Forschungszentrum Dresden Rossendorf

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Pressemitteilung

Superconducting chips to become reality

Most chemical elements become superconducting at low temperatures or high pressures, but until now, copper, silver, gold, and the semiconductor germanium, for example, have all refused superconductivity. Scientists at the Forschungszentrum Dresden-Rossendorf (FZD) research center were now able to produce superconducting germanium for the first time. Furthermore, they could unravel a few of the mysteries which come along with superconducting semiconductors. Their findings are published – marked as editor's choice – in the recent issue of "Physical Review Letters".

Superconductors are substances that conduct electricity without losses when cooled down to very low temperatures. Pure semiconductors, like silicon or germanium, are almost non-conducting at low temperatures, but transform into conducting materials after doping with foreign atoms. An established method of doping is ion implantation (ions = charged atoms) by which foreign ions are embedded into the crystal lattice of a semiconductor. To produce a superconducting semiconductor, an extreme amount of foreign atoms are necessary, even more than the substance would usually be able to absorb. At the FZD, germanium samples were doped with about six gallium atoms per 100 germanium atoms. With these experiments, the scientists could prove indeed that the doped germanium layer of only sixty nanometers thickness became superconducting, and not just the clusters of foreign atoms which could easily form during extreme doping .

As the germanium lattice is heavily damaged by ion implantation, it has to be repaired afterwards. For such purposes, a flash-lamp annealing facility has been developed at the FZD. Its application allows for a repair of the destroyed crystal lattice by rapidly heating the sample surface (within few milliseconds) while the distribution of the dopant atoms is kept almost the same.

From a scientific point of view, the new material is very promising. It exhibits a surprisingly high critical magnetic field with respect to the temperature where the substance becomes superconducting. For many materials, superconductivity occurs only at very low temperatures, slightly above the absolute zero point of -273 degrees Celsius or 0 Kelvin. The gallium doped germanium samples become superconducting at about 0.5 Kelvin; however, the FZD researchers expect the temperature to increase further by changing various parameters during ion implantation or annealing.

Physicists have been dreaming about superconducting semiconductors for a long time, but saw only few chances for the semiconductor germanium to become superconducting at all. Germanium used to be the material for the first generation of transistors; however, it was soon replaced by silicon, the current material for microelectronics. Recently, the "old" semiconductor material germanium has aroused more and more interest, as it allows, compared to silicon, for more rapid circuits. Experts even believe germanium to be rediscovered for micro- and nanoelectronics. The reason for such a renaissance lies in the fact that miniaturization in

Pressemitteilung

microelectronics industry using silicon is coming to an end. Today, extremely thin oxide layers are needed for transistors, down to a level where silicon oxide does not work well any more. Germanium as a new material for chips would come along with two big advantages: it would enable both faster processes and further miniaturization in micro- and nanoelectronics. Superconducting germanium could thus help to realize circuits for novel computers.

The scientists at the Forschungszentrum Dresden-Rossendorf followed a targeted approach when searching for a new superconducting semiconductor. Instead of doping with boron, which had resulted in superconducting silicon two years ago in France, the scientists choose gallium because of its higher solubility in germanium. In many systematic experiments they proved that the superconductivity of germanium can be reproduced. Furthermore, they were able to show that the transition temperature marking the start of superconductivity can be raised within certain limits. In the future, the scientists at the two FZD institutes "Ion Beam Physics and Materials Research" and "Dresden High Magnetic Field Laboratory" will combine their know-how in order to fine-tune different rather complex parameters for further experiments, thus hopefully discovering further mysteries of superconducting semiconductors.

Publication

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Picture capture

Artist view of the implantation of gallium ions (animated in blue) into germanium wafers followed by a reconstruction of the lattice using short-term flash-lamp annealing and, finally, of the observation of superconductivity at low temperatures. Other than in normal conductors, superconductivity is caused by the formation of electron pairs with anti-parallel momentum and spin (animated in red).

Further information

Dr. Thomas Herrmannsdörfer
Dresden High-Magnetic Field Laboratory at FZD
Phone: ++49 351 260 - 3320
Email: t.herrmannsdoerfer@fzd.de

Dr. Viton Heera
FZD Institute of Ion Beam Physics and Materials Research
Phone: ++49 351 260 - 3343 or - 2748
Email: v.heera@fzd.de

Contact to the media

Dr. Christine Bohnet
FZD – Public Relations
Bautzner Landstr. 400, 01328 Dresden / Germany
Phone: ++49 351 260 - 2450 or ++49 160 969 288 56
Email: presse@fzd.de