APPOINTMENTS

Jerome M. Pollack, acting president, Fairleigh Dickinson University, to president. . . . **Max Milam**, former chairman, political science department, University of Arkansas, to president, University of Nevada, Reno. . . . **Pauline Jewett**, professor of political science, Carleton University, to president, Simon Fraser University. . . . **Frank Newman**, director, university relations, Stanford University, to president, University of Rhode Island. . . . **Mortimer H. Appley**, associate provost, University of Massachusetts, to president, Clark University. . . . **Richard W. Lounsbury**, professor of geology, Memphis State University, to chairman, geology department at the university. . . . **Mark N. Christensen**, vice-chancellor, University of California, Berkeley, to chancellor, University of California, Santa Cruz. . . . **Philip M. Rice**, dean, College of Language and Literature, University of South Florida, to dean, Graduate School, University of Connecticut.

RESEARCH NEWS

Niobium-Germanium: Becoming a Practical Superconductor

Last month scientists at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico, reported that they have made several large samples of niobium-germanium (Nb_3Ge) which remained superconducting at temperatures above the boiling point of liquid hydrogen (20.4°K at 1 atmosphere). Subsequently, it was learned that researchers at Westinghouse Research Laboratories, Pittsburgh, Pennsylvania, have also accomplished this feat. In both laboratories, the samples were made by a process known as chemical vapor deposition, in which gaseous compounds of niobium and germanium react at elevated temperatures to form a superconducting compound on a metallic or insulating substrate. Chemical vapor deposition is a process that lends itself to fabricating superconductors in commercial quantities.

In recent years, there has been a search for new superconducting materials that remain superconducting at higher and higher temperatures (have higher transition temperatures) because the electrical properties of superconductors are enhanced when the transition temperature is high and because the cost of refrigerating the superconductor is decreased when the operating temperature is increased. In particular, scientists have been enthralled with the idea of finding a superconductor that could be operated in liquid hydrogen, which is a cheaper and a more efficient refrigerant than the present coolant, liquid helium (whose boiling point is 4.2°K at 1 atmosphere).

It was just about a year ago that J. R. Gavaler of Westinghouse caused a stir in the superconductivity community by announcing he had made Nb_3Ge that was superconducting at temperatures above 22°K (*Science*, 25 January, p. 293). However, Gavaler's compound was prepared by the sputtering process, which usually is not easily adaptable to fabricating large amounts of material in the thicknesses needed for devices that carry high electrical currents, oftentimes in high magnetic fields. Thus, while the record Nb_3Ge caused a great deal of excitement among scientists because of the potential for operating a device in liquid hydrogen, it did not appear likely that any such device would be immediately forthcoming. (Investigators in at least three other laboratories have verified the Westinghouse results by sputtering their own Nb_3Ge films with high transition temperatures.) Now, however, that Nb_3Ge with transition temperatures up to 21.5°K has been produced by chemical vapor deposition, it appears that this compound is nearing the point where it can be developed for at least some practical applications, such as superconducting power transmission lines or high field superconducting magnets. Other applications, such as rotating electrical machinery, are likely to be farther off.

The superconductor made at Los Alamos (by L. R. Newkirk and F. A. Valencia) was in the form of a deposit 25 to 50 micrometers in thickness in a copper tube 38 centimeters long. In the chemical vapor deposition process, niobium pentachloride and germanium tetrachloride are carried in a stream of hydrogen gas over a copper tube, which is held at an elevated temperature. The temperature of the tube is such that the niobium and the germanium react to form the Nb_3Ge compound on the copper substrate ($6\ NbCl_5 + 2\ GeCl_4 + 19\ H_2 \rightarrow 2\ Nb_3Ge + 38\ HCl$). According to M. G. Bowman, who headed the Los Alamos effort, the velocity of the gas flow, the concentration of the niobium and germanium species in the gas, and the temperature of the copper are all important in determining the optimum conditions for the preparation of the superconductor with high transition temperatures. The temperature is important because, as was shown conclusively in the earlier work on the compound prepared by sputtering, Nb_3Ge with the stoichiometric ratio of three niobium atoms to one germanium atom and with an ordered crystal structure can only be prepared by depositing the material at elevated temperatures in the range 700° to 1000°C.

H. Laquer and R. Bartlett of Los Alamos have made some preliminary measurements of the properties of the new material. They found, for example, that samples prepared by longitudinally sawing a 6-centimeter length of superconductor-covered tube in two could carry a current of 75,000 amperes per square centimeter at a temperature of 18.1°K. This value is sufficiently high to merit further consideration of the vapor deposited Nb_3Ge, according to one maker of commercial superconducting devices. However, Laquer and Bartlett also found that the superconducting transition temperature was not uniform along the length of longer samples, increasing by about 1°K over a distance of 15 to 22 centimeters. Viewed positively, the lack of uniformity can be taken to signify that further improvements in performance are possible. On the other hand, a uniform material is required over lengths much longer than this in applications such as the long distance, high capacity, direct current (d-c) superconducting power transmission lines that Los Alamos is working on.

For some time, Richard Stevenson

of the Canada Superconductor and Cryogenics Company, St. Lambert, Quebec, and McGill University, Montreal, Quebec, has been able to make Nb_3Ge with a transition temperature of about 19°K by a process with which his company fabricates commercial quantities of niobium-tin (Nb_3Sn) superconducting tapes, simply by replacing the tin source with a germanium source. The superconductor is vapor deposited on a moving metallic substrate in the form of a tape or ribbon, which may then be silver-plated and laminated with additional conductors. Observers are somewhat divided on the question of how easy it will be to scale up the vapor deposition process required in making high transition temperature Nb_3Ge. One pointed out, for example, that Nb_3Sn will form given the slightest excuse, whereas Nb_3Ge with the desired structure and composition forms only reluctantly. Thus, it may be quite a challenge to obtain the extra 2° or 3°K in transition temperature over what Stevenson can get now, when the Los Alamos process is enlarged from its present laboratory-sized operation.

If this challenge can be met, and Bowman is confident that it can, then Los Alamos would look very carefully at incorporating the Nb_3Ge superconductor into its designs for d-c power transmission lines, according to W. E. Keller. Niobium-tin is the superconductor that is now being explored for this application, but the germanium compound could offer the twin advantages of a higher current carrying capacity and operation at higher temperatures.

For example, the transmission line group at Los Alamos is considering the use of liquid hydrogen cooled below its normal atmospheric boiling point of 20.4°K. Cooling the liquid hydrogen is normally done in the laboratory by lowering the vapor pressure over the liquid with the aid of a vacuum pump. On a larger scale, a heat exchanger system in which liquid helium is used to cool the hydrogen is being studied. Liquid hydrogen can be cooled to 13.8°K, at which point it solidifies. Since the transition temperature of Nb_3Sn is about 18.3°K in the laboratory and often below 18°K in commercially available material, Nb_3Ge would offer a substantial improvement in performance (since performance degrades as the superconductor nears its transition temperature), in refrigeration economies, and in safety (since thermal excursions can occur, the farther the superconductor is cooled below its transition temperature, the less likely it is to transiently return to its normal nonsuperconducting state).

At Westinghouse, researchers are interested in applying high transition temperature Nb_3Ge in windings for high magnetic field magnets of a type that will be required in magnetic confinement fusion reactors. The vapor deposited Nb_3Ge made at Westinghouse was prepared (by A. Braginski and G. Roland) in much the same way as that at Los Alamos, except that the source of niobium was niobium tetrachloride instead of niobium pentachloride, and that the superconductor was deposited onto an insulating substrate rather than a metallic one. Sample thicknesses were about 5 micrometers (about the maximum possible thickness for magnet windings because of the brittleness of the superconductor) and the sample size was about 1.5 centimeters. According to Gavaler, measurements at the National Magnet Laboratory, Cambridge, Massachusetts, on the vapor deposited Nb_3Ge indicated that its superconducting current density under varying conditions of applied magnetic field and temperature was about an order of magnitude less than that of the sputtered films measured earlier. (Since Los Alamos has not made measurements in magnetic fields, it is difficult to compare the material made in the two different laboratories.)

Large Superconducting Magnets

The materials requirements for superconductors in high field magnets are somewhat more stringent than for d-c power transmission lines, in part because of the need to carry large currents in high magnetic fields (superconductors carry less and less current in an applied magnetic field up to a maximum field, the upper critical field). In fact, it is the high critical field (38 teslas) and the high current densities in such fields that would make Nb_3Ge of greatest interest. It is likely that liquid helium would continue to be used as the refrigerant for high field magnets. In addition, the large size of fusion magnets (several meters as compared with a few centimeters in laboratory magnets) makes additional demands on the mechanical properties of the superconductor, because of the large forces involved. For these reasons, one scientist concerned with the design of fusion magnets thought that it may be important for the Nb_3Ge to be in a structure with a large, rugged cross section, such as the multifilamentary configuration.

Multifilamentary superconductors were devised [first in niobium-titanium alloys, now under development in Nb_3Sn and vanadium-gallium (V_3Ga)] as a way to eliminate or at least reduce the tendency of superconductors to heat up locally to above the transition temperature. If the heat generated by the large current in the now nonsuperconducting metal spread, then the entire superconducting device could fail. This effect is minimized when the cross section of the superconductor is sufficiently small; hence the multifilamentary approach which consists of strands of superconductor imbedded in a metal matrix, usually copper. This configuration also reduces another bothersome phenomenon of superconductors, their tendency to dissipate power when carrying alternating currents (a-c) (although they do not exhibit any resistance to d-c current flow, superconductors cannot conduct a-c currents without an accompanying dissipation of power). The minimization of a-c losses is essential for applications such as a-c power transmission lines and rotating electrical machinery.

How to make a multifilamentary Nb_3Ge superconductor is not known at present. Bowman at Los Alamos has speculated that one might coat fine wires with superconductor via the chemical vapor deposition process and then electroplate over the coated wires to make up a multifilamentary cable. However, the sensitivity of the properties of Nb_3Ge to the conditions of preparation means that such speculations will remain ideas until tested experimentally.

The impact that the Nb_3Ge superconductor prepared by chemical vapor deposition could have on any particular device application was best summed up by one systems designer who cautioned that an extra 2° or 3°K of transition temperature could not be evaluated apart from all the other considerations that go into an overall system. There are too many trade offs to be optimized to allow anything more than a cautious optimism. On the other hand, the Nb_3Ge development seems sufficiently promising that the Electric Power Research Institute, Palo Alto, California, is already considering funding additional research on it, according to M. Rabinowitz, who adds that "we would be remiss if we didn't pursue Nb_3Ge."

—Arthur L. Robinson