

ECE

ELECTRICAL AND COMPUTER ENGINEERING

RESEARCH REPORT

DEVELOPING THE WORLD'S SMALLEST TRANSISTOR

Just when you thought cell phones couldn't (or shouldn't) get any smaller, Paul Bergstrom predicts that pretty soon you'll be slipping one into your wallet alongside your driver's license. "I can see the day when cell phones are as thin as a credit card," says Bergstrom, an associate professor of electrical and computer engineering.

Bergstrom is working on developing nanoscale electronic devices. It's not just a matter of making things littler. They will also be able to do far more, or, as Bergstrom says, "They can be integrated in smaller packages with a great deal more functionality."

To accomplish this, Bergstrom is working on developing the smallest transistor ever: a single electron transistor. "It could open up whole new aspects of electronics," he says. "A single electron transistor is a quantum device—it has very peculiar behavior."



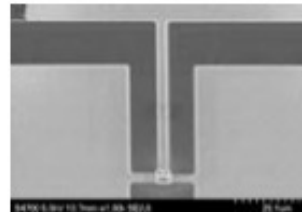
The transistor is about 40 nanometers across. Line up 6,000 of them and they'd be about as long as a human hair is wide. And on each transistor is a series of quantum dots. "Each dot is a 3D hemisphere less than 10 nanometers across," Bergstrom explains. "Electrons can be controllably trapped on that dot."

Transistors work by controlling the flow of electric current using a control electrode called a gate, functioning much like a water faucet,

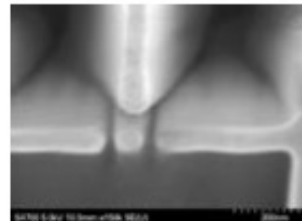
◀ Paul Bergstrom

creating the zeros and ones upon which all digital life depends. Quantum dots could change all that. By manipulating the potential energy of the electrons on each dot, "you could have multiple levels of logic," Bergstrom said, not just on or off. "Instead of having zero and one only, you could have zero, one, and two, or zero through three, and so forth," he said. The capability of digital electronic devices would increase significantly.

That said, these nano-transistors have one minor drawback. They only work at nano-temperatures. "We have to cool them to less than 4 degrees Kelvin," Bergstrom says. "That's accomplished by immersing them in liquid helium. The colder they are, the more tractable electrons become. Moving them around precisely at warmer temps is a big hassle."



◀ Magnified SEM view showing the active device area of the SET at the center connecting leads



◀ SEM view of the active SET device showing quantum island definition and localization

With funding from the Microsystems Technology Office of the Defense Advanced Research Projects Agency and the Army Research Lab, Bergstrom and his team are working to make single electron transistors that work at room temperature. Results to date have been encouraging.

"The formation of these ultra-small quantum dots is very difficult," Bergstrom said. "We're trying to engineer them with a focused ion-beam etching tool, to put each particle exactly where it should be." "This is an area with great potential," he added. "It could open up whole new aspects of the electronics industry."

◀ Bergstrom and his team in the Microfabrication Facility's Clean Room