New category of the superconducting materials discovered by UCSD and Cal Tech

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A new category of superconducting materials has been discovered by scientists at the University of California, San Diego, and the California Institute of Technology.

They have demonstrated, through a series of experiments, that it is possible to synthesize new superconducting compounds and alloys from elements which do not combine under normal conditions.

These results were published recently as a scientific paper in Science magazine by Dr. H. L. Luo of Cal Tech, and Dr. M. F. Merriam and Mr. David C. Hamilton of UCSD.

The superconducting alloys found by the scientists are metastable compounds-compounds which do not form and are not stable under normal conditions. The particular compounds prepared and investigated were synthesized from gold or silver, in combination with tellurium or germanium. None of these four is superconducting as a pure element. In fact, the last two are not even metals.

The metastable compounds were prepared using an ultra-fast cooling technique developed several years ago by Professor Pol Duwez of Cal Tech. In this technique, sometimes called "splat cooling," a droplet of liquid alloy is blasted against a copper surface by a jet of gas. The liquid metal spreads out into a thin foil and cools very rapidly by conduction to the copper. The alloy has been estimated to cool at the incredible rate of more than 4,000,000 degrees Fahrenheit a second.

When the alloy is quick-frozen in this manner the atoms do not have time to align themselves into normal patterns. Instead, a new pattern is formed with new chemical and electrical properties.

An example is an alloy of four parts silver to one of germanium. If melted and mixed together in the liquid state and allowed to cool in a normal manner, the solid will consist of a mixture of grains of germanium interspersed with grains of silver. Neither of these is superconducting nor is the mixture.

Dr. Luo and his co-workers found, however, that when the liquid was quick frozen by the "splat cooling" technique, the atoms of silver and germanium arranged themselves in a regular array and the solid was homogeneous rather than a mixture of two different materials.

Furthermore, the new silver-germanium compound was found to become superconducting at a sufficiently low temperature.

Superconductivity, a phenomenon found in many, but not all, metals at temperatures near absolute zero (zero degrees on the Kelvin scale or -459.72 degrees Fahrenheit) is the complete disappearance of electrical resistance resulting from a "condensation" of the conduction electrons into a state of frictionless motion.

The ability of superconducting wire to carry an electric current without loss is the basis of an important industrial application: superconducting magnets.

The nature of the superconducting state is still a subject of active research. Different metals and alloys vary considerably in their superconducting properties. For instance, the transition temperatures (the highest temperature at which a particular metal will superconduct) vary from near absolute zero to a high of 18 degrees Kelvin (-427.32 degrees Fahrenheit).

A compound of niobium and tin (Nb_3Sn) at 18 degrees Kelvin has the highest transition temperature now known. Lead, tin, and zinc, three common metals, are superconducting at 7.2, 3.7, and 0.9 degrees Kelvin respectively. Copper, silver, and gold, on the other hand, show no superconductivity down to the lowest temperatures at which they have been tested (about 0.020 degrees Kelvin).

The new superconductors found in the current study are important in that they point to the possibility of making superconductors with special desired properties, such as transition temperatures above 18 degrees Kelvin, without being restricted by the normal rules of chemistry.

Despite the fact that neither silver or germanium by themselves is superconducting, the silver-germanium compound was found to become superconducting with a transition temperature of 0.85 degrees Kelvin. Similarly a new compound of silver and tellurium ($AgTe_3$) was prepared and found to be superconducting at 2.6 degrees Kelvin. Other new gold-germanium and gold-tellurium compounds were found to become superconducting at various temperatures between 1.0 and 1.6 degrees Kelvin.

The very low temperatures required for these studies were achieved with the aid of liquid helium. Ordinary liquid helium (He^4) was used for temperatures down to about 1.1 degrees Kelvin. Lower temperatures, down to 0.3 degrees Kelvin, required a special apparatus utilizing the rare isotope He^3, which has only one neutron in its nucleus. (Ordinary helium has two neutrons in its nucleus.) The experimental alloy is immersed in the boiling liquid helium to bring it to superconducting temperatures. The temperature of boiling He^4 is 4.2 degrees Kelvin at atmospheric pressure. The temperature can be lowered still further by reducing the pressure over it with a vacuum pump, just as water boils at lower temperatures at higher elevations.

The low temperature measurements were made at UCSD in the laboratory of Professor B. T. Matthias, who is an authority in the field of superconductivity of compounds and alloys.

Dr. Luo, who will join the staff at UCSD this fall, is currently a Postdoctoral Research Fellow in the Materials Science Department at Cal Tech. Dr. Merriam is an Assistant Professor and Mr. Hamilton is a graduate student in the Department of Physics at UCSD.