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.

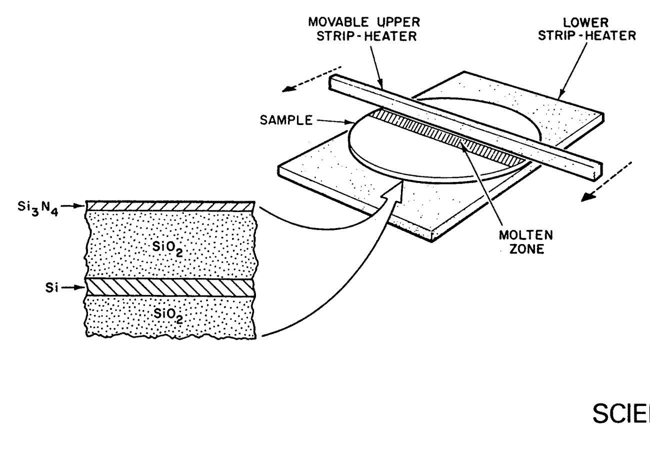
It seems, Kulsrud says, the "Happer" method, the device referred to above, will extrapolate to the required production rate for a reactor. It consists of polarizing rubidium nuclei with laser light, then having them exchange polarization with deuterons. The means of introducing polarized nuclei into 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-



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