Mercury-containing oxides offer new perspective on mechanism of superconductivity

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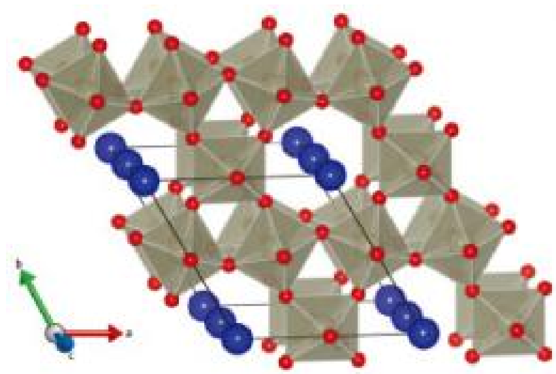

Figure 1: The crystal structure of HgxReO3. The mercury (Hg) atoms are shown in blue, oxygen (O) in red and rhenium (Re) in brown. Credit: 2011 The American Physical Society

(PhysOrg.com) -- To diversify the applications of superconductors that currently operate at chilly temperatures below 135 kelvin (K), scientists are searching for new classes of superconducting materials that will show this property at warmer temperatures. Now, a research team in Japan has synthesized a promising new class of superconductors1, made of $Hg_{0.44}ReO_3$, where an unusual motion of the mercury (Hg) atoms enhances superconducting properties at temperatures up to 7.7 K.

The Dutch physicist Heike Kamerlingh Onnes discovered superconductivity one hundred years ago, when he noticed that the electrical resistance of mercury dropped to zero suddenly at 4.2 K. Superconducting materials are now used routinely in magnetic resonance imaging scanners.

In classical superconductors such as mercury, superconductivity arises through the combined vibrations of the atoms in the crystal. This makes the crystal structure a key factor for the superconducting properties of a material. In the case of Hg_xReO_3, the atomic structure consists of rhenium (Re) and oxygen (O) building blocks. In the empty spaces between them, the mercury atoms arrange in chains (Fig. 1). However, some of the available places along these chains lack mercury atoms, and the team's work suggests that this leads to an arrangement of paired mercury atoms.

"These pairs move within the channel in an oscillatory motion known as rattling", explains team-member Ayako Yamamoto from the RIKEN Advanced Science Institute in Wako. The rattling vibrations provide a strong feedback for the electrons, and therefore reinforce superconductivity in the material. In comparison to a similar structure lacking mercury pairs, the superconducting temperature of $Hg_{0.44}ReO_3$ at 7.7 K is almost twice as high. "Despite remaining below the present record of 135 K for a superconductor, there is potential for improving operation temperatures", says Yamamoto. "The application of pressure increases the superconducting temperature to 11.1 K, and this could mean that for the right crystal structure further enhancement is possible."

Yamamoto and her colleagues are now working to optimize the crystal structure further—for example, by replacing rhenium with other elements. A better understanding of the influence of the mercury atoms' rattling motion may also provide better insight into the mechanism of superconductivity in such structures. "Mercury seems to be a magic element in superconductivity, not only for its role in Kamerlingh Onnes' discovery, but also for the fact that mercury is part of the material with the highest known superconducting temperature, $HgBa_2Ca_2Cu_3O_x$," Yamamoto explains. "Once more, mercury is playing a key role for new superconductors," she says.

More information: Ohgushi, K., et al. Superconducting phase at 7.7 K in the HgxReO3 compound with a hexagonal bronze structure. *Physical Review Letters* 106, 017001 (2011). Article

Provided by RIKEN