LANDAU QUANTUM OSCILLATIONS OF THE SURFACE RESISTANCE OF MoO_2

E.P. Vol'skii and V.M. Teplinskii
Institute of Solid State Physics, USSR Academy of Sciences
Submitted 19 March 1971
ZhETF Pis. Red. 13, No. 9, 477 - 479 (5 May 1971)

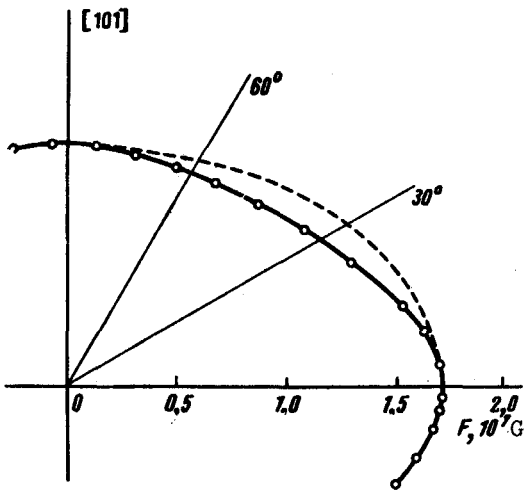
Transition-metal oxides differ strongly in their electric properties [1]. Some are good dielectrics, others have metallic conductivity, and some experience a phase transition from a metallic to a dielectric state at a definite temperature. The nature of the particular behavior is still not quite clear. It is therefore of great interest to study the electronic energy spectrum of such compounds.

For compounds with metallic conductivity, if obtained in the form of sufficiently perfect single crystals, one can use also traditional methods used in metal research, such as Landau quantum oscillations (the de Haas - van Alphen effect), and cyclotron resonance. So far, only two oxides, RuO_2 [2] and ReO_3 [3], were investigated in this manner.

In this paper we report our first results of observation of Landau quantum oscillations in MoO_2.

MoO_2 is a transition-metal dioxide having a crystallographic structure isomorphic with the structure of rutile (TiO_2), or a distorted variant of this structure. The electric conductivity of many of them, including MoO_2, has a metallic character [4].

The MoO_2 single crystal on which our measurements were made was obtained by precipitation from the gas phase by the method of chemical transport reactions. The crystal was an elongated parallelepiped with mutually perpendicular side faces, with dimensions 1.0 × 1.0 × 4 mm. The side faces coincided with the the crystallographic planes $(\bar{1}11)$ and $(11\bar{1})$ of the monoclinic lattice of MoO_2 [5].



Frequency of Landau quantum oscillations in MoO_2 vs. direction of magnetic field in the (111) plane, in polar coordinates. The dashed line shows an ellipse whose semiaxes coincide with the external values of the oscillation frequency.

The ratio of the electric resistivities of our sample, $\rho(391°K)/\rho(4.2°K)$, measured by the four-contact method, was 90. The Landau quantum oscillations of the surface resistance were measured at 4 MHz by a method described earlier [6], in a magnetic field up to 50 kG in a superconducting solenoid, at 1.3°K. The direction of the magnetic field was changed by rotating the sample with the aid of a special rotating unit.

The dependence of the quantum-oscillation frequency on the magnetic-field direction in a plane coinciding with one of the lateral faces of the crystal is shown in the figure. Owing to the inaccurate calibration of the magnetic field of the solenoid, the systematic error in the determination of the absolute frequencies of the oscillation may amount to ±5%. The relative error in the measured frequencies along the curve in the figure is determined by the scatter of the points, and does not exceed 1%.

The measurement results shown in the figure indicate that we have observed oscillations from the closed part of the Fermi surface of MoO_2. The experimental oscillation frequencies are 1.11×10^7 and 1.71×10^7 Hz, respectively.

The temperature dependence of the oscillation amplitude was measured for the magnetic field direction [101] in the temperature interval 1.3 - 2.35°K. The effective mass calculated from these data is 0.97 ± 0.2.

MoO_2 should be a compensated metal, so that its unit cell contains two Mo^{+4} ions, each of which can give up to the conduction band two electrons from the unfilled 4d shell. Thus, other sections of the Fermi surface of MoO_2 should also exist.

In conclusion, the authors are deeply grateful to A.N. Zhukov and R.K. Nikolaev for supplying the MoO_2 single crystals, to V.Sh. Shekhtman and V.I. Kozlova for an x-ray diffraction determination of the crystal orientation, and to S.F. Kosterov and S.N. Nikonov for help with the experiments.

[1] D. Adler, Sol. Stat. Phys. 21, 1 (1968).
[2] R.T. Slivka and D.N. Langenberg, Phys. Lett. 28A, 169 (1968).
[3] J.E. Graebner and. E.S. Grenier, Phys. Rev. 185, 992 (1969).
[4] D.B. Rogers, R.D. Shannon, A. Sleight, and J.L. Gillson, Inorganic Chemistry 8, 841 (1969).
[5] G.B. Bokii, Vvedenie v kristallokhimiyu (Introduction to Crystal Chemistry), MGU, 1954, p. 368.
[6] E.P. Vol'skii, Zh. Eksp. Teor. Fiz. 46, 123 (1964) [Sov. Phys.-JETP 19, 89 (1964)].

EXCITATION OF SOUND WHEN A SURFACE LAYER OF A LIQUID ABSORBS A LASER PULSE

F.V. Bunkin, N.V. Karlov, V.M. Komissarov, and G.P. Kuz'min
P.N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 22 March 1971
ZhETF Pis. Red. 13, No. 9, 479 - 483 (5 May 1971)

We report in this article the first observation of the excitation of sound when radiation pulses from a CO_2 laser are absorbed in the surface layer of a liquid. We have observed that sound pulses consisting of compression and rarefaction pulses following each other at distances equal to the light-pulse duration are excited when water is exposed to focused powerful radiation from a pulsed CO_2 laser. Their growth time is determined by the time necessary to establish the quasistationary process of evaporation of the liquid from the surface. The sound excitation was due to the recoil pulse produced upon evaporation of the liquid.

Excitation of acoustic waves by absorption of CO_2-laser radiation in gases was observed in [1, 2]. Liquids have a much higher absorption coefficient in the infrared region. For water, according to our measurements, the coefficient of absorption of CO_2-laser radiation is $\alpha > 10^2$ cm^{-1}. Therefore, at sufficiently high incident-light intensity, a thin surface layer of the liquid is strongly heated. When the density of the absorbed energy αW ($W = I\tau$, where I is the intensity of the laser pulse and τ is its duration) exceeds the value $\lambda\rho$ (λ is the specific heat of evaporation and ρ the density of the liquid), forced evaporation of the liquid takes place. For water, the threshold value $W_{ft} = \lambda\rho/\alpha$ does not exceed 25 J/cm^2. The experiments were performed way above threshold. Under these conditions there is apparently no phase equilibrium.