SOVIET PHYSICS JETP VOLUME 25, NUMBER 1 JULY, 1967

ON THE SUPERCONDUCTING PROPERTIES OF ALUMINUM FILMS

N. E. ALEKSEEVSKIĬ and M. N. MIKHAEEVA

Submitted to JETP editor July 15, 1966

J. Exptl. Theoret. Phys. (U.S.S.R.) 52, 40—41 (January, 1967)

The superconducting properties of Al films, condensed at liquid nitrogen temperature and subsequently annealed to room temperature, were investigated. The experiments indicate that the high critical temperatures of the thin Al films evidently can not be the result of the formation of an oxide layer on their surfaces.

LATELY there has appeared a series of paper papers[1-4] communicating observations of thin Al films with critical temperatures which considerably exceed T_c of the bulk metal. In all of these cases the experiments were conducted on films which could have had a layer of oxide on their surfaces (the film was taken out in the air after deposition and before mounting in a helium dewar).

Strongin, Paskin and Kammerer[1,2] explain these results with the help of Ginzburg's surface superconductivity. As is generally known[5-8], the interaction of the surface layer of the metal with atoms of a surface coating (for example, an oxide film) can lead in certain conditions to intensification of the interelectron attraction in the surface layer of the metal and to the formation of superconducting pairs of electrons. A theoretical plot of T_c against the film thickness d was constructed for Al films on the basis of the idea of surface superconductivity in[2], and good agreement with experiment was obtained.

Kresin and Tavger[9] obtained an analogous dependence for very thin films, starting from entirely different premises. Having assumed that the quantization of energy in momentum space occurs in a thin film because of its small thickness, they obtained a dependence of T_c close to that which obtains from the consideration of surface superconductivity.

The investigation of Al films prepared in different conditions probably could help confirm the point of view referred to above.

We studied their Al films evaporated in a vacuum of 10^{-6}—10^{-7} mm Hg at the temperature of liquid nitrogen. After completion of the deposition, the working vial was warmed to room temperature, sealed off, and placed in a helium dewar. The film was kept in vacuum all of the time.

The experiments demonstrated that the critical temperature of thin films varies strongly with the thickness, increasing with decreasing thickness. Thus, for example, a film with $d = 8.9 \times 10^{-6}$ cm had $T_c = 1.628$°K, a film with $d = 7.9 \times 10^{-6}$ cm had $T_c = 1.904$°K.

The critical currents of such Al films were exceedingly small, and were inversely proportional to the thickness of the sample and linearly dependent on temperature (Fig. 1). It should be noted that since the experiments were conducted below the λ-point of helium, the effect of overheating the films on the magnitude of the critical current was practically eliminated.

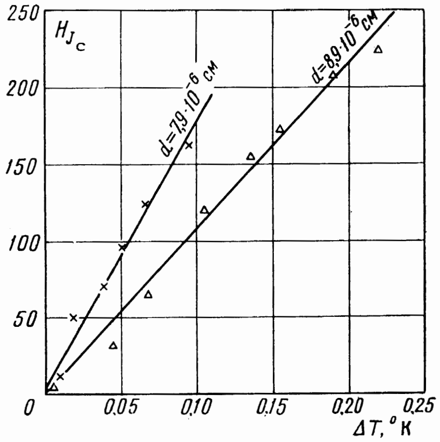

FIG. 1. Dependence of the field of the critical current H_{J_c} (in 10^{-3} Oe) on the temperature for two films of Al which were evaporated in vacuum at a temperature of 77°K and annealed subsequently to room temperature.

Leaving the films for some hours in air and annealing them at 100°C did not lead to a significant change of the results.

Since even evaporation of Al at low temperature does not eliminate the possibility of the formation of an oxide film, owing to the residual oxygen, we carried out experiments on samples prepared in an atmosphere that facilitates deoxidation. To this end, hydrogen was passed for a long period of time through the vial, which was preliminarily evacuated to 10^{-6} mm Hg. The vial was then filled with hydrogen, and left at room temperature for 48 hours, after which the vial was again evacuated. In this instance (as established by mass-spectroscopic measurements) the chief component of the residual gas was hydrogen. The evaporation of Al was conducted at liquid-nitrogen temperature.

It was found that samples prepared in such a manner also display a strong dependence of T_c on d, of the same character as in the case of films evaporated in the usual manner.

These experiments evidently indicate that the high critical temperatures of thin Al films can not be the result of the formation of an oxide layer on their surfaces.

While excluding the possibility that the increase of T_c of thin Al films can be the result of a cause which has not yet been explained, for example by the occurrence of a new crystalline modification with a higher critical temperature, it is possible nevertheless to assume that in the case of Al an explanation involving the mechanism proposed in the work of Kresin and Tavger is more likely.

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Translated by D. McDonald
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