Physicists invent plastic diode

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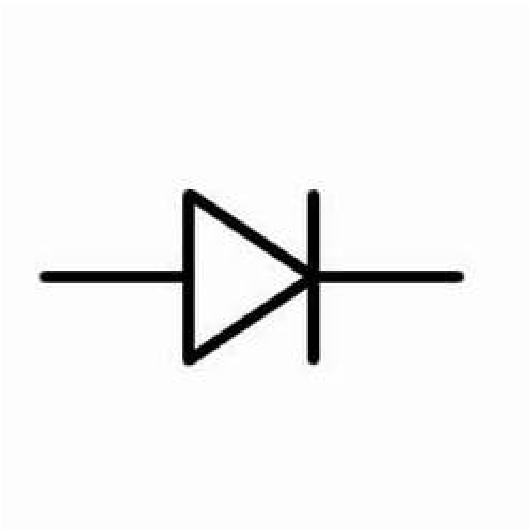

Ohio State University researchers have invented a new organic polymer tunnel diode – an electronic component that could one day lead to flexible, low power plastic computer memory and plastic logic circuits on computer chips. Today, computer chips use mainly inorganic silicon.

The diode transmits electrical current at room temperature, and its design lends itself to easy, inexpensive manufacturing for smart cards and other memory devices, said Paul Berger, a professor of electrical and computer engineering and professor of physics at Ohio State.

In tests, the team was able to fashion two diodes into a simple computer chip device called a logic switch, which was powered by the voltage equivalent to an ordinary watch battery.

Berger and his students describe their patent-pending invention in the current issue of the scientific journal *Applied Physics Letters*.

Most plastics don't conduct electricity, Berger explained. That fact hasn't stopped researchers from trying to build plastic computer chips, which could be used in lightweight, flexible electronic devices. In their most successful efforts, some groups have coaxed modest numbers of electrons through conducting plastics using quantum mechanical effects – but then only by painstakingly manipulating individual molecules of plastic at cryogenic temperatures. Those experiments have also been difficult to replicate.

Berger and his students got around that problem by taking the opposite approach. Instead of working with one plastic molecule at a time, they painted a thick layer of plastic on top of traditional chip materials, with a specially-designed layer of titanium oxide sandwiched in-between.

They got the idea in 2003 when Sita Asar – then an undergraduate physics student at Ohio State – was designing a plastic solar cell in Berger's lab. The device was designed to convert solar energy to electrical energy.

When he looked at the results of one of Asar's experiments, Berger noticed something unusual – a tiny blip in an otherwise smooth graph line charting the amount of electrical current passing through the material. At low voltages, the current spiked, and then returned to normal.

On closer inspection, he saw that the plastic was showing an effect called "negative differential resistance," in which the current actually decreases over a particular range of increasing voltage. The effect resembled that shown by a semiconductor device called a tunnel diode.

Diodes are one-way conductors that typically power amplifiers for devices such as stereo speakers. Tunnel diodes are so named because they transmit electricity via a quantum mechanical effect known as tunneling, which lets electrons pass through barriers unhindered.

Berger later worked with graduate students Woo-Jun Yoon and Sung-Yong Chung to refine a polymer tunnel diode design that demonstrates the same kind of blip that the solar cell did, but more robustly and more reliably. They also embarked on a study to uncover the physical mechanism which created this effect.

The team is still trying to fully understand why the design works as well as it does, but they have been able to achieve strong quantum mechanical effects in the plastic without manipulating individual molecules.

“The titanium oxide is the key,” Berger said. “In our experiments, when we replace it with anything else, the phenomenon goes away.”

Other research groups have tried to marry polymer tunnel diodes to titanium oxide without success. The breakthrough came when Berger decided to deposit a layer of pure titanium on a chip, and then carefully oxidize it later, instead of depositing titanium oxide all at once, as the others had done. He suspects that it's the extra control he exerted over the oxidation process that ultimately led to the diode's enhanced performance.

He and the students were able to combine two plastic tunnel diodes to form a simple logic gate – the structure that writes data on a computer chip.

The gate operated on a mere 1.5 volts of electricity – an amount equal to a watch battery. It also worked at room temperature. These results suggest that it could one day be easily incorporated into traditional computer chips for devices that required low power, Berger said.

Moreover, he and his students created their plastic layer through a process called spin casting, which costs significantly less than the processes currently used to machine silicon chips. In spin casting, drops of a liquid plastic solution are deposited on a surface, and the surface is spun at high speed to spread a thin coating evenly across the surface.

For all of the diode's good points, Berger stopped short of saying that it could lead to electronics made entirely of plastic.

“Plastic isn't going to replace silicon – at least, I don't advocate that. I think that plastic is going to augment silicon,” he said.

He envisions lightweight, portable electronics that knit silicon and plastic together to form a kind of hybrid computer logic circuit or memory. Devices like smart cards and other memory devices would be somewhat bendable and run on less power.

“This new diode is just another tool for the circuit designer's toolbox,” he said.

Source: Ohio State University