Superconductivity in a pyrochlore-related oxide KOs_2O_6.

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This paper reports the discovery of a new superconductor KOs_2O_6 with the transition temperature ~ 10K. The crystal structure is a small modification of the pyrochlore structure; the authors name it the β-pyrochlore. Soon after the discovery, other superconductors, $RbOs_2O_6$ [1] and $CsOs_2O_6$ [2] with the same structure, have been discovered by the same authors.

In 2001, the superconducting oxide, $Cd_2Re_2O_7$ with T_c = 1K was discovered. This was the first superconductor in the family of pyrochlore oxides. From NMR and photoemission spectroscopy measurements in $Cd_2Re_2O_7$, it was concluded that the superconductivity occurs in the conventional flamework of the BCS theory.

The chemical formula of pyrochlore structure is expressed as $A_2B_2O_7$ or $A_2B_2O_6O'$. The pyrochlore structure has the network of corner-shared BO_6 octahedra. In the β-pyrochlore structure AB_2O_6, the cation *A* goes into the position of O' ion. Therefore, the β-pyrochlore structure also involves the network of corner-shared BO_6 octahedra in the pyrochlore lattice. Transport and magnetic properties are dominated by the 5*d* electrons of the transition metal cation *B* in the pyrochlore lattice. In Cd_2Os_2O7, a metal-insulator transition occurs at 225 K. In these oxides, the transition metal ions Re^{5+} and Os^{5+} have $5d^2$ and $5d^3$ electron configurations, respectively. In the superconducting osmates with the β-pyrochlore oxides, an osmium ion takes the fractional valence +5.5, which is the intermediate state between $5d^2$ and $5d^3$. Such a mixed valence state in the superconducting osmates, KOs_2O_6, $RbOs_2O_6$ and $CsOs_2O_6$, reminds us of the electronic state in high-T_c cuprates and the superconductors based on BaBiO3.

The mechanism of the superconductivity in the β-pyrochlore osmates is controversial. Some of the experimental data suggest that the order parameter is anisotropic and the superconductivity may be unconventional one [3,4].

In the problems on spin systems, we often come across the pyrochlore lattice in connection with the effect of frustration. The first theoretical study of antiferromagnetic ordering on the pyrochlore lattice was given by Anderson. Due to frustration, the possible classical ground state is likely to be highly degenerate maintaining finite entropy. This effect causes rich spin structure and so-called 'spin-ice' state. Effects of the frustration in the transport properties of itinerant electronic solids are not clearly understood. Does the electronic structure have some special degeneracies? Also the spin-orbit coupling relates the frustrated spin degrees of freedom to the charge degrees of freedom. The shape of the electron cloud determines the motion of an electron and affects the transport property. Such effects can lead to crucial change of the Fermi-surface topology in the strongly correlated systems with frustration.

It is interesting to note that in the β-pyrochlore osmates with fractional valence, T_c is ten times as large as that in $Cd_2Re_2O_7$ with even number of 5*d* electrons. The osmates open a new family of superconductor in the frustrated lattice and invite a theoretical investigation of itinerant electrons on frustrated lattices.

References

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