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Abstract

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PHYSICS

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One of the interesting facts in the behavior of electrical resistance at low temperatures is the presence of a resistance minimum in its temperature dependence for a whole series of metals with impurities of elements that form local magnetic moments⁽¹⁻⁸⁾. The theoretical explanation of this phenomenon was developed in the works of Kondo⁽⁹⁾ and A. A. Abrikosov⁽¹⁰⁾. According to these works, the minimum of the electrical resistance appears when conduction electrons interact with the local moments of impurity atoms, as a result of the superposition of the ordinary electrical resistance, which decreases with temperature, and the exchange resistance, which increases. Such an explanation applies to weakly magnetic metals.

The question became more complicated with the discovery of a minimum in a metal with magnetic ordering—chromium⁽⁸⁾. However, both in the case of weakly magnetic metals and in chromium, the minimum is caused by a small amount of impurities. It seems that this question becomes of still greater interest in connection with the discovery of a resistance minimum in a metal with an extremely distorted crystal lattice—lutetium*. The present communication is devoted to this.

The minimum of electrical resistance was found in films of the rare-earth element lutetium, obtained by condensation onto a glass polished surface cooled by liquid helium, according to the method described earlier^(11,12). Films were studied over a wide range of thicknesses (300 ÷ 8000 Å), immediately after condensation and after annealing up to $T = 300 \div 400^\circ\text{K}$. Lutetium with $R_{300^\circ\text{K}}/R_{4.2^\circ\text{K}} = 15$ was used as the starting material. Its purity was better than 99.9%. (For rare-earth elements this is a fairly high purity.) All the films investigated, on the curve of the dependence of resistance R on temperature T , had a resistance minimum both in the freshly condensed (Fig. 1A) and in the annealed (Fig. 1B) state. The minimum is sharply expressed even against the background of the very large specific resistance of lutetium, created by the strong distortion of the lattice. The temperature of the minimum T_{min} depends sharply on the

Fig. 1. Temperature dependence of the electrical resistance of a lutetium film of thickness $\sim 1000 \text{ \AA}$. A—immediately after condensation; B—after annealing to 300°K .

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layer thickness d and increases from 4°K at $d = 7500 \text{ \AA}$ to 7°K at $d = 300 \text{ \AA}$ (Fig. 2). For one and the same film, T_{\min} after annealing tends to shift toward lower temperatures.

Fig. 1. Temperature dependence of the electrical resistance of a lutetium film of thickness $\sim 1000 \text{ \AA}$. **A**—immediately after condensation, **B**—after annealing to 300°K

* In the work of N. E. Alekseevskii and Yu. P. Gaidukov (⁵) it was shown that plastic deformation of gold specimens leads to the destruction of the resistance minimum.

The magnitude of the minimum $\Delta R/R = (R_{15^\circ\text{K}} - R_{T_{\min}})/R_{T_{\min}}$ increases as the thickness decreases and changes from $\sim 0.004\%$ for a film of thickness $\sim 7500 \text{ \AA}$ to $\sim 0.13\%$ for a film of thickness $\sim 300 \text{ \AA}$. In bulk lutetium, no minimum is observed in the temperature range under consideration.

The depth of the minimum after annealing decreases the more, the thicker the metal layer. Thus, for example, annealing at $T = 350^\circ\text{K}$ reduces the magnitude of the minimum of a film of thickness $\sim 7500 \text{ \AA}$ by a factor of 3.

It should be noted that the annealing curve of the condensed layers (Fig. 3) is also unusual—in the course of annealing the resistance increases instead of decreasing, as is characteristic of most metals in layers formed by a similar method (¹²). Measurements of the electrical resistance in a magnetic field perpendicular to the plane of the film showed that a field of up to 25,000 oersteds does not change the magnitude or the temperature of the minimum. A similar phenomenon was also observed for chromium (⁸), although in other metals, for example in gold (⁵), the minimum disappears in smaller fields (~ 8000 oersteds). The resistance of lutetium films in a field of 25,000 oersteds at a temperature of 4.2°K increases by $0.02 \div 0.03\%$.

Fig. 2 Fig. 3

Fig. 2. Dependence of the temperature of the minimum on film thickness

Fig. 3. Curve of the temperature dependence of the electrical resistance of a lutetium film of thickness $\sim 1000 \text{ \AA}$. The black points show the reversible course of the electrical resistance of the annealed film

Preliminary studies of thulium films also showed the existence of a sharply pronounced resistance minimum. Thus, the data of the present study indicate

the existence of some new mechanism of electron scattering at low temperatures in lutetium and thulium films.

In conclusion, we express our gratitude to L. S. Lazareva and S. I. Goridov for assistance in the magnetic measurements and to N. V. Volkenshtein for providing samples of rare-earth metals.

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REFERENCES

1. W. Meissner, G. Voigt, Ann. Phys., **7**, 832 (1930).
2. G. J. van den Berg, W. J. de Haas, Physica, **1**, 1115 (1933).
3. L. S. Kan, B. G. Lazarev, DAN, **81**, 1027 (1951).
4. M. N. Nakhimovich, J. Physics, **5**, 141 (1941).
5. N. E. Alekseevskii, Yu. P. Gaidukov, ZhETF, **31**, 947 (1956); **35**, 804 (1958).
6. J. Cape, R. Hake, Phys. Rev., **139**, No. 1A, 142 (1965).
7. Sugawara Tadashi, J. Phys. Soc. Japan, **20**, No. 12, 2252 (1965); **21**, No. 4, 725 (1966).
8. E. E. Semenenko, Pis' ma ZhETF, **3**, issue 11, 443 (1966).
9. J. Kondo, Progr. Theor. Phys., **32**, 37 (1964).
10. A. A. Abrikosov, ZhETF, **48**, 990 (1965); Pis' ma ZhETF, **1**, issue 1, 53 (1965).
11. A. I. Shal'nikov, ZhETF, **10**, 630 (1940).
12. B. G. Lazarev, E. E. Semenenko, A. I. Sudovtsov, ZhETF, **40**, issue 1, 105 (1961).

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