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The mechanism of high-temperature superconductivity is found

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Russian physicist Viktor Lakhno from Keldysh Institute of Applied Mathematics, RAS considers symmetrical bipolarons as a basis of high-temperature superconductivity. The theory explains recent experiments in which a superconductivity was reached in lanthanum hydride LaH_{10} at extra-high pressure at nearly room temperature. The results of the study are published in *Physica C: Superconductivity and its Applications*.

Superconductivity implies a total absence of electric resistance in the material when it is cooled below a critical temperature. Heike Kamerlingh Onnes was the first to observe that as the mercury temperature goes down to -270°C, its resistance decreases by a factor of 10,000. Revealing how to achieve this at higher temperatures would have revolutionary technological applications.

The first theoretical explanation of superconductivity at the microscopic level was given in 1957 by Bardeed, Cooper and Schrieffer in their BCS theory. However, the this theory does not explain superconductivity above the absolute zero. By the end of 2018, two research groups discovered that lanthanum hydride LaH_{10} becomes superconducting at record-high temperature. The first group asserts that the temperature of transition into the superconducting state is Tc = 215 K (-56°C). The second groups reports the temperature is Tc = 260 K (-13°C). On both accounts, the samples were under a pressure of more that one million atmospheres.

High-temperature superconductivity is found in new materials nearly at random since there is no theory that would explain the mechanism. In his new work, Viktor Lakhno suggests using bipolarons as a basis. A polaron is a quasiparticle that consists of electrons and phonons. Polarons can form pairs due to electron-phonon interaction. This interaction is so strong that they turn out to be as small as an atomic orbital and in this case are called small-radius bipolarons. The problem of this theory is that small-radius bipolarons have very large mass in comparison with an atom. Their mass is determined by a field that accompanies them in the course of motion. And the mass influences the temperature of a superconducting transition.

Viktor Lakhno constructed a new translation-invariant (TI) bipolaron theory of high-temperature superconductivity. According to his theory, the formula for determining the temperature involves not a bipolaron mass but an ordinary effective mass of a band electron, which can be either greater or less than the mass of a free electron in vacuum and about 1000 times less than the mass of an atom. The band mass changes if the crystal lattice in which an electron is squeezed. If the distance between the atoms decreases, the mass decreases, too. As a consequence, the temperature of the transition can several times exceed the relevant temperature in ordinary bipolaron theories.

"I have focused on the fact that an electron is a wave. If so, there is no preferable place in a crystal where it would be localized. It exists everywhere with equal probability. On grounds of the new bipolaron theory one can develop a new theory of superconductivity. It combines all the best features of modern conceptions," says Viktor Lakhno.

More information: Victor Lakhno, Superconducting properties of a nonideal bipolaron gas, *Physica C: Superconductivity and its Applications* (2019). DOI: 10.1016/j.physc.2018.10.009

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