integration into existing, silicon-based circuits, says Blick.

Blick and Scheible describe the device in the June 2004 issue of Applied Physics Letters and have applied for a patent on it through the Wisconsin Alumni Research Foundation, UW-Madison's patenting and licensing organization.

Transistors are best known as the workhorses of the computing world; a computer's microprocessor chip contains millions of these tiny, voltage-controlled switches. The off-and-on position of each transistor corresponds to the 0's and 1's, or bits of information, a computer uses to calculate, store data and do everything else computers do.

In a conventional transistor, thousands of electrons must flow for the transistor to toggle between 0 and 1. "When you use 100,000 electrons to switch a single bit of information inside a computer containing megabytes (8.5 million bits) or gigabytes (8.5 billion bits) of information, a lot of heat is dissipated," says Blick.

This heat - the result of the electrons' energy - limits the number of conventional transistors that can be squeezed together on a single chip.

In Blick's device, on the other hand, the "on" or "1" state is represented by just a single electron. Since it uses so many fewer electrons, his transistor will generate much less heat and require less power to move the electrons around - a feature very important in battery-powered mobile devices, such as cell phones.

Blick and Scheible's transistor consists of a minuscule vibrating arm topped by a gold tip, or island. The island nestles between two electrodes, known as the source and drain. When the researchers apply voltage to the source, the arm begins vibrating at a frequency of 350 to 400 million cycles per second between the electrodes. Each time the arm swings into contact with the source, a single electron hops onto the island, where its presence is detected to signify the "1" state. The arm then ferries the electron to the drain.

The incorporation of a mechanical arm into the transistor confers several advantages, says Blick. For example, his transistor withstands radiation much better than traditional transistors that work purely through electronic means. This could lead to more robust electronics for satellites or other devices bombarded by high radiation levels.

The SET also exhibits higher signal-to-noise ratios for signal processing operations. Because they are solid devices, standard transistors in the off position always allow a small amount of current, or electrons, to leak through, causing a background signal, Blick says. But in his device, the arm in its inactive, non-oscillating state has absolutely no contact with the two electrodes, completely blocking current flow.

Blick and Scheible originally designed a more elaborate SET whose manufacture required a half dozen processing steps. But when a batch of the devices - made in Germany and brought to Madison for study - was accidentally destroyed, the scientists began asking how they could quickly and easily produce more. It was then they conceived of the mechanical arm and the simplified fabrication process, involving only a lithography step followed by dry etching.

"It was the beauty and simplicity of the new design that convinced us of the merit of the mechanical approach," says Blick. "And then, of course, we were sort of mad at ourselves that we didn't think of it before."

Source: UW-Madison