SCIENCE NEWS of the week

Spinning Their Way to Nuclear Fusion

For a long time experimenters have known how to polarize beams of particles — that is, to line up all their spins in one direction, and so enhance the probability that various interactions will occur. Now physicists involved in nuclear fusion seem on the verge of taking advantage of polarization of nuclei to enhance the probability of fusion. According to Russell M. Kulsrud of Princeton University in Princeton, N.J., who spoke at the recent meeting in New Orleans of the Division of Plasma Physics of the American Physical Society, using polarized deuterons (deuterium nuclei) could increase the probability of fusion of deuterium and tritium nuclei by 50 percent, and thus significantly lower the threshold temperatures and confinement times necessary to ignite an energetically useful reaction. Polarization also promises much cleaner fusion reactions, ones in which radiation damage is significantly lessened or does not occur at all. (The subject is also treated in a paper in the Oct. 25 PHYSICAL REVIEW LETTERS by Kulsrud and Harold P. Furth and Ernest J. Valeo of Princeton and Maurice Goldhaber of Brookhaven National Laboratory.)

The idea of taking advantage of polarization is not itself new, but in the past physicists generally objected that the energy difference between the polarized and unpolarized states is so small, a millionth or a ten-millionth of an electron-volt, that the polarized state would relax back to an unpolarized equilibrium too fast to provide any advantage. Furthermore, arranging the polarization was a difficult and costly process. Thus, says Kulsrud, in the '60s and '70s there was virtually no interest in spin-polarized nuclei in the fusion community.

The current revival began in February 1982 with a meeting of Furth and Goldhaber at a cocktail party. In a discussion of orthohydrogen and parahydrogen, molecules that are distinguished by a similar spin polarization, it came out that the relaxation time is a week. By March, calculation had shown that the depolarization probability for deuterium in the conditions of a fusion experiment was much less than simple considerations of energy had led physicists to believe. Kulsrud's talk and the PRL paper are efforts to demonstrate this.

Meanwhile, work on a relatively cheap technique for producing polarized nuclei was underway. Valeo had suggested using optical pumping (that is, laser techniques) to polarize nuclei, and in March Robert F. Dicke and William Happer of Princeton and Furth and Goldhaber had produced polarized xenon, which lasted half an hour.

In the case of deuterium and tritium, the enhancement of fusion probabilities involves the energy levels of helium-5, "a nucleus that doesn't exist," Kulsrud says. That is, it is an unstable combination of deuterium and tritium that comes apart almost immediately into helium-4 and a neutron that carries away energy. But the formation of helium-5, with 3/2 units of spin, is particularly favored when the spins of deuterium (1) and tritium (1/2) are parallel to each other and add together. Statistical calculations show that starting out with all the deuterium polarized with spin upward yields 1.5 times the chance that this combination will come together compared to a sample with deuterium spins randomly oriented. (Polarizing the tritium, too, would give 3 times the chance, but that is still considered too difficult to do.) Furthermore, the energy-carrying neutrons come off in a preferred direction. This way they can more easily be caught and made to yield up their energy.

The other fusion reaction of general interest, deuterium-deuterium, would be enhanced between 1.6 and 2 times by polarization, according to work by Russian physicists B. P. Ad'yasevich and D. E. Fomenko. In a parallel development (and another talk at the New Orleans meeting) Bruno Coppi of Massachusetts Institute of Technology proposes that polarization and high density will permit use of a deuterium-helium-3 reaction. This reaction does not use radioactive fuel (tritium) and does not produce penetrating radiation (neutrons). It would thus be very clean. "We don't have helium-3 in nature," Coppi admits, "but then we don't have tritium in nature either." Both have to be made artificially.

It seems, Kulsrud says, the "Happer" method, the device referred to above, will extrapolate to the required production rate for a reactor. It consists of polarizing rubidium nuclei with laser light, then having them exchange polarization with deuterons. The means of introducing polarized nuclei into an experimental device, and managing them while there, are problems yet to be worked out technologically. The history of fusion physics records a number of good ideas that turned out to be not so spectacular in the nitty-gritty of experiment. This one has yet to prove itself, but a number of prominent people in the field are enthusiastic about it.

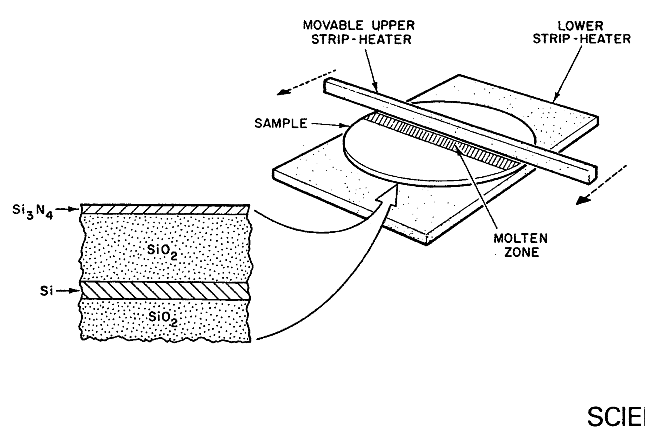
— *D.E. Thomsen*

Silicon crystals from born-again process

Imagine a wide-screen television set thin enough to hang on the wall. Envision a book-sized, high-speed computer that can display an entire page of print at one time. These are glimpses of silicon-based products of the future, perhaps the not-so-distant future. Results of studies presented at the recent Materials Research Society meeting in Boston, Mass., indicate that the ability to manufacture such flat-panel displays or compact high-speed logic devices may be within only several decades' reach.

Development of such products depends on the ability to "grow" crystals of silicon longer and thinner than those now used for integrated circuits and other solid-state devices. Naturally occurring silicon exists in either an amorphous (non-ordered) state or in patches of only short crystals. In order to get the longer device-quality crystals, the element must be melted and then re-solidified. Currently, this process involves "seeding" a vat of molten silicon with a single prototype crystal, which causes the melt to re-solidify into a huge crystalline block that in turn is cut into wafers. "This process is one that obviously works extremely well, and . . . current computer [processing] is based on it," says Walter L. Brown, one of the organizers of the MRS meeting. However, says Brown of Bell Laboratories in Murray Hill, N.J., wafers manufactured in this way are too thick to allow light to pass through them, so they cannot be used in flat-panel displays. Consequently, with few exceptions, the displays on television and com-

Geis et al



The Lincoln Laboratory set-up for the zone-melting recrystallization of silicon films with a moveable strip-heater oven.

puter screens are produced by bulky cathode ray tubes. (One exception is hand-held computer displays produced by a film of amorphous silicon; such devices, though, are much slower than their crystalline correlates would be.)

In addition, says Brown, with current silicon technology, there is no simple way to isolate the numerous wafers in a given device from each other; this limits the speed and voltage that now can be obtained with crystalline silicon. Therefore, says Brown, there is strong motivation not only to successfully grow a thin crystalline silicon film for flat-panel displays, but also to grow that film on an insulating substrate to prevent unwanted electrical interactions between the transistor devices that will be embedded in it. At the MRS meeting, several independent research groups reported progress on this front.

One of those groups was Michael Geis and colleagues of the Massachusetts Institute of Technology's Lincoln Laboratory in Lexington, Mass. They are trying to grow a thin-layered, device-quality silicon crystal using a technique called "zone-melting recrystallization." This process actually was first described in 1953 but then largely neglected, Geis says. Now, it is experiencing a rebirth, he says, due to the development of laser- and other heat source-methods that permit the melting of an entire silicon film in discrete zones.

In Geis's version of the zone-melting method, an insulating layer of quartz (SiO_2) first is laid down. Then, the thin film of amorphous silicon to be melted and recrystallized is placed on the insulation. Next, Geis and cohorts cap the silicon with a 2-micron layer of SiO_2 and a .03-micron layer of Si_3N_4; this double-layer encapsulant has been found to protect the silicon and to increase the probability that it will re-solidify into one single-oriented crystal. Finally, a graphite heater oven—a strip of carbon through which a current is passed — scans the sandwiched silicon, causing the silicon to melt, narrow-zone-by-narrow-zone. As the heater moves along, the trailing edge of liquid silicon re-solidifies into a thin, largely uniform, high-quality crystal structure.

Thus far, Geis and colleagues have not yet grown the desired perfect single crystal. Subboundaries, electrically inferior areas where ever-so-slightly different oriented crystals meet, still spontaneously appear on the film. However, the Lincoln group has discovered that by varying the temperature along their graphite strip-heater, they can manipulate where those defects occur. Such an ability to predict the location of defects could ensure that transistor devices are placed only on the defect-free areas of the film.

Moreover, says Geis, he and colleagues are "pretty close" to achieving growth of a single crystal. And, "there are several other groups close to it," he says; "I think we'll hear it reported in the next year or so." Says Brown, such an achievement would be "technologically *very* important."

—*L. Garmon*

Reagan appoints two

Earlier this year, James B. Edwards vowed not to leave the Department of Energy until his agency had been successfully dismantled. He thought better of the decision and resigned from the agency's top post on Nov. 5 to become president of the Medical University of South Carolina. "To be truthful," Edwards said in a departing address, "when I took this job, I knew that it was a losing proposition." But "all in all, it was worth leaving my oral surgery practice to take on the task of restructuring our energy problems." Donald Hodel, a 47-year-old lawyer and undersecretary of the Interior was immediately named by President Reagan to succeed Edwards as secretary of the department. Previously, Hodel served with the Georgia-Pacific Corp. and as administrator of the Bonneville Power Administration, a Northwest electric utility.

On Nov. 2, the President named Edward A. Knapp to replace National Science Foundation Director John B. Slaughter. Slaughter had resigned a day earlier to become chancellor of the University of Maryland at College Park. Appointed last September as NSF's assistant director for mathematics and physical sciences, Knapp had previously directed accelerator technology at Los Alamos National Laboratory in New Mexico.

Both appointments will require Senate confirmation. □

Berkeley voters ban ECT, shock psychiatric profession

The citizens of Berkeley, Calif., voted overwhelmingly last week to ban the use of electroconvulsive therapy, or ECT, within the city limits. The vote may represent the first occasion where citizens have taken the initiative in limiting the use of a specific medical practice. In response, organized psychiatry has raised questions not only about the wisdom but also about the constitutionality of the referendum.

Popularly known as shock therapy, ECT has been steeped in controversy since 1938, when it was first used in Italy as a treatment for psychiatric disorders. As the name suggests, ECT involves the use of electrical current (applied through electrodes to a patient's scalp) to cause convulsions; although it is not known how the convulsions work to abate psychiatric symptoms, many psychiatrists consider ECT an effective therapy (some call it the treatment of choice) for serious depression and catatonia. The ECT controversy focuses on side effects: where opponents argue that ECT treatments cause everything from headaches and nausea to significant memory loss, brain damage and even death, proponents say that ECT has been so improved as to eliminate significant risk. It is the prohibition that is dangerous, psychiatrists say, because it denies patients their right to what could be a life-saving therapy.

The Berkeley initiative was organized by the Coalition to Stop Electroshock, a patients' rights group that gathered the 1,400 signatures necessary to put the measure on the ballot. Voters approved the prohibition by a margin of 5-3, making the administration of ECT a misdemeanor punishable by a $500 fine or six months in jail.

According to Berkeley psychiatrist Wilson Yandell, who headed the opposition to the measure, the immediate consequence of the new law will be inconvenience rather than real danger; very few patients now receive ECT in Berkeley (48 in 1981), and those who require the therapy can travel 15 minutes to nearby Oakland where ECT is legal. Of much greater concern, Yandell says, is that citizens have passed a law that denies mental patients their right to appropriate treatment and intrudes upon the prerogatives of the medical profession.

Yandell says that the constitutionality of the new law will be challenged. By prohibiting the use of ECT, the Berkeley law contradicts the existing state law, which permits the use of ECT with patients who have volunteered informed consent. Ironically, Yandell says, the California law is one of the most restrictive in the nation, requiring the recommendation of two physicians; counseling about the possible side effects and the controversy surrounding ECT; a 24-hour waiting period before therapy begins; and the absolute right of the patient to withdraw from ECT at any time. Opponents of ECT argue that patients who receive ECT are so debilitated by depression that they are incapable of understanding the risks and offering truly informed consent.

In a related development, the Food and Drug Administration last week began hearings on a petition by the American Psychiatric Association to reclassify ECT devices. Currently the machines are included in the most stringent class of neurological devices, meaning that the government could prohibit marketing and demand further research on the safety and effectiveness of the product. APA would like to see the devices reclassified so that the only condition for marketing would be that the machines meet a performance standard; APA has written such a standard, which the FDA will be evaluating along with testimony from industry, mental health professionals and patients.

—*W. Herbert*