A step nearer to understanding superconductivity

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Transporting energy without any loss, travelling in magnetically levitated trains, carrying out medical imaging (MRI) with small-scale equipment: all these things could come true if we had superconducting materials that worked at room temperature.

Today, researchers at CNRS have taken another step forward on the road leading to this ultimate goal. They have revealed the metallic nature of a class of so-called critical high-temperature superconducting materials. This result, which was published in the 31 May 2007 issue of the journal *Nature*, has been eagerly awaited for 20 years. It paves the way to an understanding of this phenomenon and makes it possible to contemplate its complete theoretical description.

Superconductivity is a state of matter characterized by zero electrical resistance and impermeability to a magnetic field. For instance, it is already used in medical imaging (MRI devices), and could find spectacular applications in the transport and storage of electrical energy without loss, the development of transport systems based on magnetic levitation, wireless communication and even quantum computers.

However, for now, such applications are limited by the fact that superconductivity only occurs at very low temperatures. In fact, it was only once a way of liquefying helium had been developed, which requires a temperature of 4.2 kelvins (-269 °C), that superconductivity was discovered, in 1911 (a discovery for which the Nobel Prize was awarded two years later.)

Since the end of the 1980s (Nobel Prize in 1987), researchers have managed to obtain ‘high temperature’ superconducting materials: some of these compounds can be made superconducting simply by using liquid nitrogen (77 K, or -196 °C). The record critical temperature (the phase transition temperature below which superconductivity occurs) is today 138 K (-135 °C). This new class of superconductors, which are easier and cheaper to use, has given fresh impetus to the race to find ever higher critical temperatures, with the ultimate goal of obtaining materials which are superconducting at room temperature. However, until now, researchers have been held back by some fundamental questions. What causes superconductivity at microscopic scales" How do electrons behave in such materials"

Researchers at the National Laboratory for Pulsed Magnetic Fields, working together with researchers at Sherbrooke, have observed ‘quantum oscillations’, thanks to their experience in working with intense magnetic fields. They subjected their samples to a magnetic field of as much as 62 teslas (a million times stronger than the Earth’s magnetic field), at very low temperatures (between 1.5 K and 4.2 K). The magnetic field destroys the superconducting state, and the sample, now in a normal state, shows an oscillation of its electrical resistance as a function of the magnetic field. Such an oscillation is characteristic of metals: it means that, in the samples that were studied, the electrons behaved in the same way as in ordinary metals.

The researchers will be able to use this discovery, which has been eagerly awaited for 20 years, to improve their understanding of critical high-temperature superconductivity, which until now had resisted all attempts at modeling it. The discovery has been effective in sorting out the many theories which had emerged to explain the phenomenon, and provides a firm foundation on which to build a new theory. It will make it possible to design more efficient materials, with critical temperatures closer to room temperature.

Source: CNRS