Building a better computer out of diamond

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Almost every electronic device of the past thirty years has had silicon circuits at its core. Now, Vanderbilt researchers are hoping to overcome certain weaknesses of silicon using an unusual material: diamond. The team has employed incredibly thin films of diamond to construct all the fundamental building blocks of a computer. Their functioning diamond circuits demonstrate that, when compared to silicon, diamond-based electronics are faster, cooler, and more resistant to heat and radiation. NASA has partnered with the team to develop a heat-resistant sensor. Eventually, the team hopes to incorporate their diamond circuits into general electronic devices.

All electronic devices, whether an iPod, a digital camera, or a satellite in orbit, operate by controlling the flow of electrons through circuits. These circuits can function as computers by channelling electrons across millions of tiny structures, known as transistors and logic gates. The team of Vanderbilt electrical engineers has successfully built both of these electronic building blocks out of nano-scale diamond films. Professors Jimmy Davidson and Weng Poo Kang believe their unique design will offer an alternative to traditional silicon circuits.

Why Diamond?

In modern, silicon-based electronics, electrons move through--and collide with--solid matter as they cross transistors and logic gates. "It's like moving a BB through a sea of bowling balls," Davidson, a research professor at Vanderbilt, explains. Each collision produces heat and slows the electron stream. Additionally, outside forces, such as high temperature and radiation, can shake up the bowling balls, disrupting the stream of electrons. Moving the bowling balls out of the way and allowing the electrons to move through an empty space, known as a vacuum gap, can make computation faster and more resistant to interference.

Early, room-sized electronic computers used red hot metal to force electrons across such a vacuum gap, but produced too much heat in the process. Electrical engineers side-stepped the issue by using silicon, which cannot emit electrons, but can easily pass them through solid material. However, as faster computers approach the limits of silicon circuits, some researchers have begun to reconsider vacuum gap circuits. Diamond is known to be an incredible low-temperature electron emitter, making it ideal for vacuum gap circuits. The problem has been making diamond emitters small enough to fit into modern electronics.

Compared to silicon, diamond is far more difficult to shape. "It was a lot of trial and error," says Nikkon Ghosh, the Vanderbilt team's graduate student, responsible for etching the diamond circuits. Nikkon created a nano diamond film, less than one tenth the width of a human hair, out of a reaction of hydrogen and methane gas, two relatively inexpensive materials, before attempting to carve the desired circuits into the surface.

The numerous trials required two and a half year of work on expensive scientific equipment in multiple labs, before Nikkon perfected the fabrication technique.

Applications in Harsh Environments

Working with NASA, the team has created nano diamond pressure gauges which monitor conditions in a NASA wind tunnel, where temperatures can reach over a thousand degrees Fahrenheit. Such high temperatures cause interference in silicon circuits, but do not affect diamond vacuum gap circuits. NASA hopes the gauges will help with the development of a new plane capable of flying at twelve times the speed of sound.

Other applications could include electronic sensors and circuits in the bottom of deep oil wells or scientific research in high temperature environments. The diamond circuits' unique immunity to interference from radiation makes them well suited for use in nuclear power plants, on satellites bathed in solar radiation, and in military electronics that could be exposed to electromagnetic attack. As many of these applications require only simple electronic circuits, the basic transistors and logic gates developed by the team could be ready in the next several years.

A diamond computer on your desk?

Davidson believes their diamond circuits hold an even greater potential than these niche applications. "Diamond-based devices have the potential to operate at higher speeds and require less power than silicon-based devices," he predicts. If Davidson is correct, diamond circuits could eventually be used to build smaller, and thus faster, computer processors. As the fabrication process only requires methane and hydrogen, two very abundant materials, Davidson believes the cost could eventually become competitive with silicon manufacturing, making diamond-based computers available to consumers.

But that doesn't mean silicon computers will disappear anytime soon. "Silicon is so perfectly matched to the jobs that it does, that it is unlikely to be replaced in my lifetime and probably not in yours," says Robert Weller, a Professor of Electrical Engineering at Vanderbilt who works with silicon circuits. "Diamond and other special materials are potentially very important, but none is likely to replace silicon wholesale. It's not just technology, it's also economics."

Still, the Vanderbilt team has begun work on more complex diamond circuits, with the plan of eventually introducing diamond circuits into general electronics. "My vision," Davidson explains, "is to have a reasonably interesting, simple electronic device of diamond vacuum emitters in a package that I can put on a table for someone to say 'Oh yeah that looks like something I would find in the guts of my computer.'"