Condensed Matter Physics, 2001, Vol. 4, No. 3(27), pp. 591–594

CONDENSED MATTER PHYSICS

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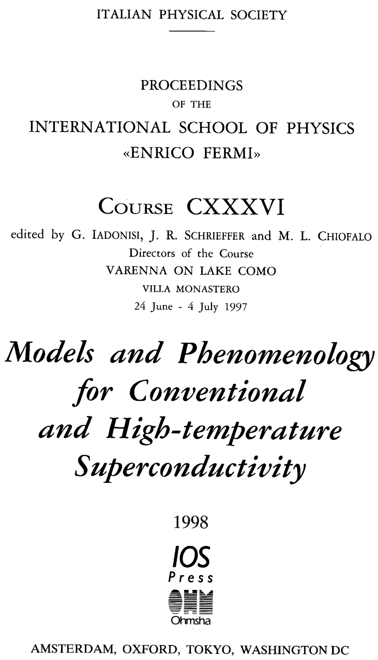
(Proceedings of the International School of Physics "Enrico Fermi")

Received August 29, 2001



ITALIAN PHYSICAL SOCIETY

PROCEEDINGS
OF THE
INTERNATIONAL SCHOOL OF PHYSICS
«ENRICO FERMI»

COURSE CXXXVI

edited by G. IADONISI, J. R. SCHRIEFFER and M. L. CHIOFALO
Directors of the Course
VARENNA ON LAKE COMO
VILLA MONASTERO
24 June - 4 July 1997

Models and Phenomenology for Conventional and High-temperature Superconductivity

1998

IOS Press
Ohmsha

AMSTERDAM, OXFORD, TOKYO, WASHINGTON DC

The book contains the proceedings of the International School of Physics "Enrico Fermi" (Course CXXXVI, Varenna on Lake Como, Italy, 24 June – 4 July 1997). The editors and the directors of the Course were G.Iadonisi, J.R.Schrieffer and M.L.Chiofalo. The main directions of school were devoted to the modern problems of the high-temperature superconductors including experiment as well as theory.

The physics of conventional and high-T_c superconductors is one of the most exciting fields in the physical science. Drawing the attention of investigators it urged the development of new techniques of experimental research, new ideas and models in the statistical physics. Despite the absence of the unified theoretical scheme, in the framework of which the mechanism of high-temperature superconductivity would be clear, the variety of new microscopic models and approaches enriched the solid state physics and at the same time opened the way to a deeper understanding of the properties of a number of new compounds in their normal (nonsuperconducting) state. Methods and approaches that appeared in this case immerse into other branches of physics.

There are 20 articles in the Proceedings, prepared by lecturers that are qualified specialists in the field. An experimental part is represented by those directions of investigations which are important from the standpoint of construction or verification of theoretical models (here the Raman and Infrared Spectroscopy, Nuclear Spin Resonance, Angular Resolved Photoemission Spectroscopy (ARPES), Josephson effect, transport phenomena are referred to). In the theoretical part of the Course the organizers of the school combined the lectures possessing elements of the tutorial nature (BCS theory, crossover from BCS to Bose-Einstein condensation, antiferromagnetism in 2D high-T_c superconductors, phenomenology of Josephson effect) and the reviews devoted to the discussion of the present viewpoints concerning the superconductivity and the physical phenomena in the HTSC systems (including phonon and non-phonon mechanisms, polaron theories, strongly correlated electron models, magnetic interactions, vortex physics). As it is mentioned by the organizers, unforgettable role in the choice of the main topics and lecturers was played by N.Mott. Emphasizing that in the book a large part of his ideas and of his recent work on high-temperature superconductivity is reflected, organizers dedicated this volume to his memory. For this reason the book opens with the lecture given by A.S.Alexandrov devoted to the scientific life of the prominent physicist.

A general description of the BCS and Eliashberg theories is given in the lecture which was held by G.S.Strinati. Addressing the young scientists and the students, the author considers the appearance of superconducting instability and its removal by creating a new phase, investigated the excitations (in particular, thermal and electromagnetic) sensitive to the superconducting state, analyzes the microscopic interactions which can be responsible for electron pairing in various materials. Attention is paid to the approximation used in the mentioned theories, considering their applicability to the "conventional" and "unconventional" (high-T_c) superconductors. The lecture by A.Barone devoted to the Josephson effect can be also partially related to the tutorial series. Here an elementary introduction to the phenomenology of the effect is given; attention is paid to its role as a tool in the study, in particular, of the order parameter (gap function) symmetry. In this connection, discussing the situation in "unconventional" superconductors the author examines heavy-fermion systems and high-temperature superconducting cuprates (in the latter case the experiments on the Josephson junction structures confirm the d-wave symmetry of the electron pairing).

A series of lectures presented in the book of proceedings are touching upon such an important and urgent question as pseudogap phenomena in high- temperature superconductors. It has recently become clear that the underdoped cuprates exhibit some special features in the normal state; the deviations are observed from the Fermi liquid behaviour due to the opening of a pseudogap above T_c. In the lecture by M.Randeria, the experimental manifestations of such anomalies in NMR, optics, thermodynamics, μSR, photoemission and tunnelling are discussed. Going from the calculations on the model systems the author argues that pseudogap is a natural consequence of the local dynamic pairing correlations in the normal state of superconductor at low densities of charge carriers. Similar questions are put in the lecture by H.B.Brom, together with the discussion of possibilities of the NMR techniques in the study of other properties of HTSC in the normal and superconducting state (including the detecting of phase separation and stripe phases). The subject matter of pseudogap phenomena is continued in the lecture by M.Randeria and J.-C.Campuzano where a detailed review of the ARPES method is given. The method is now one of the basic means of studying the HTSC materials. In particular, it makes it possible to directly observe the superconducting gap and to determine the order parameter symmetry, to study the non-Fermi liquid behaviour and pseudogap in underdoped materials. Experimental results obtained using ARPES for the optimally doped $YBa_2Cu_3O_{6.95}$, underdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ and overdoped $Nd_{2-x}Ce_xCuO_4$ crystals are discussed in the lecture held by Zhi-xun Shen.

A role of magnetic interactions and spin fluctuations as well as fluctuations of the phase and amplitude of the order parameter Δ in deviations from the Fermi-liquid behaviour in the cuprate superconductors is discussed in a lecture by J.R.Schrieffer. The author summarizes a long-term discussion concerning the paired condensate symmetry in favour of d-wave pairing. It is in agreement with an antiferromagnetic character of the spin fluctuations which in the author's opinion create a dominant part of the pairing potential. The conclusion is made regarding the importance of quantum and thermal fluctuations of the gap Δ in the underdoped materials where it becomes a dynamic quantum field.

Strongly correlated electron models and the possibilities they provide for considering the mechanisms of superconductivity in cuprates is the subject of the lectures given by T.M.Rice and by M.Marinaro and R.Citro. In particular, attention is paid to those aspects of the electron structure of the compounds which make it possible to use the $t - J$ and $p - d$ models to describe them. The properties of $t - J$ model in two dimensions, $t - J$ ladder as well as the corresponding cuprate compounds are considered. Besides, the extensions of the models leading to the phase separation are discussed.

In the context of the non-Fermi liquid behaviour of the quasi-2D metal oxides, a complementary information is brought in by H.Takagi and N.E.Hussey in their lecture devoted to the anomalous transport properties of the high-T_c superconducting cuprates (the T-linear conductivity $\rho_{ab}(T)$ of the optimally doped superconductors, the insulating $\rho_c(T)$ in the underdoped regime, the strong temperature and hole concentration dependence of the in-plane Hall effect). In the lectures given by C.Thomsen and by G.Kaczmarczyk and J.P.Franck, attention is paid to the questions of Raman spectroscopy of high-T_c superconductors at the scattering on phonons and to the experimental investigations of the isotope effect (at the ^{16}O–^{18}O and ^{63}Cu–^{65}Cu replacements) in the yttrium and lanthanum HTSC.

A considerable part in the subject matter of the school belongs to the lectures devoted to the polaronic phenomena in high-temperature superconductors. This series is opened by J.T.Devreese lecture in which a review is made of a standard concept and the results concerning polarons and Fröhlich and/or spin bipolarons, their manifestations in optical spectra of the oxides and a possible role in superconducting pairing. The detailed consideration of the polaron and bipolaron superconductivity is given in a lecture by A.S.Alexandrov. A charged Bose liquid of small polarons is considered in this theory as a clue element to understanding the high-T_c phenomenon in the metal oxides. Based on this, an explanation of a set of thermodynamic, kinetic and other properties of these materials is given. In the lecture by R.Calvani, the spectroscopic manifestations (in the IR part of the spectrum), the polaronic bands in the cuprates and the related perovskites are considered. The discussion is continued in a lecture by V.Cataudella, G.Iadonisi, D.Ninno, E.Piegari, G.Capone, M.L.Chiofalo, G. de Filippis devoted to various aspects of physics of the high-T_c superconductors related to the large polarons existence. The subject of the lecture given by J.Ranninger and E.V.L. de Mello is the problem of the internal structure of small polarons; their manifestations in spectroscopic measurements as well as a transition from the quasi-localized to the quasi-free behaviour of polarons are considered. Similar questions concerning bipolarons at the description of the latter based on the boson fermion model are the subject of the lecture, which was held by J.Ranninger and J.-M.Robin. Nonadiabatic corrections to the Eliashberg theory (connected with the going beyond Migdal approximation and caused by the smallness of the Fermi energy as well as of the momentum change at the electron-phonon scattering) at considering the superconductivity in the electron-phonon system is analyzed in a lecture given by C.Grimaldi, E.Cappelluti and L.Pietronero.

The book of proceedings finishes with a review by P.Minnhagen devoted to the vortex physics in superconductors. A special attention is paid to the vortex fluctuations and their manifestations in the dielectric response of the two-dimensional and quasi-two-dimensional (high-T_c superconducting) systems.

The scope of the school includes a wide range of questions of the physics of high-temperature superconducting systems. Obviously, it is not a complete overview of all the topics related to superconductivity. It is impossible to do it in the framework of one school; after all, it was not the aim of the organizers. Reflecting the current state of experimental and theoretical investigations of high-T_c superconductors, discussing the most interesting but still unsolved problems (which are the subject of consideration from various points of view), the scientific material presented in the book is of great interest to the scientists working in the given and in the related fields of physics.

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