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Work of exit and the internal pressure in superconductors created by electrons

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The relationship between the work of exit W of electrons of the metal superconductors in the normal state, the internal pressure of the gas P_0 of free and noninteracting electrons and the energy of the ground state of atoms $|-E|$ in the Hartree-Fock approximation were discovered.

Keywords: work of exit, free electron gas pressure, Hartree-Fock energy.

Обнаружена взаимосвязь между работой выхода W электронов из металлических сверхпроводников в нормальном состоянии, давлением газа свободных электронов P_0 и энергией основного состояния атомов $|-E|$ в приближении Хартри-Фока.

Робота виходу та внутрішний тиск у надпровідниках. *В.П.Хірний*.
Отримано взаємозв'язок між роботою виходу W електронів із металічних надпровідників у нормальному стані, тиском газу вільних і невзаємодіючих електронів P_0 та енергією основного стану атомів $|-E|$ у наближенні Хартрі-Фока.

In [1], the internal pressure of the gas P_0 of free and noninteracting electrons was determined in three-dimensional metals and metal superconductors at a temperature $T = 0$ K. The superconductors were in the normal (nonsuperconducting) state. When determining P_0, we proceeded from the assumption that if the ground-state energy of the electrons is ε, then $P_0 = -(\delta\varepsilon/\delta\ \mathrm{V})_N$ [2]. Where V is the volume occupied by N electrons, i.e. the electron density in the gas was $n = N/V$. Since $\varepsilon = (3/5)NE_F$, according to the work [2] we obtain:

$$P_0 = 0.4nE_F, \qquad (1)$$

where E_F — Fermi energy, which has a value common to the atomic binding ground state energies. The pressure P_0 is balanced by the Coulomb attractive forces between electrons and ions, so the motion of electrons is limited by the volume V of the metal. In [1], the properties of three-dimensional metal samples ignoring the surfaces were studied. In this case, the metal superconductors had a singularity observed in the normal state [1] in the dependences $E_F(P_0)$ and $E_F(|-E|)$, where $|-E|$ is the ground-state energy of atoms in the Hartree-Fock approximation. The peculiarity was that the E_F values were located within certain limits, varying from 7.1 eV to 15.4 eV, common to superconductors, from the minimum value in magnesium to the maximum in vanadium.

The objective of this paper is to study the changes in the energy of electrons, which leave two-dimensional metallic superconductors when moving. It is known that in many cases the presence of the surface in the samples must be taken into account. For example, for determining the current-voltage or tunnel characteristics of metals,

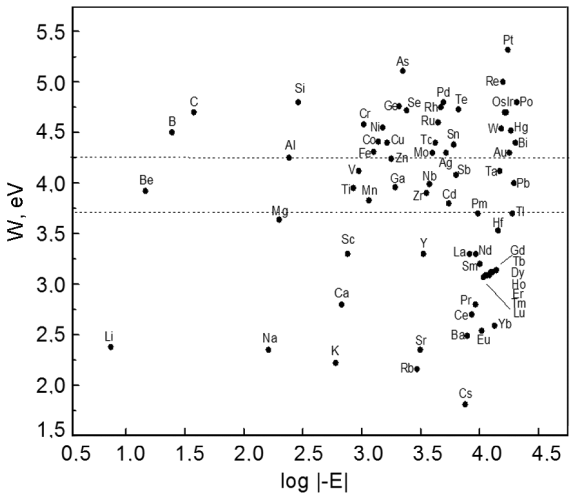

Fig. 1. Dependences of the work of exit W of electrons of the metal superconductors in the normal state on the energy of the ground state of atoms $|-E|$ in the Hartree-Fock approximation.

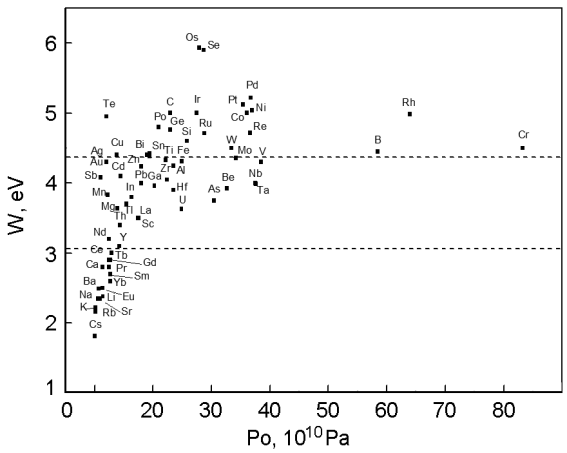

Fig. 2. Dependences of the work of exit W of electrons of the metal superconductors in the normal state on the pressure of gas of free and noninteracting electrons P_0.

when an electron moves from one metal to another. That is, the energy required to extract an electron from a metal always depends both on the conditions in the bulk of the sample, and on the surface conditions, where deviations occur in the distribution of the electron charge in the bulk of the sample. The minimum energy required to remove an electron from a solid body and place it near a surface is called the work of exit W. To remove an electron from a sample, it must be energized [2]

$$W = -E_F + W_S, \qquad (2)$$

where W_S work required to transfer an electron through an electric field in a double electron layer.

According to formulas (1) and (2), the value E_F to some extent influences the kinetic properties of electrons both in bulk and near the surface. Since there are singularities in the dependences $E_P(P_0)$ and $E_F(|-E|)$ [1], according to formulas (1) and (2), it follows that both the dependences $W(P_0)$ and $W(|-E|)$ should also have singularities. That is, there will be a relationship between the work of exit W and the values $|-E|$ and P_0 in the superconducting metals that have passed to the normal state. Such a relationship does exist at values W ranging from = 3.75 to = 4.25 (in case of W on $|-E|$ dependence, see Fig. 1) and from 3.1 eV to 4.4 eV (in case of W on P_0 dependence, see Fig. 2). These areas are marked by dashed lines. Figures 1 and 2 show two small boundary transition regions, 0.2 eV wide, above and below the location of superconductors. These areas locate both superconductors and normal metals. The values W are taken from [3].

Thus, the values of the work of exit of electrons, which depend on the surface conditions of the samples, have features that distinguish the superconductors in the normal state from the nonsuperconducting metals.

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