Resistivity of the metallic phase of epitaxial VO_2 films

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(Submitted 27 September 1994)
Pis'ma Zh. Eksp. Teor. Fiz. **60**, No. 9, 637–638 (10 November 1994)

The temperature dependence of the resistivity of thin epitaxial films of VO_2 was studied. The films, as distinguished from single crystals, are not destroyed at the metal-insulator phase transition. It was concluded that the metallic phase of VO_2 might not be a conventional Fermi liquid. © *1994 American Institute of Physics.*

Pure vanadium dioxide undergoes a striking first-order metal–insulator phase transition at a temperature $T_c \simeq 340$ K. It is marked by an electrical jump (up to five orders of magnitude) and by a crystalline phase change which involves an atomic displacement and a small volume increase from a low-temperature ($T<340$ K) monoclinic to a high-temperature ($T>340$ K) tetragonal structure.[1] The metallic phase of VO_2 ($T>340$ K) has been the subject of considerable experimental and theoretical investigations which were motivated by a desire to understand the nature of the metal-insulator transition and the unusual metallic properties of this compound.

Recently, Allen *et al.*[2] studied the resistivity of the high-temperature metallic phase of VO_2 single crystals and found that "like the normal state of copper-oxide superconductors, metallic VO_2 might not be a conventional Fermi liquid." They also noted that there might be a "trivial" interpretation of the unusual parameters of metallic VO_2 obtained in their work; e.g., the very short electron mean free path (3.3 Å) can result from cracks of a VO_2 single crystal as a result of undergoing a phase transition. A possible way to avoid this problem is to study thin films.[2]

The VO_2 films were deposited by a two-beam lazer-ablation technique using a vanadium metal target and a YAG pulse lazer.[3] The thickness of the films varied from 150 to 200 nm. To achieve a high epitaxial and structural quality, VO_2 films were grown on polished TiO_2 single-crystal substrates. The structure of VO_2 at a deposition temperature of 600 °C is rutile and the lattice constants nearly match those of TiO_2. The x-ray and Rutherford backscattering measurements showed a high degree of epitaxial VO_2 films. The very sharp and large ($>10^4$) resistivity jump at T_c, shown in Fig. 1a, indicates the high epitaxy of VO_2 films. The dc conductivity was measured using the four probe method.

The thin VO_2 films are free of failure when undergoing a phase transition. It is therefore interesting to compare the temperature dependence of the resistivity in the metallic phase of VO_2 films with that of single crystals. The result of a comparison (see Fig. 1a) shows that the resistivity of a thin film and a single crystal agrees within the experimental error of the film thickness measurements. It must be emphasized that the temperature dependence of the resistivity of a thin film shown in Fig. 1b does not change when cycling more than 20 times through the phase transition.

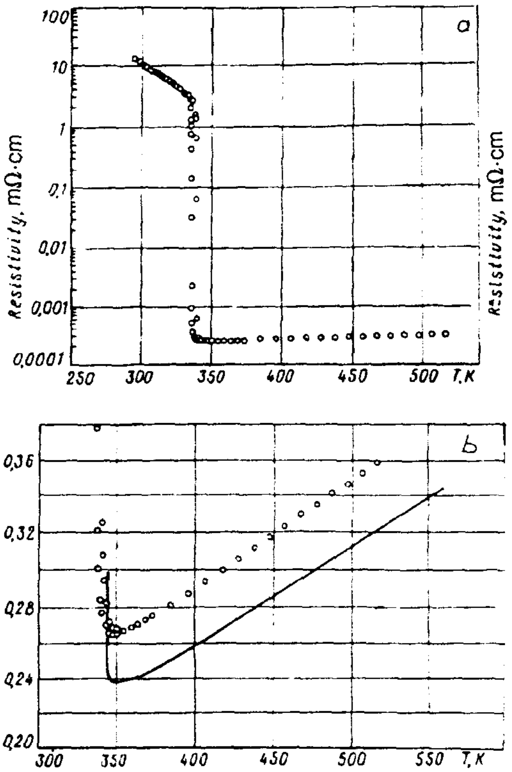

FIG. 1. Temperature dependence of the resistivity of VO_2 thin films. (a) Dielectric and metallic phases; (b) metallic phase. Triangles—Thin films. Solid line—Single crystals from Ref. 2.

The "trivial" reason of the resistivity data influenced by cracks produced as a result of heating the sample through T_c must therefore be ruled out. Following Allen *et al.*,[2] we suggest that the metallic phase of VO_2 might not be a conventional Fermi liquid.

The fact that a very broad Raman scattering background of the metallic phase of VO_2 (Ref. 4) is similar to the normal state in copper-oxide superconductors[5] and in K_3C_{60} (Ref. 6) is an added reason to suggest that metallic VO_2 is not strictly a Fermi liquid, and that it can be described by using the Varma *et al.*[7] marginal Fermi-liquid theory.

We would like to thank Prof. P. B. Allen for providing the manuscript of the article[2] before publication.

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