SIXTH ALL-UNION CONFERENCE ON LOW TEMPERATURE PHYSICS

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THE Sixth All-Union Conference on Low Temperature Physics took place in Sverdlovsk, between June 27 and July 2, 1960.

The conference considered approximately 50 papers. Along with the plenary sessions, seminars were held to discuss topics interesting to a narrower circle of people. In these seminars some twenty papers were discussed, a brief summary of which was presented at a plenary session by the directors of the seminars. Approximately 300 persons took part in the work of the conference, among this number some 200 participants from other cities — physicists from Moscow, Leningrad, Khar'kov, Kiev, Tbilisi, Sukhumi, Krasnoyarsk, Dubna, and other cities, as well as scientific workers from the Chinese Peoples' Republic, Poland, and Hungary. Plenary sessions were devoted to magnetic phenomena at low temperatures, superconductivity, electronic properties of metals, polymorphism, ultrasonics, and semiconductors. At the seminars the following were considered: papers on the investigation of liquid helium, methods for production of low temperatures and the technique of low temperature physical experimentation, mechanical properties of metals, ferromagnetic resonance, and low temperature properties of semiconductors. Two large seminars were held by the theoreticians.

The director for problems in low temperature and solid state physics, Academician **P. L. Kapitza,** spoke at the conference opening, which drew an audience of 900 persons. He described the general situation in low temperature physics at the present time, and analyzed the history of the development of physics at Sverdlovsk. **P. L. Kapitza** particularly emphasized the significance which work with ultra-pure materials holds for low temperature physics. Lowering the temperature leads, as is well known, to a reduction in the crystal lattice deformations arising from thermal motion of the atoms. It is evident that there is no point in cooling the sample under investigation to temperatures at which the lattice deformations associated with thermal motion become much fewer than the "statistical deformations" of the lattice associated with impurities, dislocations, and similar crystalline defects. **P. L. Kapitza** noted that it is possible at the present time to carry out chemical and physical purification of certain crystals to such a degree that the lattice deformations in them correspond to the thermal agitation of the atoms at a temperature much lower than 1°K. Efforts toward the production of extremely pure substances and the development of super-sensitive methods of analysis (in particular, activation analysis) now rank among the most essential.

A. Ferromagnetic and antiferromagnetic properties of materials at low temperatures.

The inclusion of ferromagnetism in the program of the conference was connected with the fact that the Sverdlovsk Institute of Metal Physics is the leading scientific institution in this field. To the colleagues of this institute belong the greatest of accomplishments, both in the field of the theory of ferromagnetic metals and alloys, and in the field of their experimental investigation, as well as many important technical applications. Work is currently being carried out at the Institute in connection with low temperature magnetism.

In a paper by **S. V. Vonsovskiĭ, Yu. P. Irkhin,** and **V. G. Shavrov** (Institute of Metal Physics, Acad. Sci. U.S.S.R.) the Hall effect in ferromagnetics was investigated. In non-ferromagnetic substances the Hall e.m.f. is determined by the external field: $E_H \sim RH$. In ferromagnetics, as follows from experiment, $E_H \sim (R_0H + R_SM)$, where M is the intensity of magnetization, while the "spontaneous" Hall constant R_S at high temperatures exceeds by 10 times the normal Hall constant R_0, and is characterized by a strong temperature dependence. In the paper an attempt is made to explain certain anomalies of the Hall effect in ferromagnetics on the basis of an $(s - d)$-exchange model with spin-orbit interaction taken into account. It is shown that the temperature variation of R_S may be directly associated with the temperature dependence of the square of the electrical resistance. A formula is also obtained for the temperature dependence of R_0 in a ferromagnetic, the electrical resistance of which is determined by collisions of electrons with phonons and ferromagnons.

N. V. Vol'kenshteĭn and **G. V. Fedorov** (Institute of Metal Physics) have investigated experimentally the temperature dependence of the Hall effect in pure ferromagnetics — nickel, iron, and cobalt. The measurements were conducted over the broad temperature range from 300 to 4.2°K. It was found that even the ordinary Hall constant R_0 in ferromagnetic metals has an anomalous temperature dependence, differing from the temperature dependence of R_0 for non-ferromagnetic metals. From the data obtained, the conclusion is drawn that the Hall effect in ferromagnetics depends, not only upon the intensity of magnetization, but also upon the crystallographic structure.

The paper by **E. A. Turov** and **A. I. Mitsek** (Institute of Metal Physics) was devoted to a theoretical investigation of the temperature dependence of the anisotropy constant of a ferromagnetic, for crystals of various symmetry. The phenomenological spin-wave theory was employed. It proved possible to relate the temperature dependence of the anisotropy constant to the temperature variation of the spontaneous intensity of magnetization. The authors note that precise measurements of the magnetic anisotropy constant at low temperatures are of great importance for verification of the fundamental bases of the theory of ferromagnetism.

A. S. Borovik-Romanov and **I. E. Dzyaloshinskiĭ** (Institute for Physical Problems, Acad. Sci. U.S.S.R.) have investigated experimentally and theoretically piezomagnetism in the antiferromagnetic fluorides of cobalt and manganese. With a particular structure the antiferromagnetics may possess a piezomagnetic effect. This effect can be regarded as a manifestation of weak ferromagnetism in the antiferromagnetic as a result of a variation in the magnetic symmetry due to deformations. In the case of the indicated substances, piezomagnetism can appear only as a result of shearing stresses. The investigation was carried out with single crystals. For measurement of the magnetic moments as a function of the field a sensitive balance was used, with which it was possible to measure forces of 10^{-7} g. A piezomagnetic effect was found in both substances, manifesting itself as a spontaneous intensity of magnetization in the deformed samples. The magnitude of the spontaneous piezomagnetic moment constituted several c.g.s. magnetic units per mole (of the order of 0.01% of the nominal magnetic moment of ferromagnetics). **P. L. Kapitza** noted the close correspondence between theory and experiment during the course of this investigation. The success of the work was also assured by the procurement of single-crystal samples of these difficult-to-grow crystals (the samples were produced by N. I. Mikhaĭlov at the Institute for Physical Problems).

E. A. Turov and **V. E. Vzdornov** (Institute of Metal Physics) have developed a theory for the weak ferromagnetism in rare-earth orthoferrites — compounds of the type $MeFeO_3$ (where Me is a rare-earth element from samarium to lutecium) having a rhombic lattice. The possible directions for the spontaneous moment of the weak ferromagnetism are given in their relation to the magnetic structure. The variation of the intensity of magnetization in a magnetic field has also been studied. Weak ferromagnetics of the type described have a number of peculiarities distinguishing them from the uniaxial weak ferromagnetics investigated by Dzyaloshinskiĭ.

During the discussion **A. S. Borovik-Romanov** reported on studies of the magnetic properties of cobalt sulfate performed by **N. M. Kreĭnes** at the Institute for Physical Problems. In the absence of a field this substance, an isomorphic orthoferrite, possesses no weak ferromagnetism; in a magnetic field, however, it transforms into a state having weak ferromagnetism.

E. A. Turov and **N. G. Guseĭnov** (Institute of Metal Physics) have computed the magnetic resonance frequency in a weakly-ferromagnetic rhombohedral crystal (of the type of hematite or manganese carbonate), with anisotropy taken into account. The corresponding wavelengths lie in the millimeter and centimeter regions. The dependence of the resonance frequency upon the magnitude and direction of the magnetic field has been found. The results agree with measurements by Japanese authors. The magnitude of the "Dzyaloshinskiĭ field," computed from data from the resonance measurements, agrees to within a few percent with the value obtained as a result of magnetic measurements. **P. L. Kapitza** emphasized the great significance which experimental resonance investigations hold for the study of this and many other phenomena in low temperature physics.

V. V. Tolmachev (Mathematical Institute, Acad. Sci. U.S.S.R.) gave a talk on the mathematical theory of ferromagnetism. He showed that the Heisenberg model of a ferromagnetic is mathematically equivalent to the problem of a Hamiltonian, quartic in Fermi operators, which had previously been formulated in the theory of superconductivity. The speaker indicated a number of advantages in the proposed method.

M. O. Kostryukova (Moscow State University) has carried out measurements on the specific heats of nickel, zinc, and mixed nickel-zinc ferrites (20% Ni). The measurements were performed over a range of temperatures from that of liquid hydrogen to approximately 2°K. In the mixed ferrite near 10°K an anomaly was found: its specific heat in the helium temperature region was some 170 times greater than the specific heat of the pure nickel ferrite. The temperature dependence of the specific heat of the mixed ferrite at helium temperatures is described by the relation $AT^3 + BT^{3/2}$, while the cubic term is some 30 times greater than the lattice specific heat.

An interesting paper was presented by **R. A. Alikhanov** (Institute for Physical Problems). He has performed, over a broad temperature range, a neutron-diffraction study of antiferromagnetic nickel fluoride. The neutron-diffraction investigation method was considerably improved by comparison with the methods of other authors. The anhydrous sample of NiF_2 was produced at the same institution by N. N. Mikhaĭlov. The temperature dependence of the intensities of the magnetic reflections was investigated; a law close to T^2 was obtained. From consideration of the relationships of the (100) and (001) reflections (the latter of which is well resolved, thanks to improved resolution) the conclusion was drawn that the magnetic moments of the Ni^{++} ions lie in the (001) plane. It was also shown that NiF_2 possesses weak ferromagnetism. The spontaneous intensity of magnetization vectors of the sublattice form an angle of 13° with the [100] direction.

N. V. Vol'kenshteĭn and **M. I. Turchinskaya** (Institute of Metal Physics) have made an experimental study of the anisotropy of the intensity of magnetization of the disordered alloy Ni_3Mn at helium temperatures. The investigation was carried out with single-crystal samples out in the [111] [110] and [100] directions. Intensity of magnetization curves for these samples were obtained at room, nitrogen, hydrogen, and helium temperatures. The [111] direction remains at all temperatures the direction of easy magnetization. With cooling to 77°K the magnitude of the moment in a field of the order of 100 oersteds rises sharply, and then falls with further decreasing temperature. The increase in the saturation field with reduction of the temperature from the nitrogen to the helium region, even for the direction of easiest magnetization, cannot be explained by an increase in the magnetic anisotropy. **E. A. Turov** indicated the possibility of explaining this anomaly by a transition of the substance in the magnetic field from an antiferromagnetic into a ferromagnetic state.

O. S. Galkina and **L. A. Chernikova** (Moscow State University) have measured the temperature dependence of the electrical resistance of ferromagnetic copper-nickel alloys at 8 — 30°K, as well as the variation of the resistance in a magnetic field at 20°K. A correlation has been established between the two effects. The results obtained are regarded as confirmation of the influence of scattering of electrons on ferromagnons.

E. I. Kondorskiĭ, O. S. Galkina and **L. A. Chernikova** (Moscow State University) have discovered an anomaly in the electrical resistance of cupro-nickel alloys near the Curie point. For example, the resistance of an alloy of 59% nickel with 41% copper has a small maximum (approximately a half-percent) which lies a few tenths of a degree above the Curie point. In a magnetic field the effect diminishes. An explanation for this anomaly is proposed, based upon the idea of magnetic fluctuations near the ferromagnetic transition point.

E. I. Kondorskiĭ and **V. L. Sedov** (Moscow State University) have studied the influence of hydrostatic compression upon the saturation intensity of magnetization and the electrical resistance of iron, nickel, and certain ferromagnetic alloys at low temperatures.

V. E. Rode (Moscow State University) has measured the susceptibility of nickel-copper and nickel-aluminum alloys in fields up to 7000 oersteds (in the para-process region). Within a broad range of temperatures and concentrations the susceptibility of the para-process is proportional to $TH^{-1/2}$. **M. I. Kaganov** remarked that the value obtained for the susceptibility agrees in order of magnitude with ideas on the fields required for reorganization of the internal wave functions ($\sim 10^8$ oersted).

B. Superconductivity

In the field of superconductivity, following the work of Bardeen, Cooper, and Schrieffer, by whom the foundations of a microscopic theory of superconductivity were established, there now remains as the most important problem the study of possibilities for theoretical prediction of new superconductors having higher critical temperatures. The question of a criterion for superconductivity gave rise to a lively discussion at the conference. In particular, this question was touched upon in the speech by **S. V. Vonsovskiĭ** and **M. S. Svirskiĭ** (Institute of Metal Physics) who showed (proceeding from consideration of a model for a metal in the spirit of the microscopic theory) that there is a definite correlation between the property of superconductivity and the value of the effective charge of the ions of a metal. Computation of the effective ionic charge (following Slater) showed that for all superconductors, with a few exceptions, the effective charge turns out to be greater than three. Even this criterion, however (as also or others, such as the criterion of Matthias), does not appear to be complete, as is evident, for example, from the fact that one and the same metal, in different crystalline modifications, may or may not be a superconductor.

I. B. Borovskiĭ (Institute of Metallurgy) has made a study of the fine structure of the x-ray spectra (emission and absorption) of a series of superconducting compounds, and has made an attempt to correlate the features of these spectra with the occurrence of superconductivity.

N. E. Alekseevskiĭ remarked during the discussion that a correlation is observed empirically between the critical temperature for bismuth alloys and the atomic radius of the second metal. If one is to speak of more fundamental criteria, then an important quantity might be, for example, the number of conduction electrons per unit volume. The question of a criterion for superconductivity, however, as yet remains an open one.

V. L. Ginzburg (Physics Institute, Acad. Sci. U.S.S.R.) has carried out a comparison of the experimental data with the Ginzburg-Landau macroscopic theory of superconductivity. The formulae of this theory have been modified to take into account the circumstance (demonstrated by L. P. Gor'kov; see below) that the universal charge figuring in the theory is equal to double the electronic charge (the summed charge of the Cooper pairs). Values are obtained for the parameters of the theory of tin and (less reliably) for aluminum; the quantity κ for tin is about 0.15, and for aluminum an order smaller. V. L. Ginzburg also expressed ideas regarding the comparison of the macroscopic theory with the results for thin films (which have been obtained many times previously). The significant effect of the mean free path for electrons upon the properties of a superconductor (above all, upon the depth of penetration of the magnetic field) has recently been established. It may be regarded as certain that it is impossible from the properties of films to derive directly the penetration depth characteristic of the bulk metal. From the point of view of contemporary theory, a film is to be regarded rather as an alloy, with completely different values for the penetration depth and other characteristics. From this viewpoint, the experimental results of N. V. Zavaritskiĭ for thin films appear to be incomprehensible. **N. E. Alekseevskiĭ**, however, indicated in the discussion that the recently-obtained results of B. K. Sevast'yanov (Institute of Crystallography, Acad. Sci. U.S.S.R.) on critical fields for films agree well with Zavaritskiĭ's data on films and with the data for the bulk metals.

An interesting communication was presented by **L. P. Gor'kov** (Institute for Physical Problems). In his first paper there was presented a derivation of the equations of the Ginzburg-Landau macroscopic theory on the basis of microscopic theory. It was shown that the Ginzburg-Landau equations are a consequence of the micro-theory, the Ψ function taking on the sense of a wave function for the Cooper pairs. The significance of the parameter κ has also been found: its magnitude indicates whether a given metal belongs to the London or the Pippard types of superconductors; an expression for this parameter has been obtained in terms of the micro-theory. A corresponding study was also carried out for alloys, which are distinguished principally by a large value for κ (greater than $1/\sqrt{2}$). It was shown that if for pure metals the region of applicability of the macroscopic theory is confined to the immediate neighborhood of T_c ($10^{-3} - 10^{-4}$ of a degree in the case of a Pippard metal), then when impurities are present this region is substantially enlarged. In another paper, L. P. Gor'kov presented a microscopic theory of the magnetic supercooling effect, and found expressions for the critical field for supercooling. It was shown that London superconductors in strong fields must possess the special properties of superconducting alloys as regards the supercooling effect.

S. V. Vonsovskiĭ and **M. S. Svirskiĭ** (Institute of Metal Physics) have investigated theoretically the question of superconductivity in ferromagnetic metals. They found that the (s − d)-exchange interaction must affect the critical temperature of the superconductor and the properties of the superconducting phase. In particular, the interaction of electrons with ferromagnons must weaken the electron-phonon attractive interaction, and, as a consequence, oppose superconductivity. The authors advanced a hypothesis concerning the possibility, in principle, of the appearance of low-temperature phonon ferromagnetism as a result of a strong electron-phonon interaction involving the inner electrons (analogous to the development of superconductivity as a result of the electron-phonon interaction of the conduction electrons).

G. F. Zharkov (Physical Institute, Acad. Sci. U.S.S.R.) has investigated the problem of the pure superconducting and intermediate states of ferromagnetic superconductors. These states are possible in certain ranges of magnetic fields under known conditions. The structure of the intermediate state in a thin plate in a transverse field has been computed (in the spirit of Landau's study).

The paper by **A. I. Shal'nikov** and **N. I. Ginzburg** (Moscow State University) was devoted to the properties of thin films. Films from 0.1 to several microns thick in the form of hollow cylinders were deposited by simultaneous evaporation, under high vacuum, onto glass substrates at room temperature. The critical magnetic fields and critical currents were investigated in the neighborhood of the critical temperature. Reduction of the data was carried out on the basis of the Ginzburg-Landau theory. The effect of temperature and thickness predicted by the theory is qualitatively confirmed; the critical currents, however, turn out to be anomalously small (due to the presence of structural defects). The magnetic field penetration depth obtained was approximately 0.2 micron — three times greater than from the data of Zavaritskiĭ. In the discussion **M. N. Mikheeva** (Institute for Physical Problems) reported that she, together with **N. E. Alekseevskiĭ**, had also carried out a study of critical currents in films of tin, but with a different geometry (circular disks with radial current flow). Films deposited onto glass at both room and low temperatures were investigated by a pulse method. A dependence of the critical current upon $\Delta T = T_c - T$ corresponding to the theoretical $(\Delta T)^{2/3}$ law is observed, for films produced by the first method, only for $\Delta T \leq 0.05°$; for larger ΔT (and, for the films evaporated at liquid nitrogen temperature, beginning even with the smallest values of ΔT) a linear dependence holds. In absolute magnitude, the critical currents turned out to be close to those predicted by theory. It was emphasized by many participants in the discussion that a most important role is played by the structure of the film, which may be very far from the ideal structure assumed in the theory. The recommendation was made that electron microscopic studies be made of the films under investigation. It was also noted that it would be desirable to carry out, concurrently with measurements of critical currents and fields, determinations of the electron mean free path in a film.

Great interest was aroused by the paper of **Yu. V. Sharvin** and **V. F. Gantmakher** (Institute for Physical Problems) concerning an investigation of the dependence of the magnetic field penetration depth in a superconductor upon the magnitude of the field. This relation is of interest from the standpoint of improving the precision of the parameters of the contemporary version of the Ginzburg-Landau theory. The authors have developed a delicate method for the measurement of small variations in the penetration depth. The measurements were carried out through comparison of the frequencies of two generators completely immersed in liquid helium. The sample, to which was applied a longitudinal magnetic field, was placed within an induction coil in the circuit of one of the generators; the frequency of the second generator was held constant. The frequency difference was determined from the beats. The sensitivity of the apparatus was such that it was found possible to measure a variation in the penetration depth of 0.2 A. The authors have obtained preliminary results for tin. In the region of small fields the penetration depth grows proportionately to H^2 (as was to be expected); in larger fields a deviation from this dependence is observed. **N. E. Alekseevskiĭ** noted that this method, also developed by Schawlow in the U.S.A., may be used for various measurements of small variations in dimensions (for example, for determination of the volume change resulting from destruction of superconductivity).

N. V. **Zavaritskiĭ** (Institute for Physical Problems) reported on new measurements he has performed on the thermal conductivity of gallium at temperatures of 0.1 – 4.2°K. Samples of varying purity (ratio of resistances at helium and room temperatures from 0.005% to 1.5%) and varying crystallographic orientation were investigated. The thermal conductivity was measured in the superconducting, normal, and intermediate states. In the superconducting state an anisotropy in the thermal conductivity was observed which, evidently, is a reflection of the anisotropy in the width of the energy gap in the spectrum of gallium. In the intermediate state the thermal resistance increases significantly both for the case of lattice, as well as for that of electronic heat conductivity. The latter effect is evidently associated with the scattering of the normal electrons on the boundaries of the superconducting and normal regions.

P. A. Bezuglyĭ, A. A. Galkin and **A. P. Korolyuk** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) have measured ultrasonic attenuation at a frequency of 70 Mcs (wavelength of the order of 0.1 mm) in superconducting tin, as a function of crystallographic direction. The attenuation coefficient depends strongly upon the crystallographic direction, which, in the authors' view, provides evidence of anisotropy in the energy gap. The data obtained by the authors provide, in their opinion, a basis for assuming that there exists a slight dependence of the critical temperature upon the crystallographic orientation.

N. N. **Zhuravlev, G. S. Zhdanov** and **N. E. Alekseevskiĭ** (Moscow State University) presented a paper on the superconductivity of bismuth compounds. The investigations which the authors have carried out for a long series of bismuth alloys, many of which possess superconductivity, have made it possible to distinguish two groups of isomorphous superconducting compounds of bismuth with alkali and transition metals: the type ABi_2 (A = K, Rb, Cs) and the type BBi (B = Ni, Rh, Pt). A number of correlations between the critical temperature and the structural characteristics of the compounds (atomic radii of the components, Bi – Bi spacings) have been found. A number of ideas were expressed concerning the probable structure of superconducting modifications of pure bismuth.

C. Electronic Properties of Metals at Low Temperatures.

The papers by N. E. **Alekseevskiĭ** and **Yu. P. Gaĭdukov** (Institute for Physical Problems) "The Study of Galvanomagnetic Properties as a Method for Investigating the Fermi Surfaces of Metals" and by **I. M. Lifshitz** and **V. G. Peschanskiĭ** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R. and Khar'kov University) "Towards a Theory of Galvanomagnetic Phenomena" (read by N. E. Alekseevskiĭ) were most circumstantial and interesting. In obtaining the results reported at the preceding conference at Tbilisi, a study was made of the resistance in a magnetic field of single crystals of gold, copper, silver, tin, mercury, thallium, and gallium. The results obtained permit one to draw the definite conclusion that all of these metals have open Fermi surfaces. In the case of copper and silver, similarly to the case for gold, averaging over angle leads to the linear rule, for the variation of the resistance of polycrystals in a magnetic field, discovered by P. L. Kapitza. This rule may be regarded as a criterion for the existence of an open Fermi surface in monovalent metals. On the basis of stereographic projections obtained for specific directions of the magnetic field it is concluded that for gold, silver, and copper the Fermi surfaces are in the form of a space lattice composed of corrugated cylinders, with axes along [111] and [110] (gold, silver), and [111], [110], and [001] (copper). For thallium and gallium (less symmetrical structures), the Fermi surface is evidently a corrugated plane. Lead and tin have, possibly, a Fermi surface of the first type, with cylindrical axes along [111] (lead) and [010] and [111] (tin). A comparison of the experimental data obtained with the results of a computation for several particular types of Fermi surfaces, carried out by I. M. Lifshitz and V. G. Peschanskiĭ, permitted determination of the values of the parameters for the Fermi surface of gold. For the electron concentration, a value of almost exactly 1 electron per atom was obtained. Measurement of the Hall constants for silver, performed for two directions of the magnetic field (the minimum and the maximum of the polar diagram), made it possible to determine the radius of the Fermi sphere; it equals 6.1 ev. The diameter of the tube forming the space lattice was also evaluated. N. E. Alekseevskiĭ also reported on attempts made to influence the Fermi surface by means of pressure (400 atm gave no result in the case of tin) and impurities (in solidified lead-sodium solutions, for example, the possibility of such effects was demonstrated). Summarizing, it may be stated that silver, gold, copper, lead, tin, thallium, gallium, zinc, cadmium, and lithium can be classified (with a greater or lesser degree of certainty) as metals with open Fermi surfaces, while — bismuth, antimony, indium, sodium, beryllium, tungsten, aluminum, and mercury have closed surfaces.

E. S. Borovik and **V. G. Volotskaya** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) have studied galvanomagnetic phenomena in indium and aluminum in large effective fields, attained as a consequence of the high purity of the metals (ratios of resistances at 4.2°K and 290°K of 0.008% and 0.04%, respectively). The ratio of the mean free path and the radius of the Larmor orbit amounted to several tens. The dependence of resistance upon magnetic field, and the Hall effect were measured. In aluminum, saturation of the resistance as a function of magnetic field was observed, which refutes the results of Lüthi and Olsen, obtained with pulsed fields. In strong magnetic fields the Hall field exceeds by several times the electrical field along the current. The results for indium indicate that its Fermi surface is closed.

An interesting theoretical paper, devoted to consideration of possible anomalies in galvanomagnetic effects in the region of high pressures, was presented by **I. M. Lifshitz** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.). These anomalies are associated with the fact that with the application of high pressure the topology of the Fermi surface may change, which should lead to a sharp change in the properties of the metal; i.e., to a phase transition. A singularity in the electron density observed at the transition should give rise to a change in the thermodynamic properties (specific heat, magnetic susceptibility, compressibility) and a change in the dynamic characteristics, to a variation in the kinetic coefficients (for example, a variation in the resistance). It is curious that singularities in the first and second groups should appear on different sides of the transition point. The thermodynamic potential as a function of pressure contains, for $p > p_c$ (where p_c is the transition pressure), the term $(p - p_c)^{2\frac{1}{2}}$, i.e., the transition may be called, in Ehrenfest's terminology, a "$2\frac{1}{2}$-th order transition." An estimate of p_c leads to values of tens of thousands of atmospheres. Impurities are, in a certain sense, equivalent to high pressures (impurities of the order of tenths of a percent are required); impurities, however, smear out the transition.

L. S. Kan and **B. G. Lazarev** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) presented preliminary results of an experimental study of the influence of pressure (up to approximately 1700 atm) upon the resistance, at low temperatures, of single crystals of zinc and tin. As a result of the application of pressure, an increase of 20 — 30% in the resistance was observed. For zinc samples whose axes were oriented close to the direction of the hexagonal crystalline axis, an exceptionally large magnitude for the effect was found, and a complicated, non-monotonic dependence of resistance upon pressure.

G. E. Zil'berman and **I. O. Kulik** (Khar'kov) have considered theoretically the problem of quantum oscillations in the ejection of electrons in the photo-effect as a function of magnetic field. The study of these oscillations, as distinguished from other methods for investigating the electronic structure, can evidently yield information, not only on the Fermi surface itself, but on deeper layers as well.

A. A. Galkin and **A. P. Korolyuk** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R. and Institute of Radiotechnics and Electronics, Acad. Sci. U.S.S.R.) have investigated oscillations in the ultrasonic attenuation coefficient for frequencies of 17 — 220 Mcs in single crystals of zinc, tin, and bismuth, in a magnetic field at low temperatures. This method makes it possible to study the Fermi surface in metals. The period of the oscillations is constant (as a function of 1/H), but depends upon frequency. A strong anisotropy has been found for the effect.

As a result of a study of the magnetic susceptibility of bismuth at temperatures of 0.05 — 0.1°K in fields up to 13,000 oersteds (which was done for the first time, in this temperature region, by the author), **N. B. Brandt** (Moscow State University), has discovered, in addition to the ordinary oscillations, oscillations of high frequency, and has drawn a number of conclusions concerning the Fermi surface for the group of holes responsible for this phenomenon.

B. N. Aleksandrov, B. I. Verkin, and **I. V. Svechkarev** (Physico-Technical Institute, Acad. Sci. Ukr. S.S.R.) have investigated the magnetic susceptibility of single-crystal samples of indium, lead, and tin over the broad range from room to hydrogen temperatures. It has been found that the anisotropy of the susceptibility varies substantially with temperature. In indium, for example, the susceptibility parallel to the principal axis increases by a factor of three for the indicated reduction in temperature, while the perpendicular component scarcely changes at all. In the authors' opinion, these experiments indicate that the temperature variation of susceptibility for elements showing the de Haas — van Alphen effect is determined by groups of anomalously small numbers of electrons.

B. I. Verkin and **I. M. Dmitrienko** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) have measured the dependence of the period of the oscillations in the susceptibility of zinc upon pressure over the range from 0 to ~2000 atm. For measurement of the pressure, use was made of the displacement of the critical temperature of a superconducting ring of tin, located in a high-pressure bomb and surrounding the sample. The dependence of the period of the oscillations upon pressure turned out to be exceedingly complex.

D. Polymorphism, Semiconductors, and Other Problems.

I. A. Gindin, B. G. Lazarev, Ya. D. Starodubov, and **V. I. Khotkevich** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) presented a paper devoted to a further study of the phenomenon of low-temperature polymorphism. The circle of metals possessing low-temperature polymorphism has now been somewhat enlarged: to tin, lithium, sodium, bismuth, mercury, and beryllium have now been added potassium and (less certainly) zinc and magnesium. Consideration of this list confirms ideas to the effect that this phenomenon is characteristic of metals not having close-packed lattices. Various data were obtained on the properties of the low-temperature modification of bismuth; mechanical deformation curves were carefully measured in the 77°—90°K temperature range, and the accuracy of the transition temperature was improved (it is equal to 83°K ± 2°). Measurements of the electrical conductivity showed that the low-temperature modification of bismuth has the higher conductivity, and that at a temperature near 7°K it goes over into the superconducting state.

B. G. Lazarev, E. E. Semenenko, and **A. I. Sudovtsev** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R) presented a report on the superconductivity of beryllium and its low-temperature polymorphism. The investigations were carried out on thin films (400 — 1500 A thick). The low-temperature modifications exists up to approximately 30°K. On heating to higher temperatures and re-cooling to helium temperatures the superconducting transition (which characterizes the low-temperature phase) is found to be incomplete; upon heating to 60° (this temperature depends somewhat upon the time over which it is maintained) the low-temperature modification completely disappears. Curves were measured for the change in resistance during the process of heating the films to room temperature; two plateaus were observed: in the region over which the low-temperature modification exists, and beyond the transition (up to approximately 200°K). It is possible that the low-temperature modification observed in the films is the same as the low-temperature modification which is obtained by plastic deformation of the bulk metal.

B. N. Samoĭlov, B. V. Sklyarevskiĭ, and **E. P. Stepanov** (Atomic Energy Institute, Acad. Sci. U.S.S.R.) have studied the nuclear polarization of weakly-magnetic elements introduced into a ferromagnetic at extremely low temperatures. The polarization parameters for In^{114}, Sb^{122}, and Au^{198}, dissolved in iron, were determined at a temperature of a few hundredths of a degree, from the anisotropy ϵ of the γ radiation from these nuclei. According to present hypotheses, the experimentally-determinable quantity $\sqrt{\epsilon}$ is governed by the effective internal magnetic field H at the sites of the radioactive nuclei. Evaluation of H demonstrated that the internal field amounts, for the case of solutions of indium, antimony, and gold, to more than 150,000, 340,000, and 1,200,000 oersteds, respectively. The degree of polarization of these nuclei at the low temperatures reached (30—50%) is sufficient to permit a number of nuclear experiments to be carried out. The method employed for polarization of the nuclei is, clearly, a universal one. **A. V. Kogan** reported that at the Leningrad Physico-Technical Institute similar experiments have been performed on mixtures of Sc^{56} and Co^{60} in iron; values close in magnitude were obtained for the internal fields.

K. B. Vlasov (Institute of Metal Physics, Acad. Sci. U.S.S.R.) has investigated theoretically the rotation of the plane of polarization for elastic waves, in metals magnetically polarized by the application of a magnetic field. The attenuation of ultrasonics in a magnetic field may be formally described by use of a dynamic tensor for the modulus of elasticity whose components are complex quantities and depend upon the magnetic field. New components of this tensor appear in the magnetic field, to which correspond new physical phenomena. Specifically, there should be a considerable rotational effect for the plane of polarization of a transverse elastic wave propagated along the field; the rotation in fields of the order of 1000 oersteds should amount to degrees (and possibly to tens of degrees) per centimeter of acoustic path.

Considerable interest was attracted by an experiment performed by **N. I. Krivko, A. I. Gubanov,** and **N. M. Reĭnov** (Leningrad Physico-Technical Institute, AN. S.S.S.R.). The authors investigated the diamagnetic resonance of Cu_2O crystals at liquid helium temperatures. The measurements were carried out on platelets of dimensions 3 × 3 × 1 mm placed at an antinode of the electric field within a wave guide; the wavelength was about 3 cm. The absorption spectra obtained confirm the existence of polarons in cuprous oxide. The experiments permitted evaluation of the effective mass of the polaron: it was found to be on the order of 6—7 electron masses.

In the plenary session five papers on semiconductors were discussed (all but one of them from the Semiconductor Institute, AN. S.S.S.R.). The first three communications, by **S. S. Shalyt** and **I. N. Timchenko, I. V. Mochan** and **T. V. Smirnova,** and **Yu. N. Obraztsov,** concerned the study of the phenomenon of entrainment of current carriers in semiconductors by phonons moving in the process of heat propagation (this phenomenon was predicted also for the case of the metals computed by **L. Ê Gurevich**). The first paper reported measurements on the thermal emf of tellurium over the broad temperature range from 2 to 300°K. At low temperatures (below 50°K) a sharp rise is observed in the thermal emf, which with further reduction of the temperature (below 8°K) falls again. The temperature dependence of the thermal emf agrees satisfactorily with the conclusions of a theory developed for the interaction of a non-equilibrium distribution of phonons with current carriers in a non-uniformly heated semiconductor. In the second paper, the influence of entrainment upon the thermomagnetic effect in p-germanium was investigated. The temperature variation of the longitudinal and transverse effects was examined. The temperature dependences of the relaxation times characterizing the interaction of holes and electrons with long-wavelength longitudinal phonons turned out to be the same. In the paper by Yu. N. Obraztsov there was presented a theory for the influence of the entrainment of current carriers by phonons upon thermomagnetic effects in semiconductors. The theoretical curves were close to the experimental results of I. V. Mochan and T. V. Smirnova.

A theoretical paper by **G. E. Pikus** and **G. L. Bir** dealt with the effects of mechanical deformations upon the properties of semiconductors having complex structure. In semiconductors whose energy spectra are degenerate, the low-temperature electrical properties should vary sharply (a change in the effective mass of the carriers, the appearance of anisotropy, etc.) under deformations leading to an alteration in the symmetry of the crystal. In cubic crystals this effect may be expected at temperatures near 0.1°K under relative deformations of the order of 10^{-4}.

I. M. Lifshitz and **M. I. Kaganov** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) considered theoretically electronic resonance in semiconductors under conditions of crossed electric and magnetic fields. As is well known, a free electron in crossed fields drifts in a direction perpendicular to both fields, and simultaneously performs oscillations with the Larmor frequency $\omega = eH/mc$. The frequency of the oscillations in the case of a solid semiconductor is determined by the form of the dispersion law. This may be experimentally manifested in the dependence of the diamagnetic resonance frequency upon the current passed through the sample. The change in the resonance frequency $\Delta\omega/\omega = (c/v)\, E/H$ (for small electric fields). In metals, the effect must be small, due to the smallness of E for a given current. In semiconductors a quadratic dispersion law usually holds. The effect, however, should seemingly be observed in the case of hole-type germanium and silicon, where the dispersion law deviates from a quadratic one; in these cases, it appears, an effect of the order of 30% may be expected for electric fields of the order of 40–50 v/cm. For metals, such an effect might most likely be observed in bismuth.

In the concluding plenary session reports were presented by the chairmen of the symposia which took place during the course of the conference. These reports were presented by **I. M. Lifshitz**, **M. P. Malkov**, **S. S. Shalyt**, and **A. N. Orlov**, who recounted briefly the content of the papers considered in the symposia. One of these papers, that by **I. M. Lifshitz** on the kinetics of ordering processes, gave rise to a spirited discussion by the participants in the conference. The problem is formulated thus: a system is, by quenching, transferred into the temperature region below a phase transformation point (a region of order), and the ordering process is considered with time. The simplest case, that of a system characterized by two states "+" and "−" (for example, orientation of ionic spins "up" and "down"), was considered in concrete form. In the ordering process, all space is divided into alternating regions "+" and "−". The process develops towards the direction of minimizing the surface of the "web" of boundaries, in such a way that the regions are gradually consolidated. The principal role in the process is played by the unprofitability, from the standpoint of entropy, of the boundary surfaces. The mean dimension $\bar{R}$ of the regions grows with time t according to the law $\bar{R} \approx (a^2/\tau)^{1/2} t$ (here a is the lattice parameter and τ is a characteristic time), until the regions reach the order of size of crystallites; thereafter, the regions "eat" one another. The time τ, for the case of the ordering of a solid solution, appears to be of the order of fractions of a second to minutes; in the case of an antiferromagnetic transformation it is of the order of 10^{-8} second. This work is of great interest for low temperature physics, where it is often necessary to deal with phase transitions of the second order.

The following papers were also heard at the symposia. **I. A. Krasnikov** and **V. V. Tolmachev** (Mathematics Institute, Acad. Sci. U.S.S.R.) reviewed certain questions in the application of the methods of the theory of superconductivity to the problem of the ground state of an antiferromagnetic, and made an attempt to evaluate the energy of this state. The Polish scientist **Z. Golasewicz** (Joint Institute for Nuclear Research) considered a system of interacting fermions (a superconductor), and showed that there may exist in the energy spectrum of such a system a branch corresponding to coupled particles with identical spins (somewhat on the order of spin waves). **L. P. Pitaevskiĭ**, **E. M. Lifshitz**, and **I. E. Dzyaloshinskiĭ** (Institute for Physical Problems) discussed the properties of helium II films. It was shown that there enters into the thermodynamic potential for the film a term dependent upon its thickness d, of the form A/d^3; the constant A may be expressed in terms of the properties of the film and substratum. **Yu. G. Mamaladze** and **S. G. Matinyan** (Tbilisi University) considered theoretically the effect of rotation upon the damping coefficient for the oscillations of a disc in helium II, and explained some of the special features of this phenomenon which have been observed experimentally. **B. N. Esel'son** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) spoke on the use of charcoal absorption pumps for producing low temperatures (temperatures of the order of 0.8°K are readily obtained). **N. B. Brandt** (Moscow State University) gave a report on a simple spring balance having a sensitivity of 0.05 milligram, and on a method for production of high pressures (up to 15—20 thousand atmospheres), at low temperatures. **A. G. Zel'dovich** (Joint Institute for Nuclear Research) reported on the development and initiation of a liquid hydrogen ionization chamber of 50 l. volume, working in a magnetic field of 14,000 oersteds, on the production of liquid hydrogen containing 80% para-hydrogen (the evaporation rate of such converted hydrogen in storage is reduced by several times, as compared with the ordinary variety), and on the system developed in their laboratory for purifying gases of oil in liquefiers. **I. D. Kurova** (Moscow State University) reported on investigations of the properties of extremely pure germanium at temperatures of 300°—2.5°K. **É. I. Zavaritskaya** spoke concerning the temperature dependence of the p-n transition in germanium, investigated over a broad range of temperatures by herself and **B. M. Vul**. The effect of preliminary plastic deformation of industrial iron upon its mechanical properties at low temperatures, particularly at the elastic limit, was investigated by **I. A. Gindin** (Physico-Technical Institute, Acad. Sci. Ukr.S.S.R.) **N. M. Reĭnov** and **A. P. Smirnov** (Leningrad Physico-Technical Institute, Acad. Sci. U.S.S.R.) determined the elastic limits of single crystals of tin and indium at a temperature of the order of 0.1°K, making use of the superconductivity of these metals.

P. L. Kapitza summarized the conference in his concluding statement.

It is planned to hold the Seventh All-Union Conference on Low Temperature Physics in Khar'kov, in June-July 1960.

Translated by S. D. Elliott