ELECTRICAL AND THERMAL PROPERTIES OF NIOBIUM-BASE CERMETS

B. S. Skidan, A. S. Vlasov, V. A. Alekseev, T. S. Myl'nikova, and Yu. F. Ryzhkov

In the work described below a study was made of the behavior of Nb-Al₂O₃ cermets at very low temperatures. In order to determine the effect of corundum on the behavior of superconducting cermets of this composition, it was necessary to produce composites of minimum metal content at which paths for the passage of current would still be preserved. A problem of this kind can be solved either by invoking the theory of percolation [1] or by carrying out model experiments [2].

A model system was employed consisting of a mixture of the refractory oxide Al₂O₃ and the metal Nb. Starting materials of "ch." ("pure") grade, containing not less than 99.5% of the main components, were used. To corundum powder was of 1- to 2-μm particle size, and the niobium powder of 5- to 10-μm particle size. The powders, taken in the required proportions, were mixed together in a vibratory mill with a binder — 1% aqueous solution of polyvinyl alcohol. The mixtures were pressed into 5-mm-square × 50-mm-long and 16-mm-diameter × 16-mm-high specimens, which were then dried to constant weight at 110°C and sintered in a vacuum at 1800°C. Their relative density was 95-97%.

According to x-ray phase analyses, the resultant specimens consisted of a mixture of α-Al₂O₃ and niobium. Examinations of their microstructure revealed that the metal was fairly evenly distributed in their ceramic matrix and was in the form of grains up to 20 μm in size (Fig. 1). These cermets are superconductors. Measurements were made of their temperature of transition (°K) into the superconducting state. The volume electrical resistivity of the cermets, measured by the four-point method, before the transition into the superconducting state was ~1 Ω·m at metal contents of up to 20 vol.% and decreased sharply, to ~10⁻² Ω·m, at higher metal contents (Fig. 2). This was indicative of the presence of contacts between the metal particles. The sudden fall in electrical resistivity above a certain niobium concentration in the cermets was a result of qualitative changes in their conducting structure, such as have been observed in experiments carried out on a model material [1].

The transition into the superconducting state was accompanied either by a sharp fall in electrical resistivity (composites with metal content of more than 20%) or by the appearance


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of a horizontal portion in the resistivity curve (composites with metal contents of less than 20%) (Fig. 3). In composites of high metal content the transition into the superconducting state occurred at a temperature of 6-7°K, and in composites of low metal content, at 1-2°K. With the latter, a horizontal plateau in the curve was observed in the temperature range 2-5°K, which was probably a result of the existence of a reaction zone between the metal and corundum [3]. This was apparently also responsible for the comparatively low (1Ω-m) volume electrical resistivity before the transition into the superconducting state.

The thermal conductivities of the materials investigated were determined by comparison with those of other materials [4]. As reference materials copper, niobium, and corundum were employed. Cylindrical specimens of the metals, corundum, and cermets containing 16 and 30 vol.% niobium were prepared by the above-described method. Thermal conductivities were calculated with the expression

$$\lambda_x = \lambda_0 \frac{\Delta T_0}{\Delta T_x},$$

where $\lambda_0$ and $\Delta T_0$ are, respectively, the thermal conductivity of a reference material and the temperature drop across it, and $\lambda_x$ and $\Delta T_x$ are, respectively the thermal conductivity of a specimen being investigated and the temperature drop across it. Measurements at 20-100°C showed that the thermal conductivity of the cermets steadily increased with rising metal content (Fig. 4).

The results obtained were processed with the Maxwell–Aitken equation, derived for a continuous medium containing dispersed spherical particles of a second phase [5]. It was found that, when allowance was made for specimen porosity (3-5%), experimental and calculated data closely matched. Discrepancies increased, reaching a maximum of 15%, at higher metal contents, which was probably due to the presence of direct contacts between metal particles.