James' company employs 20 scientists. Some are trying to make sheep more eff -cient producers of FIX, the salvation for many hemophiliacs, and AAT, which might be used to treat emphysema patients. Others are working on means of purifying the proteins from the ewes' milk. "There are already well-established techniques for getting rid of the fats in milk and precipitating out some of the proteins," says James. "We have to go a bit further."

Transgenic animals will no doubt be used for making proteins that cannot be obtained any other way. For an entrepreneur like James, however, their great advantage is economic. Making a gene construct, demonstrating it in mice, and producing the f rst transgenic sheep might cost a couple of million dollars. Building up a milking flock might cost another million. "That's nothing by pharmaceutical standards," he says.

James calculates that to satisfy the potential market for AAT in an economic fashion he will need sheep that can secrete 2 grams of AAT per liter of milk. Clark and his team have a paper in press reporting the highest ever levels of AAT in milk, 7 grams per liter. The method is not yet practical because the source of the milk is mice, who make only microliters each. But these results do demonstrate that transgenic animals may soon revolutionize the supply of therapeutic compounds. James has his eye on tissue plasminogen activator, for dissolving blood clots, erythropoietin, which controls the synthesis of red blood cells, and many other proteins. Other companies, too, are eyeing transgenic animals for making these products, and it will be a race to see who can make the f rst sales. But James is conf dent. "I can't tell you what our f rst product will be," he says, "but we will have one, and soon, I can tell you that."

The kind of thing James is doing is only the f rst practical fruit of the work that will be done at the new center, which the AFRC last year pledged to support for 10 years to the tune of some £15 million (about $25 million). Among the others might be cows that produce milk better suited to human digestion, disease-resistant livestock, substances that reverse the transformation of ordinary cells into cancerous ones, and maybe even genetic studies of such things as aging and memory. And all this stemming from a government-supported research unit that was on the verge of dissolution a mere 7 years ago.

"It is extraordinary," says Lathe, now director of the CAGR. "A few years ago, the AFRC didn't know what to do with us in Edinburgh. Now we have so many good projects we hardly know where to begin."

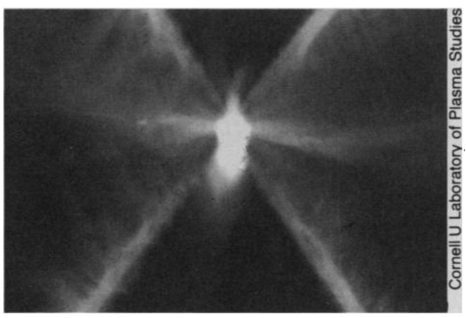
■ Jeremy Cherfas

X Marks the Spot

A recently developed method of creating powerful x-rays with an x-shaped pair of wires could be x-actly what the semiconductor industry needs. A group of researchers at Cornell University in Ithaca, New York, has shown that a simple x-ray source could lead to a relatively inexpensive way to make advanced computer chips.

Today, the patterns on integrated circuit chips are etched out of semiconductors using optical or ultraviolet lithography. The semiconductor is first covered with a layer of photosensitive material, or photoresist, and this in turn is covered by a stencil-like mask in the shape of the desired electric circuit. When the chip is exposed to visible or ultraviolet light, a chemical change takes place in all of the unprotected areas. Then, depending on the process, either the exposed or the unexposed part of the photoresist—with the semiconductor lying directly underneath it—is etched away by acid, leaving a pattern in the shape of the mask.

But if computer chips are to continue getting smaller, industry experts say, lithography will probably have to be done with x-rays, which have shorter wavelengths than visible or ultraviolet light and thus can create much smaller circuits. The problem is that machines that can produce x-rays powerful and concentrated enough for lithography are both expensive and cumbersome. One option, for instance, is to extract x-rays from a synchrotron—a ring-shaped particle accelerator in which electrons give off x-rays as they are deflected in a strong magnetic field. Several Japanese companies are building compact synchrotrons for x-ray lithography, but these machines cost tens of millions of dollars and, at 10 meters across, they are only relatively "compact."



X-ray crossing. *The bright spot is producing x-rays of wavelength 7.2 to 7.8 angstroms.*

The Cornell method may make the synchrotron extraneous, however. The team of David Hammer, Daniel Kalantar, Nian-Sheng Qi, and Kailash Mittal at Cornell's Laboratory of Plasma Studies generated high-intensity x-rays, comparable to those from a synthrotron, by sending short, powerful pulses of electric current—in one experiment they used an 80-nanosecond, 450,000-ampere pulse—through crossed wires of aluminum or magnesium. The intense current vaporizes the very fine wires, Kalantar explains, and also ionizes them, leaving the atoms with only one or two electrons. These electrons are in excited energy states, and when they drop down to the ground state they emit x-rays.

Even after the wires are vaporized, the resulting plasma continues to carry the electric current, and magnetic fields created by this current concentrate the plasma and further intensify its x-ray emissions. The magnetic fields also pinch the plasma in toward the center of the "x," creating an intense concentration of plasma at that point, so that much of the x-radiation comes from one small spot, called the x-pinch.

When the Cornell group measured the radiation from the x-pinch, they found that the aluminum wires generated about 23 joules of x-ray radiation with wavelengths from 7.2 to 7.8 angstroms. With six magnesium wires all meeting at one point and a current of 550,000 amperes, they measured 85 joules at 8.4 to 9.2 angstroms. That should be good enough, Hammer says, for x-ray lithography, although the group has not yet tried to expose a photoresist with x-rays generated by their device.

If the x-rays test out well on photoresists, the researchers will build a prototype machine to do x-ray lithography on computer chips. The major tasks here will be building a mechanical device that replaces the wires after they have been vaporized and designing a pulsed power generator to supply electrical pulses with optimum characteristics. It should not be difficult to engineer a machine with these capabilities, says Cornell colleague Steve Glidden, who has joined with Hammer and Kalantar to form a company to build the machine. The researchers will also have to find a way to protect the computer chips from any debris created by the vaporizing wires and to make sure that the x-pinch produces no harmful radiation along with the desired x-rays.

Glidden predicts that they will be able to build an x-ray lithography machine that generates ten pulses of x-rays a second for under $500,000. It would also be much smaller than a compact synchrotron—probably only a few cubic meters, Glidden says. All in all, he says, the prospects are x-cellent.

■ Robert Pool