Principles of electron tunneling spectroscopy

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E. L. Wolf. *Principles of Electron Tunneling Spectroscopy.* Oxford University Press, New York; Clarendon Press, Oxford, 1985. pp. 576 (International Series of Monographs on Physics. V. 71).

The title of the book very clearly defines its direction and corresponds to its contents completely. During the period of almost thirty years the tunneling effect in solids has turned from being the object of investigations into an elegant, unusually informative and reliable experimental instrument—the method of tunneling spectroscopy. The book emphasizes first of all the possibilities of the method in principle. However, the physical results obtained with its aid play the role of somewhat meager, but expressive ornamentation—they bring out the new qualities of the method, convincing the reader of the multifaceted and universal character of tunneling spectroscopy. Such an approach to writing the book is entirely justified and will guarantee for a long time the timeliness of the questions raised in it.

The huge factual material, both theoretical and experimental, has been rigorously systematized by the author (in accordance with the title of the book) and is contained in eleven chapters and three appendices. The greater part of the book is devoted to the presentation of the basis of the spectroscopy of superconductors (Ch. 3–7). The methodological side of the tunneling effect has attained perfection specifically in the case of this object. The second and the eighth chapters are devoted to the spectroscopy of the normal state (metals, semiconductors, magnetic materials, organic molecules etc.) and the prospects of its development. The profusion of illustrations (there are more than 250) of the excellent quality with detailed captions is an aid to a better understanding of all the principles of the method of electron tunneling.

The first chapter of the book is introductory. It discusses the basic concepts concerning tunneling as a highly quantum phenomenon and different aspects of electron tunneling in solids, introduces ideas concerning the quasiparticle and superconducting (Josephson) tunneling effect, and calls the attention of the reader to the spectroscopic aspects of tunneling phenomena. The second chapter provides details of the theoretical and experimental aspects of tunneling in normal structures. Attention is paid to investigation of many-particle effects, and a description is given of different real types of structures—junctions and their difference from ideal ones, due to defects in barriers. A discussion is given of the influence of band structure and density of electron states on the volt-ampere characteristics of normal junctions.

The third chapter presents the theories of superconductivity and tunneling in superconductors—both of the quasiparticle and Josephson type. Also here are presented results of the tunneling investigation of the energy gap in superconductors with strong and weak electron-phonon interaction (EPI), its anisotropy, the influence of the magnetic field, of magnetic impurities, of high pressures, of thermal fluctuations and of an external electromagnetic field. The fourth chapter is devoted to a description of the theory of superconductors with strong EPI based on the Eliashberg equations. Methods are presented for solving these nonlinear equation in order to obtain the EPI spectral function $\alpha^2(\omega)F(\omega)$—the iteration procedure of MacMillan and Rowell and the dispersion method of Galkin, D'yachenko and Svistunov. The fifth chapter contains the main concepts concerning the proximity effect arising in junctions of a normal metal with a superconductor, an analysis is given of the corresponding theoretical models of the proximity effect, and the spectroscopy of normal and superconducting objects based on this effect is discussed. The sixth chapter is devoted to the spectroscopy of the vibrational spectrum and the electron-phonon interaction of superconductors—both ordinary and transition metals, alloys, compounds, amorphous superconductors, and to the changes in their properties as a result of applying external influences. Nonequilibrium effects in normal and superconducting structures arising in the case of tunneling injection of quasiparticles and external pumping, and their effect on the energy gap in superconductors are described in chapter 7.

The eighth chapter emphasizes the spectroscopic possibilities of tunneling for the study of the normal state. An analysis is given of the quantum size effects in thin metallic films, surface effects in semiconductors and spin polarization in ferromagnetic substances. Considerable attention is paid to the inelastic interaction of tunneling electrons with magnons, surface and volume plasmons, barrier phonons and surface phonons of the electrodes forming a tunneling junction. Questions of stimulating electron transitions and of electron-electron interaction in metallic systems, specifically energy-associated effects in degenerate semiconductors and zero anomalies in tunneling conductivity are discussed. The ninth chapter introduces the reader to the relatively recent work on tunneling in unusual materials: ultrathin films and small superconducting particles, artificial superlattices and organic conductors. The tenth chapter presents the bases of molecular spectroscopy by the method of inelastic tunneling. It deals with the investigation of a very small quantity of a material imbedded into a barrier, sufficient to obtain spectral characteristics—vibrational and rotational spectra of molecules analogous to IR and Raman-spectroscopy. Chapter 11 is devoted to the practical applications of the tunneling effect: from superconducting interferrometers to tunneling scanning microscope with ultrahigh resolution.

The concluding part of the book contains three appendices (A–C). Appendix A presents achievements in the technology of preparation of tunneling strutures with differ-

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ent barriers, and methods of recording tunneling characteristics. Appendix B presents numerical methods of reducing tunneling data and obtaining the spectral functions of the EPI, while Appendix C contains quantitative results on tunneling investigations of solids. Over 1500 cited primary sources together with a subject index enable one to explore any particular problem in greater detail and more deeply. The availability of such a "guidebook to the literature" is one more merit of the book by E. L. Wolf.

The appearance of the book being reviewed can be regarded as an important event for specialist in the fields of physics of the solid state, of low temperatures of junction phenomena. The breadth of the presented material makes it interesting also to a wider circle of readers—students, graduate students, beginning researchers, specializing not only in the field of physics, but also in chemistry and biology.