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SPINTRONICS BEGINS TO LOOK PLAUSIBLE

"Even if we have to compute in a vacuum chamber, spintronics will be ten times faster than anything else and everybody will want it," University of Arkansas physicist Vincent LaBella tells "Inside R&D." He has just moved this new kind of electronics, in which the electrons' spins, not their charge, make things happen, into a much more likely stage. He sees a way for the concept to work in the real world. Spintronics has had a beginning: We can easily build a source of electrons with specified spin polarizations and we can get them to stay polarized a long time, 100 microseconds. What we hadn't been able to do is get the polarized electrons from the source into silicon without losing it. The Arkansas lab has done it. They have injected a large spin-polarized current from a ferromagnetic metal into a nonferromagnetic semiconductor at 100. And they have moved their current of spin-polarized electrons--all spin-up or all spin-down--with a 92% efficiency.

The promise of spintronics is high. Using the electron's spin, the intrinsic angular momentum of the electron which, by the rules of quantum mechanics can be either up or down, spintronics researchers hope to revolutionize computers and other electronic technologies. If they can control and move the spins the way they want, they will be able to build devices analogous to conventional electronic switches and transistors, but many times smaller. The technology now seems closer to reality than quantum computing—and a lot more versatile (even when and if quantum computing becomes practical it will only be good for certain kinds of calculations).

But to realize its potential, spintronics must not only achieve coherent transport of spins through materials, but be able to transfer the polarized electrons from a ferromagnetic to a nonferromagnetic semiconductor without degradation. Ferromagnetic metal contacts have given spin-injection of only a few percent at 4 K. Injection efficiencies have been as high as 90% using ferromagnetic semiconductors as contacts, but again you have to get the device down to 4 K.

This all-semiconductor approach encouraged the thought that an epitaxial lattice-matched system was needed for efficient spin injection, a thought dispelled by other experiments which have achieved high efficiencies with large lattice mismatches. The Arkansas researchers realized that they would have to determine the origin of spin-flip scattering mechanisms on a nanometer-length scale.

Going to STS (scanning tunneling spectroscopy), they found that vacuum tunneling preserves the spin-polarization properties of the electrons. They also found that surface features can disrupt it. Their efficiency is only high when the current tunnels into a flat terrace on the material's surface. When the injection point is near a nanoscale step, the efficiency drops by a factor of six. They use a 100% spin-polarized STM (scanning tunneling microscopy) tip as the electron source to locally inject polarized electrons into a p-type GaAs(110) surface while measuring the polarization state of the recombination luminescence.

As the step reduced the injection efficiency by a factor of six, the spin-relaxation lifetime was reduced by a factor of 12--all due to the metallic of the step edge. The metallic property has two implications. It indicates that there would be nonradiative, phonon channels to the valence band stages, explaining the large decrease in light intensity. Second, the half-filled bonds would create unpaired spins which would substantially affect the spin-injection process through spin-spin scattering events. This is how the step reduces the spin-relaxation lifetime.

Another implication: We might be able to use both the charge and spin of the electron in future semiconductor devices.

How far are we from practical spintronics? LaBella agrees with most in the field that we are still 10 to 20 years away. But he also reminds us that the same had been expected of GMR (giant magnetoresistance) when it had reached this point. With heavy research (and a bit of luck), we had GMR in hard drives in five years.

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