# PREFACE

The selection of review papers for this collection was guided by two factors. Firstly, all of them deal with closely related subjects: most of the papers are devoted to superconductivity. The superfluidity of helium II discussed in one paper and superdiamagnetism considered in another are both phenomena associated with superconductivity to a certain extent. Secondly, all but one of the authors are on the staff of the I. E. Tamm Department of Theoretical Physics at the Lebedev Physical Institute of the USSR Academy of Sciences. This department, which celebrated its fiftieth anniversary in 1984, is one of the largest departments of theoretical physics not only in the USSR but in the whole world. Many fields of scientific activity are being developed here, the solid-state physics and, in general, the condensed state of matter occupying one of the leading positions among them. It is this branch of physics to which the problems discussed in this collection obviously pertain.

Since the contributors to this collection are all theoretical physicists, all the papers mainly concern the theoretical aspects. It is well known, however, that theory and experiment in physics are essentially related. In any case, the authors are neither abstract theoreticians nor mathematicians who have taken upon themselves the task of solving physical problems. Hence, reference is inevitably made to experimental results, and, if one may say so, the emphasis in these papers is laid on physics rather than on mathematics.

The phenomenon of superconductivity was discovered as far back as the beginning of this century (in 1911). Although the development of the microscopic theory of superconductivity involved a great deal of efforts, it was nevertheless completed about thirty years ago (in 1957). In spite of this, extensive investigations are still being carried out in the field of superconductivity, let alone its applications in engineering, and the range of topics brought under the purview of research in superconductivity is being continuously extended. Thus, new fields like the creation and study of organic and heavy-fermion superconductors emerged in the last decade. Studies of superconductors in nonequilibrium state and of magnetic superconductors were initiated somewhat earlier and are gathering momentum even now.

To my mind, however, the problem of high-temperature superconductivity is of utmost importance and I would even call it the question number one in superconductivity. Research in this field was started in our department in 1964 and the next few years were full of intense activity. A tangible outcome of this activity was the publication of the first collective monograph under the title *High-tempera-*

*ture Superconductivity* (Nauka, Moscow, 1977). A revised and enlarged version of this book, which is the first of its kind in the world, was translated into English in 1982. We believe that many points were clarified in this work, though the problem of high-temperature superconductivity could by no means be considered as "solved". It must be observed, however, that the initial optimism turned out to be exaggerated and it became clear that many barriers have to be overcome in the creation of high-temperature superconductors. In particular, it was found that the existing theoretical approaches and hypotheses, which were found to be highly successful for solving many problems in the theory of superconductivity, are insufficient for a reliable evaluation of the critical temperature $T_c$ for high-temperature superconductors. Consequently, the theory is not in a position to indicate infallible ways to the attainment of the goal, viz. a sharp increase in $T_c$ up to the values close to the liquid nitrogen boiling temperature $T_{b,N_2} = 77.4$ K and higher. This requires further research both in theory and various experimental aspects.

In compiling this collection of papers, the following approach was deemed appropriate by us. In the short introductory paper "High-temperature Superconductivity" by V. L. Ginzburg and D. A. Kirzhnits, intended for the layman, the problem is briefly outlined and the general characteristics of the present-day state-of-the-art are given. The next article "Superconductivity and Dielectric Function" by O. V. Dolgov, D. A. Kirzhnits and E. G. Maksimov is addressed mainly to theoreticians and essentially describes the difficulties and problems which have inhibited the creation of high-temperature superconductors.

The third paper in the collection, "Magnetic Superconductivity" by L. N. Bulaevskii, is devoted to the problem of the coexistence of superconductivity and ferromagnetism or antiferromagnetism. Although this problem has attracted the attention of scientists for over thirty years, significant progress has been made only during the last few years. This is adequately reflected in this paper, which is rich in content in spite of the fact that it does not cover all the aspects of the problem.

The paper by G. F. Zharkov "Thermoelectric Effect and Flux Quantization in Hollow Superconductors" briefly describes the results of investigation of thermoelectric phenomena in superconductors. In other words, it considers a certain type of nonequilibrium processes in superconductors. The main emphasis is laid on the description of the results obtained recently in our department. Among other things, a detailed analysis of the behaviour of hollow superconducting cylinders in a magnetic field was required for interpreting the obtained experimental results. Hence, considerable attention is paid to this question which is also of wider interest.

Within certain limits and under certain conditions, superconductors are ideal diamagnetics with a magnetic susceptibility $\chi = \chi_{1d} = -1/(4\pi)$. The susceptibility $\chi$ of ordinary diamagnetics, however, is quite low ($|\chi| \simeq 10^{-6}$-$10^{-4}$). Scientists have been debating for a long time the existence of superdiamagnetic materials that are not superconductors, i.e., whose diamagnetic susceptibility, although smaller than the ideal value $|\chi_{1d}| = 1/(4\pi)$, is at any rate comparable with $1/(4\pi)$. Theoretical studies of the recent past suggest that such a situation is indeed possible in the case of magnetic semiconductors with toroidal ordering (which means that the density of the toroidal dipole moment serves as order parameter of the material). It is interesting to note that the very concept of toroidal dipole moment, let alone magnetic materials with a toroidal moment, is little known and, to my knowledge, has not been specifically considered in any textbook or even monograph. The paper by A. A. Gorbatsevich and Yu. V. Kopaev, "Magnetic State with Orbital Toroidal Ordering and Superdiamagnetism", is devoted just to magnetic materials with toroidal ordering and to the possibility of their superdiamagnetism. The problem of superdiamagnetism, which is an interesting subject of investigation in itself, is quite important in the quest for high-temperature superconductivity.

The collection ends with the article "Superfluidity of Helium II near the λ-Point" by V. L. Ginzburg and A. A. Sobyanin. Both liquid helium and the λ-transition from helium I to helium II occupy a special position in physics. Suffice it to say that the region in the vicinity of the λ-point in liquid helium (we are talking about $^4$He ≡ helium-4 only) can be studied under quite "pure" conditions down to very small fractions of a degree near the transition point. At the same time, the critical (fluctuation) region near the λ-point in helium-4 (i.e., the region where the Landau theory of phase transitions cannot be applied) is quite large, and hence, in the light of what has been stated above, can be investigated easily. Leaving aside the kinetic effects, it can be said that the situation is more or less clear, at least from an experimental point of view, for homogeneous helium. However, there is a large number of problems concerning the boundaries, narrow channels or films, flows, etc., for which a consistent theory describing the behaviour of helium II near the λ-point has not been developed so far. The Ψ-theory of superfluidity described in this paper provides answers to such questions, but in turn it needs experimental verification and development. The following point is worth mentioning in this connection. After the discovery in 1972 of the phase transitions in liquid $^3$He at temperatures below 3 mK, the study of the low-temperature (superfluid) phases of $^3$He drew the attention of scientists engaged in low-temperature research. The theoretical and experimental investigations of these phases of $^3$He can undoubtedly be classified as the outstanding achievements of the physics of condensed state. Due to this success, the investigation of liquid helium-4, which was started as early as 1908, was pushed into background. However, it must be stated that liquid helium-4 has at least one decided advantage over liquid helium-3. As a matter of fact, the critical region near the λ-point in $^3$He is very narrow and, in any case, is not easily accessible. Hence, when we are talking of the critical region, it is helium-4 (to be more precise, helium II) that completely retains its original significance and, in our opinion, still deserves undistracted attention.

To sum up, it can be stated that all the papers comprising this collection are devoted to topics of current interest. Their authors are specialists in their respective fields and are actively engaged in study of the problems touched upon by them. Hence I am confident that this collection of papers will attract the attention of the reader and will prove to be beneficial.

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