## Electromagnets for micromotors

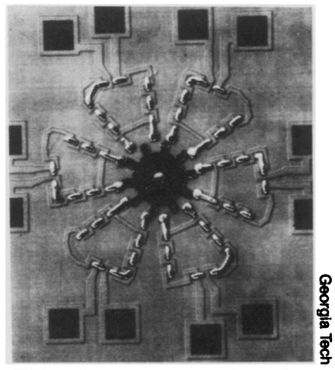
Electromagnets in the form of coils of copper wire wound around iron cores have long served as crucial components of transformers, relays, electric motors, and other devices. But the difficulty of fabricating such coils, or inductors, on a silicon chip has severely limited their use in electronic circuitry. Now, a team of electrical engineers at the Georgia Institute of Technology in Atlanta has come up with an innovative technique for constructing tiny electrical windings and nickel-iron cores directly on a silicon surface.

"We have developed fabrication technologies that allow people for the first time to make these devices on the surface of a silicon chip in fully integrated form," says Georgia Tech's Mark G. Allen. "We have made prototype magnetic relays, magnetic micromotors, and microinductors that can be used in voltage converters."

To make it possible to produce these devices on a silicon chip, the researchers ended up turning the conventional coil inductor inside out, in effect "wrapping" the nickel-iron core around the electrical conductor. "From a fabrication point of view, it's easier to wrap a core . . . around a . . . zigzag of wire than it is to wrap wire around a planar core," Allen says. Yet the magnetic effect remains the same.

The fabrication process begins with the deposition of a thick, patterned layer of a nickel-iron alloy atop a silicon surface. This base layer is then coated with an insulating polymer blanket. A carefully positioned mat of zigzagging copper wires makes up the next layer, which is also topped by a polymer coating. Holes drilled vertically through the polymer layers and filled with metal link the base layer with a top layer of nickel-iron alloy to complete the structure. Allowing electrical current to flow through the copper layer turns this microscopic sandwich into a miniature electromagnet.

This procedure improves on previous fabrication techniques, in which iron cores and electrical windings were constructed separately before being added to electronic circuits. The integrated magnetic inductors also operate at lower voltages than devices based on competing technologies that involve electrostatic forces. Thus, magnetic inductors may prove useful in dust-filled environments, electrically conducting liquids, and other settings in which high voltages are unacceptable.



Georgia Tech

*This micromotor consists of a ring of miniature electromagnets surrounding a nickel-iron rotor, a toothed disk 500 micrometers wide and 40 micrometers thick.*

Allen and his coworkers have already demonstrated the potential of their fabrication technique for creating tiny relays, which may someday replace transistors for rapidly switching on or off certain types of high-frequency signals. They have also looked into the possibility of making miniature voltage converters, which could dramatically reduce the size and weight of power supplies for laptop computers and other portable equipment. The same technology has been used to create magnetic micromotors.