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PREFACE

Recent years have been characterized by widespread development of electron paramagnetic spectroscopy (EPR spectroscopy) in the millimeter and submillimeter ranges, which seems to be more promising in the studies of condensed systems. However, this development faces some difficulties associated mainly with a weak and complicated element base (SHF elements, including a cavity, cryogenic equipment, etc.), sample preparation procedure, and appropriate investigation methods.

From its appearance in the 1960s, the idea of broadening the EPR spectroscopy frequency range seemed to be mainly an intellectual game without concrete theoretical and practical future application. It was stipulated mainly by fragmentary investigations of specific objects in the millimeter EPR range, which could not enable full and clear arguments, thus proving the necessity of the development of EPR spectroscopy directed towards the increase of registration frequency. However, the elaboration and creation of the first multifunctional universal 2-mm wave band EPR spectrometer at the Russian Institute of Chemical Physics allowed the successful investigation of various condensed systems (solutions, polymers, etc.), in which complex molecular and relaxation processes occur, including slow anisotropic motions, cross-relaxation, etc. This development resulted in a wave of enthusiasm among chemists, physicists and biologists, and an explosive development of applications of various methods. However, today the importance of 2-mm EPR spectroscopy is not its successful application but the potential to obtain new qualitative information on well-known compounds and to understand various phenomena, from specific interactions and correlated relaxation in condensed media to charge transfer in biological systems and polymer semiconductors. This new appreciation of the essence of quantum mechanical phenomena lies beyond the framework of electron paramagnetic resonance as a special discipline and no doubt will promote a breakthrough in such other fields as biology, physics, and chemistry.

The present book appears as a monograph on the application of high-frequency 2-mm EPR spectroscopy to the study of physical-chemical properties of various condensed systems and their interpretation from the standpoint of modern conceptions of molecular physics. The methods of measurements at 2-mm wave band EPR considered here found their application in the investigation of both simple (solutions, ion crystals) and complex (biopolymers, enzymes, conducting polymers, ion-radical salts, etc.) condensed systems, and their potential is not yet exhausted. 2-mm wave band EPR spectroscopy enables the profound investigation of the structure, dynamics, other specific characteristics of radical centers and their local environment, and elementary charge transfer processes in these systems.

The monograph contains mainly the original results, obtained by the author in the last decade, of the investigation of various model, biological, and other high-molecular weight compounds by 2-mm wave band EPR spectroscopy. Therefore, special attention is paid to the description of various practical applications of the method in the study of liquids and solids.

The first chapter follows the Introduction, which appears as a brief survey of the main stages of millimeter EPR spectroscopy development. Chapter 1 presents a concise summary of the theoretical fundamentals of EPR spectroscopy and a body of mathematics necessary for the interpretation of experimental results. It considers the most important magnetic resonance parameters of paramagnetic centers, the processes of spin relaxation, and the factors affecting it. Among them various experimental approaches of EPR spectroscopy are considered such as steady-state signal saturation, the saturation transfer method, and the method of spin label and probe, which is necessary for the investigation of various properties of condensed systems.

The success of 2-mm EPR spectroscopy is attributed mainly to a high spectral resolution over the g-factor. Chapter 2 describes the reason for the choice of the 2-mm wave band for registering EPR spectra of organic radicals, and the advantages of 2-mm wave band EPR spectroscopy are manifested by using organic peroxide and nitroxide radicals in model systems. This chapter contains the description of the development of steady-state saturation of spin-packets, microspin label and probe, macrospin probe, and saturation transfer methods applied to 2-mm wave band registration, which enables a more accurate and complete analysis of dynamic and relaxation properties of radical microenvironments in condensed systems.

Chapter 3 starts with the analysis of the restrictions of the common EPR method in the study of biological systems and exhibits the data, confirming the advantages of 2-mm EPR spectroscopy in investigating the structure, dynamics, and polarity of radical microenvironments in real biological objects.

And finally, Chapter 4 contains the discussion of the principal results obtained by using 2-mm wave band EPR for studying structural and electrodynamic peculiarities of the known conducting compounds, such as conjugated polymers, ion-radical salts, and high-temperature superconductors.

In order to appeal to a wide range of readers, the book provides the examples of experimental investigation of various classes of compounds, offering a more complete study of the systems.

Although this monograph is devoted almost entirely to EPR spectroscopy, it should be emphasized that it might be considered only as one of numerous useful and fruitful methods on the general background of physics and chemistry of condensed media. All the results obtained with this method attain their whole significance only by being combined with the data obtained by other methods. The results, presented in Sections 2.IV, 3.II, and 4.I may be considered as examples.

The author hopes that this book will be valuable to radio spectroscopists and investigators in neighboring branches of science such as molecular biology, radiation and photochemistry, organic and analytical chemistry, liquid and solid state physics, and for students specializing in chemistry, physics, and biology.

The author is very grateful to his teachers Professor Ya. S. Lebedev and Professor G. I. Likhtenstein, who promoted the development of his interests in classic and millimeter EPR spectroscopy.

The author expresses his gratitude to his colleagues, who contributed by carrying out the experiments and taking part in the discussion. The author is especially grateful to O. Ya. Grinberg, A. A. Dubinski, A. V. Kulikov, L. M. Goldenberg, I. B. Nazarova, S. D. Cheremisov, H.-K. Roth, K. Lüders, F. Lux, A. E. Pelekh, S. A. Brazovskii, L. I. Tkachenko, and O. N. Efimov.

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THE AUTHOR

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Dr. Krinichnyi received his higher education at Kazan State University. His Ph.D. thesis research concerned 2-mm wave band EPR spectroscopy as a method of investigation of paramagnetic centers in biological and conducting organic polymers. After obtaining his Ph. D. in 1986 he joined the Institute of Chemical Physics in Chernogolovka as a scientific researcher, and since 1991 he has been employed as a senior scientific researcher in the same institute. He received his Dr. Sci. degree in physics and mathematics in 1992 after completing research on high resolution 2-mm wave band EPR spectroscopy in the study of biological and conducting polymers.

From 1989 to 1991 he headed a group of young scientists dealing with the synthesis and study of organic conducting and inorganic superconducting compounds as basic materials for molecular electronics, a project sponsored by the Russian Academy of Sciences.

Since 1975 Dr. Krinichnyi has published over 60 scientific papers relating mainly to the development of high resolution EPR spectroscopy for the investigation of various model, biological, and organic high-molecular weight compounds. He has collaborated with colleagues in Russia, Germany, France, Israel, and Japan.

Dr. Krinichnyi is also the author of three reviews concerned with the investigation of biological systems by high resolution 2-mm wave band EPR, published in the *Journal of Applied Spectroscopy* (in Russian), the *Journal of Biochemical and Biophysical Methods*, and *Applied Magnetic Resonance*.

At present his research in the physics of condensed matter is mainly concerned with the practical application of 2-mm wave band EPR spectroscopy in the study of biological systems with emphasis on the study of conducting polymers and high-temperature superconductors. Concerning these materials Dr. Krinichnyi's focus is on the analysis of dynamic properties of nonlinear excitations in conducting polymers and other compounds. The results of his investigations were reported at the Technology Universities of Leipzig and Berlin.

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LIST OF SYMBOLS AND ABBREVIATIONS

$\mathbf{A}$ tensor of huperfine interaction

A anisotropic huperfine interaction constant

A orientation degree of chains (Eqs. 161–164)

a isotropic huperfine interaction constant

$\langle a \rangle = \frac{1}{3} \sum A_{ii}$ averaged huperfine interaction constant

a_N^0 imperturbable huperfine interaction constant (Eqs. 102, 104, 107, 108)

A/B asymmetry factor of EPR spectrum

$\mathbf{B}_0$ external magnetic field vector

B_0 external magnetic field modulus ($1T = 10^4$ Oe, G)

B_1 amplitude of magnetic component of polarizing field

B_{c_1} lower critical magnetic field in superconductor

B_m amplitude of modulation of external magnetic field

B_{loc} local magnetic field strength

c light velocity ($c = 2.9979 \cdot 10^8$ m s^{-1})

D diffusion coefficient (m^{2}s^{-1})

d dimensionality of a disordered system (Eqs. 58, 150, 152)

E energy (1 eV $= 1.6021 \cdot 10^{-19}$ J $= 8.0660 \cdot 10^3$ cm^{-1})

$E_{\alpha(\beta)}$ eigenvalues of spin Hamiltonian

E_a activation energy (eV)

$\mathbf{E}$ electrostatic field strength

e elementary charge ($e = 1.6022 \cdot 10^{-19}$ K)

$f(r)$ spherically symmetric function

$\mathbf{g}$ splitting tensor

g Lande splitting factor ($g_e = 2.00232$ for free electron)

$\langle g \rangle = \frac{1}{3} \sum g_{ii}$ averaged g-factor

g_{iso} isotropic g-factor

$g(\omega)$ factor of line shape

H enthalpy

$\mathcal{H}$ Hamiltonian of magnetic interaction

$h = 2\pi\hbar$ Planck quantum constant ($h = 6.6262 \cdot 10^{-34}$ Js)

I transfer integral

I nuclear spin

I ionization potential

I_c Coulombic integral (Eq. 120)

I_c critical current for type-II superconductor

I_i intensity of ith spectral component (Eq. 109)

J total electron angular momentum

$J(\omega)$ spectral density function

k Boltzmann constant ($k = 1.3807 \cdot 10^{-23}$ JK^{-1})

k reaction rate constant (Eqs. 140–142)

k_f coefficient of cavity filling (Eq. 116)

L total orbital moment of electron

$\mathbf{M}_0$ equilibrium magnetization of spin ensemble

$\mathbf{M}$ total magnetization of spin ensemble

M molecular mass (Eqs. 108, 124)

m_e mass of electron ($m_e = 9.1095 \cdot 10^{-31}$ kg)

m orientation magnetic number (Eqs. 3, 5, 6, 30, 34, 91, 92)

$N_{\alpha,\beta}$ population of electron energy levels (Eqs. 12, 13)

N number of spins in volume unit (m^{-3})

N halfwidth of nonlinear excitations in cell units (Eq. 165)

$n(\varepsilon_F)$ density of states at the Fermi level ε_F

n concentration of paramagnetic centers per monomer unit

P probability (Eqs. 52–54, 135)

$P(r_0, r, t)$ spin motion propagator (Eqs. 55–57, 61, 62)

P power of microwave oscillator (Eq. 116)

Q quality of MWF cavity (Eq. 116)

Q McConnell proportionality constant (Eq. 38) ($Q = 2 \div 3$ mT)

R relative humidity degree

$\mathbf{r}$ radius vector between two dipoles

r_{NO} distance between N and O atoms in nitroxide radical

r' hydrodynamic radius of nitroxide probe

$\mathbf{S}$ spin quantum number

S total electron spin of molecule

s saturation factor

T_1 electron longitudinal (spin-lattice) relaxation time

T_2 electron transverse (spin-spin) relaxation time

t time

T absolute temperature (K)

$U_n(\omega)$ dispersion signal component detected in phase with respect to applied Zeeman modulation at the nth harmonic of modulation

$U'_n(\omega)$ dispersion signal component in $\pi/2$-out-of-phase (in phase quadrature) with respect to applied modulation detected at the nth harmonic of modulation

u_i amplitude of dispersion signal ith component (Eqs. 100, 136–139)

V sample volume

$V_n(\omega)$ absorbtion signal component detected in phase with respect to applied Zeeman modulation at the nth harmonic of modulation

$V'_n(\omega)$ absorbtion signal component $\pi/2$-out-of-phase (in phase quadrature) with respect to applied modulation detected at the nth harmonic of modulation

$\mathbf{V}$ potential with matrix elements V_i (Eqs. 102, 103)

v velocity (Eq. 166)

$W_{\alpha\beta}$ power absorbed by spin ensemble at $\alpha \rightarrow \beta$ transition (Eq. 13)

x, y, z axes of molecular coordinate system

α decay length of localized state

α, β spin levels

$\langle\alpha|\mu|\beta\rangle$ matrix element of magnetic moment component

β resonance integral of C = C coupling (Eqs. 102, 104, 107, 108)

γ_e gyromagnetic ratio for electron ($\gamma_e = 1.7608 \cdot 10^{11}$ $\mathrm{T^{-1}s^{-1}}$)

γ_p gyromagnetic ratio for proton ($\gamma_p = 2.6751 \cdot 10^{8}$ $\mathrm{T^{-1}s^{-1}}$)

ΔB_{pp} linewidth from peak to peak

$\Delta E_{\alpha\beta}$ difference in electron energy α and β levels

ΔG profile of reaction (Eq. 143)

$\Delta\omega$ anisotropy of magnetic interaction

$\Delta\omega_{ij}$ distance between a spin packets in frequency units

$\langle\Delta\omega^2\rangle$ second momentum of absorbtion signal

δ skin layer thickness

$\delta\Delta B_{\mathrm{pp}}$ spectral line broadening

δB shift of spectral line

ε dielectric constant

ε_{F} Fermi energy level

ξ decay length for charge carries (Eq. 146, 147)

ξ superconducting coherence length

η coefficient of dynamic viscosity

η_{r} anisotropy parameter of radical rotation (Eq. 125)

$\varkappa$ parameter of rotation diffusion of a radical (Eq. 110)

Λ soliton width (Eq. 166)

λ spin-orbit coupling constant (eV)

μ_e electron magnetic moment

μ_{I} nuclear magnetic moment

μ_{B} Bohr magneton ($\mu_{\mathrm{B}} = 9.2741 \cdot 10^{-24}$ J $\mathrm{T^{-1}}$)

μ_0 permeability for vacuum ($\mu_0 = 4\pi \cdot 10^{-7}$ $\mathrm{VsA^{-1}m^{-1}}$)

μ dipole moment (Eqs. 105–108)

μ mobility

ν_e resonance frequency for free electron

ν_{ex} frequency of spin-packets exchange

$\rho(r)$ density of unpaired electron at r distance from nucleus

ρ apparent density of radical microenvironment

σ_{AC} alternating current electric conductivity ($\mathrm{Sm^{-1}}$)

σ_{DC} direct current electric conductivity ($\mathrm{Sm^{-1}}$)

$\sigma_{n\mathrm{D}}$ nD specific conductivity

σ cross section of irradiation process (Eqs. 140, 141)

τ effective relaxation time

τ_c correlation time of radical rotation

τ_m mechanical relaxation time (Eqs. 132, 133)

χ magnetic susceptibility with real (χ') and imaginary (χ'') components

χ_0 static magnetic susceptibility of spin ensemble

$\Psi(r)$ wave function for electron localization ($\Psi^2(r) = \rho(r)$)

ω_e resonance angular frequency of electron transition between α and β levels

ω_L Larmor angular frequency of electron precession

ω_m angular frequency of Zeeman magnetic modulation

AC alternating current

DC direct current

EPR electron paramagnetic resonance

HFI huperfine interaction

HFS huperfine structure

HTSC high-temperature superconductor

MRP magnetic resonance parameter

MWF microwave frequency

NMR nuclear magnetic resonance

NR nitroxide radical

PR peroxide radical

ppm percents per million cell units

SOI spin-orbital interaction

CONTENTS

Chapter 4.

2-mm Wave Band EPR Spectroscopy of Conducting Compounds

INTRODUCTION

EPR spectroscopy is one of the most widely used and productive physical methods in structural and dynamic studies of various condensed systems that contain free radicals, ion-radicals, molecules in triplet states, transition metal complexes, and other paramagnetic centers (PCs).

EPR spectroscopy became a powerful investigation tool after Zavoiskii carried out the first electron relaxation studies in salts.[1] From that moment this method began to play an important role and is used successfully in physical, chemical, and biological investigations. Many fundamental and general works concerning this field of knowledge[2–20] are evidence of this process.

This method can be applied the most effectively to the study of elementary chemical reactions. Voevodskii, who was the first in these investigations, found[21] that transformation mechanisms in oxidation and cracking, radiolysis and photolysis, homogeneous and heterogeneous catalysis, and chemical processes were stipulated mainly by the properties of PC and especially free radicals, involved in these processes.

EPR has been widely used in recent decades for solving such important problems of chemical and biological physics as the elucidation of the role of electron transport in biological processes, the effect of molecular dynamics in viscous and heterogeneous media on the rate and mechanism of transformations which occur there,[6,16,18] etc.

EPR gave rise to the development of the method of spin labels and probes, suggested by Hamilton and McConnell,[22] which provided significant progress in the study of biological substrates, polymers, and other condensed systems.[23–30] The success was achieved due to the unique properties of nitroxide radicals, which were commonly used as spin labels and probes, and the development of biochemistry. However, the utilization of the EPR method as a sensitive and informative instrument[26,27] played a dominant role in these investigations.

In solving these problems the restrictions of the EPR method emerged clearly, being associated in particular with the fact that the signals of organic free radicals were registered in a narrow magnetic field range, which resulted in the overlapping of the lines of complex spectra or spectra of different radicals with close g-factor values. Thus, new experimental techniques that improve the efficiency of the method and open absolutely new fields of application have been recently developed. They are laser spectroscopy of magnetic resonance at submillimeter[31] and near-infrared[32] wave bands, which are generally used to study radical reactions in gas phase; electron spin echo spectroscopy,[33,34] which is used mainly to study PC in solids; different methods based on the effect of spin polarization, in which the EPR signal is registered optically[35] or, depending on the change of chemical yield;[36–38] methods of double electron-nuclear resonance;[39,40] EPR spectroscopy with microwave frequency (MWF) saturation transfer;[41] EPR in inhomogeneous fields;[42] and some others.

However, most of these methods may be applied only to solve specific problems and investigate special objects. The transition to higher magnetic fields and registration frequencies is known to be the most common method to elevate the precision and informativeness of the method.

This practice was already used successfully to enhance the sensitivity and resolution of nuclear magnetic resonance (NMR),[43] which is complementary to EPR. However, a similar approach was almost not applied to widen EPR spectroscopy possibilities. This may be explained by the fact that the element base of 3-cm and 8-mm wave bands was found to be suitable initially, since it satisfied the standards of resolution and sensitivity,[4,49] and, thus, was widely used. Besides, some difficulties exist with the selection of MWF radiation source of sufficient power in the millimeter wave band as well as with the generation of strong magnetic fields with the intensity of several Tesla.

In the 1970s an EPR spectrometer of 2-mm wave band containing superconducting solenoid[44] was designed at the Institute of Chemical Physics, Russia, for physical-chemical investigations. It was the first in a series of analogous devices, which are still unique. These spectrometers are especially characterized by a high spectral resolution and an absolute sensitivity of $5 \cdot 10^{11}$ spin/T.

This book reports on the possibilities of 2-mm wave band EPR spectroscopy of high spectral resolution over g-factor and reviews the principal results obtained in the investigation of various condensed systems at this wave band.

The first chapter includes a brief description of some EPR fundamentals, which are to be used to interpret experimental results.

The second chapter contains a consideration of the methodic foundation of 2-mm wave band EPR spectroscopy, and some results of the study of model systems are presented, which reveal the possibilities of high resolution over g-factor in the study of different condensed systems.

The results presented in the third chapter confirm the principal advantages of the method in investigating the structure, conformation, and molecular dynamics of biological objects with spin labels and probes.

The fourth chapter considers 2-mm EPR spectroscopy possibilities in the study of a large group of organic polymer semiconductors and other conducting compounds.

References

Zavoiski, E.K. , Spin magnetic resonance in paramagnetics, J. Phys. USSR, 9, 211; 245, 1945.

Ingram, D.I.E. , Free Radicals as Studied by Electron Spin Resonance, Butterworths, London, 1958.

Altshuler, S.A. and Kozirev B.M. , Electron Paramagnetic Resonance (in Russian), Fizmatgiz, Moscow, 1961.

Blumenfeld, L.A. , Voevodski V.V. , and Semenov A.G. , Application of Electron Paramagnetic Resonance in Chemistry (in Russian), Izdat. SO AN USSR, Novosibirsk, 1962.

Carrington, F. and McLachlan A.D. , Introduction to Magnetic Resonance with Application to Chemistry and Chemical Physics, Harer & Row, New York, 1967.

Schoffa, G. , Electronenspinresonanz in der Biologie, Verlag G. Braun, Karlsruhe, 1964.

Hamman, J.E. , Ed., Theoretical Foundation of Electron Spin Resonance, Academic Press, New York, 1978.

Ayscough, P. , Electron Spin Resonance in Chemistry, Methaen and Co., London, 1967.

Ehrenberg, A. , Malmstrm, B.G. , and Vngard T. , Eds., Magnetic Resonance in Biological Systems, Pergamon Press, Oxford, 1967.

Ingram, D.I.E. , Biological and Biochemical Application of Electron Spin Resonance, Adam Ailder Ltd., London, 1969.

Altshuler, S.A. and Kozirev B.M. , Electron Paramagnetic Resonance of Compounds of Elements of Intermediate Groups (in Russian), 2nd ed., Nauka, Moscow, 1972.

Lebedev, Ya. S. and Muromtsev V.I. , EPR and Relaxation of Stabilized Radicals (in Russian), Khimija, Moscow, 1972.

Geschwind, S. , Ed., Electron Paramagnetic Resonance, Plenum Press, New York, 1972.

Wertz, J.E. and Bolton J.R. , Electron Spin Resonance, McGraw-Hill, New York, 1972.

Ranby, B. and Rabek J.F. , EPR Spectroscopy in Polymer Research, SpringerVerlag, Berlin, 1977.

Shulman, R.G. , Ed., Magnetic Resonance Studies in Biology, Academic Press, New York, 1979.

Buchachenko, A.L. , Ed., Structural Investigation of Macromolecules by Spectroscopic Methods (in Russian), Khimija, Moscow, 1980.

Berliner, L.J. and Reuben J. , Eds., Biological Magnetic Resonance, Plenum Press, New York, 1984.

Roth, H.-K. , Keller, F. , and Schneider H. , Hochfrequenz-spectroskopie in der Polymerforschung, Academic Verlag, Berlin, 1984.

Bernier, P. , The magnetic properties of conjugated polymers: ESR studies of undoped and doped systems, in Handbook of Conducting Polymers, Vol. 2, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 1099.

Voevodskii, V.V. , Physics and Chemistry of Elementary Chemical Processes (in Russian), Nauka, Moscow, 1963.

Hamilton, C.L. and McConnell H.M. , Spin labels, in Structural Chemistry and Molecular Biology, Rich, A. and Davidson N. , Eds., Freeman, San Francisco, 1968, 115.

198 Buchachenko, A.L. and Wasserman A.M. , Stable Radicals, Khimija, Moscow, 1973.

Likhtenstein, G.I. , Spin Labels in Molecular Biology, Nauka, Moscow, 1974.

Kuznetsov, A.N. , Spin Probe Method, Nauka, Moscow, 1976.

Berliner, L. , Ed., Spin Labeling. Theory and Application, Vol. 1, Academic Press, New York, 1976.

Berliner, L. , Ed., Spin Labeling. Theory and Application, Vol. 2, Academic Press, New York, 1979.

Wasserman, A.M. and Kovarski A.L. , Spin Labels and Probes in Physics and Chemistry of Polymers, Nauka, Moscow, 1986.

Likhtenstein, G.I. , Spin-Labeling Methods in Molecular Biology, Wiley Interscience, New York, 1989.

Zhdanov, V.R. , Ed., Bioactive Spin Labels, Springer-Verlag, New York, 1992.

Evenson, K.M. , Broida, H.P. , Wells, J.S. , Mahler, R.J. , and Mirushiwa M. , Electron paramagnetic resonance absorption in oxygen with the HCN laser, Phys. Rev. Lett., 21, 1038, 1968.

Broude, S.V. , Gershenson, Yu. M. , IIin, S.D. , Kolesnikov, S.A. , and Lebedev, Ya. S. , Magnetic resonance spectrometer on the base of C02-laser: registration of the absorption spectra of NF2 radical in gaseous phase, Dokl. Akad. Nauk SSSR, 223, 366, 1975 (in Russian).

Mims, W.B. , Electron spin echoes, in Electron Paramagnetic Resonance, Geschwind, S. , Ed., Plenum Press, New York, 1972, 263.
Salikhov, K.M. , Semenov, A.G. , and Tsvetkov, Yu. D. , Electron Spin Echo and its Utilization (in Russian), Nauka, Novosibirsk, 1976.
Geschwind, S. , Optical techniques in EPR in solids, in Electron Paramagnetic Resonance, Geschwind, S. , Ed., Plenum Press, New York, 1972, 353.
Frankevich, E.L. and Pristupa A.I. , Magnetic resonance of excited complexes with charge transfer detected using fluorescence at room temperature, Pisma JETF, 24, 397, 1976 (in Russian).
Molin, Yu. N. , Sagdeev, R.Z. , and Anisimov O.A. , Oblique methods of magnetic resonance spectra registration based on spin effects in reactions of radical pairs, Khim. Fiz., 4, 437, 1983 (in Russian).
Muus, L.T. , Atkins, P.W. , McLauchlan K.A. , and Pedersen J.B. , Eds., Chemically Induced Magnetic Polarization, Reidel Publishing, Dordrecht, 1977.
Poole, Ch. P. , Electron Spine Resonance, International Science Publishers, London, 1967.
Kevan, L. and Kispert L.D. , Electron Spin Double Resonance Spectroscopy, Wiley Interscience, New York, 1976.
Hyde, J.S. and Dalton L.R. , Saturation-transfer spectroscopy, in Spin Labeling. Theory and Application, Vol. 2, Berliner, L. , Ed., Academic Press, New York, 1979, 1.
Karte, W. and Wehrsdorfer E. , The measurement of inhomogeneous distributions of paramagnetic centers by means of EPR, J. Magn. Reson., 33, 107, 1979.
Ernst, R.R. , Bodenhansen, G. , and Wokaun A. , Principles of Nuclear Magnetic Resonance in One and Two Dimensions, Clarendon Press, Oxford, 1987.
Galkin, A.A. , Grinberg, O. Ya. , Dubinski, A.A. , Kabdin, N.N. , Krimov, V.N. , Kurochkin, V.I. , Lebedev, Ya. S. , Oranski, L.G. , and Shuvalov, V.F. , Two-millimeter wave band spectrometer for chemical investigations, Prib. Tekh. Eksp., 4, 284, 1977.
199 Memory, J.D. , Quantum Theory of Magnetic Resonance Parameters, McGraw-Hill, New York, 1968.
Slichter, C.P. , Principles of Magnetic Resonance, 2nd ed., Springer, Berlin, 1978.
Landau, L.D. and Lifshits E.M. , Quantum Mechanics (in Russian), Nauka, Moscow, 1972.
Bazin, N.M. and Tsvetkov, Yu. D. , Hyperfine Structure of EPR Spectra of Free Radicals, Novosibirsk University, Novosibirsk, 1971.
Bloch, F. , Hansen, W.W. , and Packard M.F. , Nuclear induction, Phys. Rev., 69, 127, 1946.
Waller, I. , On magnetization of paramagnetic crystals in alternating fields, Z. Phys., 79, 370, 1932.
Fatkullin, N.F. , The theory of spin-lattice relaxation in thermolyzed polyphenileacetylene, Vysokomol. Soedin. B, 22, 816, 1980 (in Russian).
Kurzin, S.P. , Tarasov, B.G. , Fatkullin, N.F. , and Aseeva R.M. , Electron spin-lattice relaxation in pirolized PMEP, Vysokomol. Soedin. A, 24, 117, 1982.
Abragam, A. , The Principles of Nuclear Magnetism, Clarendon Press, Oxford, 1961.
Butler, M.A. , Walker, L.R. , and Soos Z.G. , Dimensionality of spin fluctuations in highly anisotropic TCNQ salt, J. Chem. Phys., 64, 3592, 1976.
Torrey, H.C. , Nuclear spin relaxation by translation diffusion, Phys. Rev., 92, 962, 1953.
Mizoguchi, K. , Spin dynamics in conducting polymers, Macromol. Chem. Macromol. Symp., 37, 53, 1990.
Krasicky, P.D. , Silsbee, R.H. , and Scott, J.C. , Studies of a polymeric chromium phosphinate. Electron-spin resonance and spin dynamics, Phys. Rev. B, 25, 5607, 1981.
Dyson, F.J. , Electron spin resonance absorbtion in metals. II. Theory of electron diffusion and the skin effect, Phys. Rev., 98, 349, 1955.
Wilamovski, Z. , Oczkiewicz, B. , Kacman, P. , and Blinowski J. , Asymmetry of the EPR absorption line in CdF2 with Y, Phys. Status Solidi B, 134, 303, 1986.
Bugai, A.A. , Passing effects for inhomogeneously broadened EPR lines at high-frequency-modulation of magnetic field, Fiz. Tverd. Tela, 4, 3027, 1962 (in Russian).
Salpeter, E.E. , Nuclear induction signals for long relaxation times, Proc. Phys. Soc., 63A, 337, 1950.
Feher, G. , Electron spin resonance experiments on donors in silicon. I. Electronic structure of donors by electron nuclear double resonance technique, Phys. Rev., 114, 1219, 1959.
Weger, M. , Passage effects in paramagnetic resonance experiments, Bell. Syst. Tech. J., 39, 1013, 1960.
Ammerlaan, C.A.J. and van der Wiel, A. , The divacancy in silicon: spinlattice relaxation and passage effects in electron paramagnetic resonance, J. Magn. Reson., 21, 387, 1976.

Pool, Ch. P. , Electron Spin Resonance, A Comprehensive Treatise on Experimental Techniques, John Wiley & Sons, New York, 1983.
Lsche, A. , Kerninduction, VEB Deutscher Verlag, Berlin, 1957.
Gullis, P.R. , EPR in inhomogeneously broadened systems: a spin temperature approach, J. Magn. Reson., 21, 397, 1976.
200 Konev, S.V. , Electron Excited States of Biopolymer, Nauka i Tekhnika, Minsk, 1965.
Goldansky, V.I. , Mssbauer Effect and Its Application to Chemistry, SSSR Academy of Sciences, Moscow, 1963.
Kiselyov, N.A. , Electron Microscopy of Biological Molecules, Nauka, Moscow, 1965.
Likhtenstein, G.I. , Chemical Physics of Metalloenzyme Catalysis, Springer-Verlag, Heidelberg, 1988.
Buchachenko, A.L. , Complexes of Radicals and Molecular Oxygen with Organic Molecules, Nauka, Moscow, 1984.
Reddoch, A. and Konishi S. , The solvent effect on di-tert-butyl nitroxide. A dipole-dipole model for polar solutes in polar solvents, J. Chem. Phys., 70, 2121, 1979.
Radchenkoro, N.F. , Filonenko, G.V. , and Kuts V.S. , Study of influence of composition of free nitroxide radical-aromatic ligand -complexes on their thermodynamic characteristics, Teor. Eksp. Khim., 17, 774, 1981 (in Russian).
Radchenko, N.F. , Philonenko, V.D. , and Kuts V.S. , Investigation of the composition influence of -complexes of free nitroxide radical-aromatic ligand on their thermodynamic characteristics, Teor. Eksp. Khim., 17, 774, 1981 (in Russian).
Goldman, S.A. , Bruno, G.V. , and Freed J.H. , Estimating slow-motion rotational correlation times for nitroxides by electron spin resonance, J. Chem. Phys., 76, 1858, 1972.
Antsiferova, L.I. , Wasserman, A.M. , Ivanova, A.N. , Livshits, V.A. , and Nazemets N.S. , Atlas of EPR Spectra of Spin Labels and Probes, Nauka, Moscow, 1977.
Livshits, V.A. and Bobrov, Yu. A. , Analysis of anisotropy of spin probes rotation by EPR spectra with transfer of SHF-saturation, Teor. Eksp. Khim., 22, 331, 1986 (in Russian).
Winter, H. , Sachs, G. , Dormann, E. , Cosmo, R. , and Naarmann H. , Magnetic properties of spin-labelled polyacetylene, Synth. Metals, 36, 353, 1990.
Morriset, J. , Spin labels in investigation of structure and functions of enzymes, in Spin Labeling. Theory and Application, Vol. 1, Berliner, L. , Ed., Academic Press, New York, 1976, 298.
Likhtenstein, G.I. , Kulikov, A.V. , Kotelnikov, A.I. , and Levchenko L.A. , Methods of physical labeling: combined approach to the study of microstructure and dynamics in biological systems, Biochem. Biophys. Methods, 12, 1, 1986.
Lakharst, J. , Biradicals as spin probes, in Spin Labeling. Theory and Application, Vol. 1, Berliner, L. , Ed., Academic Press, New York, 1976, 156.
Roth, H. , Wnsche, P. , Lembicz, F. , Roth, H.-K. , Krinichnyi, V.I. , and Fester B. , ESR and NMR measurements on a liquid-crystalline side chain polymer (to be published).
Kokorin, A.I. , Zamaraev, K.I. , Grigoryan, G.L. , Ivanov, V.P. , and Rozantzev E.G. , Measuring of the distance between paramagnetic groups in solid solutions of nitroxide radicals, biradicals and spin-labeled proteins, Biofizika, 17, 34, 1972.
Robinson, B.H. and Dalton L.R. , Anisotropic rotational diffusion studied by passage saturation transfer electron paramagnetic resonance, J. Chem. Phys., 72, 1312, 1980.
201 Johnson, M.E. , Lie, L. , and Fung W.M. , Models for slow anisotropic rotational diffusion in saturation transfer electron paramagnetic resonance at 9 and 35 GHz, Biochemistry, 21, 4459, 1982.
McCain, D.C. and Palke W.E. , Theory of electron spin g-values for peroxy radicals, J. Magn. Reson., 20, 52, 1975.
Jidomirov, G.M. , Lebedev, Ya. S. , Dobrjakov, S.N. , Steinsteider, N. Ya. , Chirkov, A.K. , and Gubanov V.A. , Interpretation of Complicated EPR Spectra, (in Russian), Nauka, Moscow, 1975.
Duret, D. , Beranger, M. , and Moussavi M. , High resolution low field EPR spectrometer, Synth. Metals, 27, B127, 1988.
Mizoguchi, K. , Kume, K. , and Shirakawa H. , Frequency dependence of electron spin-lattice relaxation rate at 5450 MHz in pristine trans-polyacetylene, Solid State Commun., 50, 213, 1984.
Herlach, F. , Ed., Strong and Ultrastrong Magnetic Fields and their Applications, Springer-Verlag, Berlin, 1985.
Kocharjan, K.N. and Mirzahanjan A.A. , Sensitive millimeter wave band EPR spectrometer, Izv. Akad. Nauk SSSR, 11, 484, 1976 (in Russian).

Souzade, M. , Pontnau, J. , Lesas, P. , and Silhouette D. , Resonance paramagnetique de ion V+3 dans Al2O3 en ondes millimetriques etchamps, Phys. Lett., 19, 617, 1966.
Magarino, J. , Tuchendler, J. , and DHaenens, J.P. , High-frequency EPR experiments in niobium-doped vanadium dioxide, Phys. Rev. B, 14, 865, 1976.
Mock, J.B. , Broadband millimeter wave paramagnetic resonance spectrometer, Rev. Sci. Instrum., 31, 551, 1960.
Basosi, R. , Antholine, W.E. , Froncisz, W. , and Hyde J.S. , Spin-Hamiltonian input parameters in the EPR analysis of liquid phase copper complexes, J. Chem. Phys., 84, 4849, 1984.
Halitov, V. Yu. , EPR Study of n-InSb at Submillimeter Waves, Ph. D. thesis, Moscow University, 1986.
Souzade, M. , Pontnau, J. , and Girard B. , Sur la electronique en ondes millimetriques utilisant une bobine supraconduetiice, Comptes Rand., 258, 4458, 1964.
Vinogradov, E.A. , Irisova, I.A. , Zvereva, G.A. , Mangelstam, T.S. , and Prohorov A.M. , EPR investigation of Dy2+ ion with CaF2 at submillimeter wave band, in Paramagnetic Resonance 19441969 (in Russian), Rubinstein, G.M. , Ed., Nauka, Moscow, 1971, 66.
Shestopalov, V.P. , Problems of difractional electronics, Vestn. Akad. Nauk SSSR, 10, 8, 1975 (in Russian).
Isaacs, N.A. and Russell, D.K. , Millimeter-wave spectroscopy with solid-state IMPATT oscillator source, Rev. Sci. Instrum., 57, 414, 1986.
Kuska, H.A. and Rogers M.I. , EPR of transient metals complexes, in Radical Ions, Kaiser, E.T. and Kevan L. , Eds., Interscience Publishers, New York, 1968, 31.
Antsiferova, L.I. , Grinberg, O. Ya. , Dubinski, A.A. , Krinichnyi, V.I. , and Lebedev, Ya. S. , Passage effects at 2-mm waveband EPR (in Russian), Depon. VINITI, 1987, R. J Khimija, 1B3164DP, 1, 1, 1988.
Grinberg, O. Ya. , High Resolution Spectroscopy on g-Factor, Hab. D. Thesis, Moscow Institute of Chemical Physics, Moscow, 1988.
202 Jidomirov, G.M. , Schastnev, P.V. , and Tchuvilkin N.D. , Quantum-Chemical Calculation of Magnetic Resonance Parameters (in Russian), Nauka, Novosibirsk, 1987, 367.
Stone, A.J. , Gauge invariance of the g-tensor, Proc. R. Soc. A, 271, 424, 1963.
Stone, A.J. , g-Factor of aromatic free radicals, Mol. Phys., 6, 509, 1963.
Segal, B.G. , Kaplan, M. , and Fraenkel G.K. , Measurement of g-values in the electron spin resonance spectra of free radicals, J. Chem. Phys., 43, 4191, 1965.
Sullivan, P.D. , Bolton, J.R. , and Gieger W.G., Jr. , Oxygen-17 and carbon-13 hyperfine interaction in the electron paramagnetic resonance spectrum of hydroquinone cation radical, J. Am. Chem. Soc., 92, 4176, 1970.
Dixon, W.T. , Kok, P.M. , and Murphy D. , Calculations of g-factor of phenoxyl radicals, phenol radical cations and alkyl-aryl-ether radical cations, J. Chem. Soc. Faraday Trans., 2, 1528, 1978.
Gavar, R.A. and Stradin, Ya. P. , Measurement of g-factor in the EPR spectra of anion radicals of nitric-phurane series, Teor. Eksp. Khim., 11, 93, 1975 (in Russian).
Kawamura, T. , Matsunami, S. , Yonezawa, T. , and Fukui K. , The effect of hydrogen-bonding on the g-value of diphenyl nitric oxide, Bull. Chem. Soc. Jpn., 38, 1935, 1965.
Allendoerfer, R.D. , Comment on the determination of absolute g-values, J. Chem. Phys., 55, 3615, 1971.
Griffith, O.H. , Dehlinger, P.J. , and Van S.P. , Shape of the hydrophobic of phospholipid bilayers: evidence for water penetration in biological membranes, J. Membr. Biol., 15, 159, 1974.
Fessenden, R.W. and Schler R.H. , Electron spin resonance studies of transient alkyl radicals, J. Chem. Phys., 39, 2147, 1963.
Grinberg, O. Ya. , Dubinski, A.A. , Shuvalov, V.F. , Oranski, L.G. , Kurochkin, V.I. , and Lebedev, Ya. S. , Submillimetric EPR spectroscopy of free radicals, Dokl. Akad. Nauk SSSR, 230, 884, 1976 (in Russian).
Krinichnyi, V.I. , Shuvalov, V.F. , Grinberg, O. Ya. , and Lebedev, Ya. S. , Electron paramagnetic resonance of peroxide radicals at 2-mm wave band, Khim. Fiz., 5, 621, 1983 (in Russian).
Lebedev, Ya. S. , Antsiferova, L.I. , Grinberg, O. Ya. , Dubinski, A.A. , Krinichnyi, V.I. , Lubashevskaya, E.V. , and Poluectov O.G. , High field EPR in studies of molecular dynamics, Proc. 2nd Int. Conf. Modern Meth. Radiofreq. Spectr., Friedrichroda, DDR-5804, 1985, 48.
Krinichnyi, V.I. , Study of biological systems by method of high resolution 2-mm EPR spectroscopy (Russ), Zurn. Prikl. Spektr., 52, 887, 1990.

Krinichnyi, V.I. , EPR of 2-mm Wave Band as a Method for Investigation of Paramagnetic Centers in Biological and Organic Polymers, Ph. D. Thesis, Institute of Chemical Physics in Chernogolovka RAN, Chernogolovka, 1986.
Kurita, Y. and Gordy W. , Electron spin resonance in a gamma-irradiated single crystal of L-cystine dihydrochloride, J. Chem. Phys., 34, 282, 1961.
Antonovski, V.A. , Organic Peroxide Initiators (in Russian), Khimija, Moscow, 1972.
Denisov, E.T. , The Rate Constants of Liquid-Phase Homolitic Reactions (in Russian), Nauka, Moscow, 1971.
Laidler, K.J. , Chemical Kinetics, McGraw-Hill, New York, 1965.
203 Ingold, K.U. and Morton J.R. , Electron spin resonance spectra of organic oxy radicals, J. Am. Chem. Soc., 86, 3400, 1964.
Mebrein, D.C.H. and Slater T.F. , Eds., Free Radicals, Lipid Peroxidation and Cancerogenes, Academic Press, London, 1982.
Zwolenik, J.J. , Photolytic generation and kinetic electron spin resonance spectrometry of cumylperoxy radicals, J. Phys. Chem., 71, 2464, 1967.
Howard, J.A. , Absolute rate constants for reactions of oxyl radicals, Adv. Free-Radical Chem., 4, 49, 1972.
Bennett, J. and Sumers R. , Electron spin resonance spectra of secondary alkylperoxy radicals, J. Chem. Soc. Faraday Trans. II, 7, 1043, 1973.
Adamik, K. , Ingold, K.U. , and Morton J.R. , Electron spin resonance spectrum of oxygen-17 enriched t-alkyl peroxy radicals, J. Am. Chem. Soc., 92, 922, 1970.
Dmitruk, A.F. , Kholoimova, L.I. , Krinichnyi, V.I. , Grinberg, O. Ya. , Shuvalov, V.F. , and Lebedev, Ya. S. , Structure and properties of alkyl peroxy radicals, Khim. Fiz., 5, 479, 1986 (in Russian).
Zahradnik, R. and arsky, Conjugated radicals. II. Semiempirical calculations of electronic spectra of radial-anions derived from alternant hydrocarbons, J. Phys. Chem., 74, 1240, 1970.
Balanced Dynamics of Native Structure of Proteins (in Russian), Burstein, E.A. , Ed., IBF Publ., Puschino, 1977.
Emanuel, N.M. and Knorre, D.G. , Course of Chemical Kinetics (in Russian), Vysshaya Shkola, Moscow, 1974.
Dudich, I.V. , Timofeev, V.P. , Volkenstein, M.V. , and Misharin, A. Yu. , Macromolecule rotative correlation time measurement by ESR method for covalently bound spin label, Mol. Biol., 11, 685, 1977 (in Russian).
Isaev-Ivanov, V.V. , Lavrov, V.V. , and Fomichev V.N. , The non-modulation method of registration of the EPR signal, Dokl. Akad. Nauk SSSR, 229, 70, 1976 (in Russian).
Hyde, J.S. and Dalton L. , Very slowly tumbling spin labels: adiabatic fast passage, Chem. Phys. Lett., 16, 568, 1972.
Hwang, J.S. , Mason, R.P. , Hwang, L.P. , and Freed J.U. , Electron spin resonance studies of anisotropic rotational reorientation and slow tumbling in liquid and frozen media. III. Perdeuterated 2, 2, 6, 6-tetrametyl-4-piperidone-N-oxide and analysis of fluctuating torques, J. Phys. Chem., 79, 489, 1975.
Ondar, M.A. , Grinberg, O. Ya. , Oranski, L.G. , Kurochkin, V.I. , and Lebedev, Ya. S. , Direct measurement of magnetic resonance parameters of stable nitroxide radicals in frozen solution by means of 2-mm waveband EPR method, Khim. Fiz., 22, 173, 1981 (in Russian).
Krinichnyi, V.I. , Investigation of biological systems by high resolution 2-mm wave band ESR, Appl. Magn. Reson., 2, 29, 1991.
Ondar, M.A. , Grinberg, O. Ya , Dubinski, A.A. , and Lebedev, Ya. S. , Investigation of medium influence on magnetic parameters of nitroxide radicals by high resolution EPR spectroscopy, Khim. Fiz., 3, 527, 1984 (in Russian).
Mamedov, S.D. , Khalilov, A.D. , and Guseinova M.K. , Crystalline and molecular structure of the 2, 2, 6, 6-tetramethyl-piperidin-l-aminoxyl-4-(N-2-oxy-l-naftaldehydimene), Zh. Strukt. Khim., 15, 103, 1974 (in Russian).
Borderaux, P. , Lajzerowicz, J. , Briere, R. , Lemaire, H. , and Rassat A. , Organic Magnetic Resonance, Vol. 5, Heyden and Sons, New York, 1973, 47.
204 Shibaeva, R.P. , Atovmjan, L.D. , and Neigaus M.G. , Crystalline and molecular structure of the 2, 2, 6, 6-tetramethyl-4-piperidon-l-oxyl nitroxide radical, Zh. Strukt. Khim., 13, 887, 1972.
Berliner, L. , Refinement and location of the hydrogen atoms in nitroxide 2, 2, 6, 6-tetramethyl-4-piperidinol-l-oxyl, Acta Crystallogr. B, 26, 1198, 1970.
Ament, S.S. , Wetherington, J.B. , and Moncrief J.W. , Determination of the absolute configuration of (+)-3-carboxy-2, 2, 5, 5-tetramethyl-l-pyrrolidinyloxyl, J. Am. Chem. Soc., 95,

7846, 1973.
Shevyrev, A.A. , Belikova, G.S. , Volodarski, L.B. , and Simonov V.I. , Molecular and crystallographic structure of the stable nitroxide radical 2, 2, 5, 5-tetramethyl-4-phenyl-3-imidazolil-3-oxyd-l-oxyl, Kristallografija, 24, 784, 1979 (in Russian).
Shibaeva, R.P. , Structure of organic paramagnetics of nitroxide radical, Zh. Strukt. Khim., 16, 330, 1975 (in Russian).
Shapiro, A.B. , Volodarski, L.B. , Krasochka, O.N. , and Atovmjan L.D. , Cyclemetaling of the imidazoline nitroxide radical with nitrone function, Dokl. Akad. Nauk SSSR, 255, 1146, 1980 (in Russian).
Grinberg, O. Ya. , Dubinski, A.A. , Poluektov, O.G. , and Lebedev, Ya. S. , Investigation of peroxide radicals in PTFE on 2-mm wave band EPR spectra, Teor. Eksp. Khim., 17, 806, 1981 (in Russian).
Dubinski, A.A. , Grinberg, O. Ya. , Kurochkin, V.I. , Oranski, L.G. , Poluektov, O.G. , and Lebedev, Ya. S. , Investigation of anisotropy of nitroxide radical rotation using 2-mm wave band EPR spectra, Teor. Eksp. Khim., 17, 231, 1981 (in Russian).
Poluektov, O.G. , Dubinski, A.A. , Grinberg, O. Ya. , and Lebedev, Ya. S. , Application of 2-mm wave band electron paramagnetic resonance for the study of rotational moving using spin probe method, Khim. Fiz., 11, 1180, 1982 (in Russian).
Poluektov, O.G. , Grinberg, O. Ya. , Dubinski, A.A. , Sidorov, O. Yu. , and Lebedev, Ya. S. , Dynamics characteristics and intermolecular interactions of the nitroxide radicals in polar solution, Khim. Fiz., 2, 854, 1986 (in Russian).
Grinberg, O. Ya. , Dadali, A.A. , Dubinski, A.A. , Wasserman, A.M. , Bucha-chenko, A.L. , and Lebedev, Ya. S. , Determination of components of g- and A-tensors and rotational mobility of nitroxide radicals using 2-mm EPR spectroscopy, Teor. Eksp. Khim., 15, 583, 1979 (in Russian).
Poluektov, O.G. , Dubinski, A.A. , Grinberg, O. Ya. , and Lebedev, Ya. S. , Dynamics study of spin-labeled macromolecules by the method of electron paramagnetic resonance at two-millimeter wave band, Khim. Fiz., 2, 182, 1983 (in Russian).
Lubashevskaya, E.V. , Antsiferova, L.I. , and Lebedev, Ya. S. , The analysis of slow molecular motion by 2-mm wave band EPR spectra of nitroxide radicals, Teor. Eksp. Khim., 1, 46, 1987 (in Russian).
Valiev, K.A. and Ivanov E.N. , Rotational Brownian motion, Usp. Fiz. Nauk, 109, 31, 1973 (in Russian).
Livshits, V.A. , Slow anisotropic tumbling in ESR spectra of nitroxyl radicals, J. Magn. Reson., 24, 307, 1976.
Antsiferova, L.I. and Lubashevskaya E.V. , Atlas of 2-mm Wave Band EPR Spectra of Nitroxide Radicals, OIHF AN SSSR Publ., Chernogolovka, 1986.
Frenkel, L.I. , Kinetics Theory of Liquids (in Russian), Nauka, Leningrad, 1975.
205 Kuznetsov, A.N. and Ebert B. , Investigation of dependence of character of the molecular rotation for size of rotating particle by spin probe method, Zh. Fiz. Khim., 49, 1622, 1975 (in Russian).
Livshits, V.A. , Krinichnyi, V.I. , and Kuznetsov A.N. , A study of the character of molecular rotation of nitroxide radicals in liquids by ESR and dielectric relaxation methods, Chem. Phys. Lett., 45, 541, 1977.
Poluektov, O.G. , Lubashevskaya, E.V. , Dubinski, A.A. , Grinberg, O. Ya. , Antsiferova, L.I. , and Lebedev, Ya. S. , Determination of the model of isotropic rotational motion using 2-mm EPR spectra, Khim. Fiz., 4, 1615, 1985 (in Russian).
Freed, J.H. , Anisotropic rotational diffusion and electron spin resonance linewidths, J. Chem. Phys., 41, 2077, 1964.
Freed, J.H. and Fraenkel G.K. , Theory of line widths in electron spin resonance spectra, J. Chem. Phys., 39, 326, 1963.
Wasserman, A.M. , Kuznetsov, A.N. , Kovarski, A.L. , and Buchachenko A.L. , Anisotropic rotational diffusion of stable anisotropic radicals, Zh. Strukt. Khim., 12, 609, 1971 (in Russian).
Kuznetsov, A.N. and Mirzojan A.T. , Investigation of degree of non-spherical Brownian rotation of organic nitroxide radicals, Zh. Fiz. Khim., 50, 38, 1976 (in Russian).
Goldman, S.A. , Bruno, G.V. , and Freed J.H. , ESR studies of anisotropic rotational reorientation and slow tumbling in liquid and frozen media. II. Saturation and nonsecular effects, J. Chem. Phys., 59, 3071, 1973.
Krinichnyi, V.I. , Investigation of biological systems by high resolution 2-mm wave band ESR, J. Biochem. Biophys. Meth., 23, 1, 1991.

Poluektov, O.G. , 2-mm Wave Band EPR as Method of Study of Molecular Motion, Ph. D. thesis, Moscow Institute of Chemical Physics, Moscow, 1982.
Ondar, M.A. , Grinberg, O. Ya. , Dubinski, A.A. , Shestakov, A.F. , and Lebedev, Ya. S. , 2-mm waveband EPR spectroscopy and magnetic resonance parameters, Khim. Fiz., 1, 54, 1983 (in Russian).
Kivelson, D. and Lee S. , Theory of ESR parallel-edge lines of slowly tumbling molecules, J. Chem. Phys., 76, 5746, 1982.
Krinichnyi, V.I. , Grinberg, O. Ya. , and Lebedev, Ya. S. , Macrospin method in the study of viscous systems at 2-mm wave band EPR (to be published).
Ljubovskaja, R.N. , Organic metals and superconductors based on tetra-thiafulvalene derivatives, Usp. Khim., 52, 1301, 1983 (in Russian).
Bartenev, G.M. and Sanditov D.S. , Relaxation Processes in Glass-State Systems (in Russian), Nauka, Novosibirsk, 1986.
Pelekh, A.E. , Krinichnyi, V.I. , Brezgunov, A. Yu. , Tkachenko, L.I. , and Kozub G.I. , EPR study of the relaxation parameters of paramagnetic centers in polyacetylene, Vysokomol. Soedin., 33, 1731, 1991 (in Russian).
Strigutski, V.P. , Study of Passage Effects for Analysis of Single EPR Signal (Polymers with Conjugated Bonds), Ph. D. Thesis, Moscow Institute of Chemical Physics, Moscow, 1974.
Bazonic, D.A. , Mergerian, D. , and Minarik R.W. , Electron spin-echo measurements of E1 centers in crystalline quartz, Phys. Rev. Lett., 21, 541, 1968.
Robinson, B.H. and Dalton L.R. , Anisotropic rotational diffusion studied by passage saturation transfer electron paramagnetic resonance, J. Chem. Phys., 72, 1312, 1980.
206 Hemminga, M.A. and de Jager, P.A. , Magnetic saturation transfer electron paramagnetic resonance spectroscopy: a new ST-EPR technique insensitive to the null-phase setting, J. Magn. Reson., 43, 324, 1981.
Vistnes, A.J. , Magnetization hysteresis electron paramagnetic resonance, Biophys. J., 43, 31, 1983.
Krinichnyi, V.I. , Grinberg, O. Ya. , Dubinski, A.A. , Livshits, V.A. , Bobrov, Yu. A. , and Lebedev, Ya. S. , Study of anisotropic molecular rotations by saturation transfer EPR spectroscopy at 2-mm wave band, Biofizika, 32, 534, 1987 (in Russian).
Livshits, V.A. , Utilization of the modulation methods for study of slow tumbling of nitroxide radicals, Teor. Eksp. Khim., 13, 780, 1977.
Likhtenstein, G.I. , Multinuclear Reduction-Oxidation Metalloenzymes (in Russian), Nauka, Moscow, 1975.
Beresin, I.V. and Martinek K. , The Principles of Physical Chemistry of Enzyme Catalysis (in Russian), Vysshaya Shkola, Moscow, 1977.
Morrisett, J.D. , The use of spin labels for studying the structure and function of enzymes, in Spin Labeling. Theory and Application, Vol. 1, Berliner, L. , Ed., Academic Press, New York, 1, 1976, 274.
Kivelson, D. , Theory of ESR linewidths of free radicals, J. Chem. Phys., 33, 1094, 1960.
Walach, D. , Effect of internal rotation on angular correlation functions, J. Chem. Phys., 47, 5258, 1967.
Kjaivjarainen, A.I. , Separate determination of proper correlation times of spin-labeled proteins and labels connected to them, Mol. Biol., 9, 805, 1975 (in Russian).
Timofeev, V.P. , Dudich, I.V. , and Volkenstein M.V. , Comparative study of dynamic structure of pig and chicken asparate aminotransferases by measuring the rotational correlation time, Biophys. Struct. Mech., 7, 41, 1980.
Freed, J.H. , Theory of slow tumbling ESR spectra for nitroxides, in Spin Labeling. Theory and Application, Vol. 1, Berliner, L. , Ed., Academic Press, New York, 1976, 53.
Judanova, E.I. , The Study of Spin Exchange of Nitroxide Radicals in Model and Biological Systems by Means of Continuous Saturation of EPR Spectra, Ph. D. Thesis, Institute of Chemical Physics, Chernogolovka, 1983.
Griffith, O.H. and Jost P.C. , Lipid spin labels in biological membranes, in Spin Labeling. Theory and Application, Vol. 1, Berliner, L. , Ed., Academic Press, New York, 1976, 453.
Belonogova, O.V. , Likhtenstein, G.I. , Levashov, A.V. , Khmelnitskij, Yu. L. , Klyachko, N.L. , and Martinek K. , A spin-label study of the state of the active center and microenvironment of -chymotrypsin solubilized in octane, using the surfactant aerosol OT, Biokhimija, 48, 379, 1983 (in Russian).
Marupov, R. , Bobodjanov, P.H. , Jusupov, I.H. , Mavljanov, A.M. , Frolov, E.N. , and Likhtenstein G.I. , Study of the temperature stability of plant fibres by the spin label method, Biofizika, 24, 519, 1979 (in Russian).

Grinberg, O. Ya. , Dubinski, A.A. , and Lebedev, Ya. S. , EPR of the free radicals at 2-mm wave band, Usp. Khim., 52, 1490, 1983 (in Russian).
Grinberg, O. Ya. , Dubinski, A.A. , Oranski, L.G. , Kurochkin, V.I. , and Lebedev, Ya. S. , EPR spectroscopy at 2-mm wave band, in Non-Thermal Effects of Millimeter Radiation (in Russian), Devjatkov, N.D. , Ed., Nauka, Moscow, 1981, 42.
207 Krinichnyi, V.I. , Grinberg, O. Ya. , Bogatirenko, V.R. , Likhtenstein, G.I. , and Lebedev, Ya. S. , Study of microenvironment effect on magnetic resonance parameters of spin-labeled human serum albumin in a 2-mm EPR range, Biofizika, 30, 216, 1985 (in Russian).
Krinichnyi, V.I. , Grinberg, O. Ya. , Judanova, E.I. , Lubachevskaya, E.V. , Antsiferova, L.I. , Likhtenstein, G.I. , and Lebedev, Ya. S. , Study of lysozyme by spin label of two millimeter range, Biofizika, 32, 215, 1987 (in Russian).
Belonogova, O.V. , Likhtenstein, G.I. , and Krinichnyi V.I. , Effect of micro-and macroviscosity and local polarity on electron transfer in donor-acceptor pair in modified -chymotrypsin, Biophysics, in press.
Krinichnyi, V.I. , Grinberg, O. Ya. , Judanova, E.I. , Borin, M.L. , Lebedev, Ya. S. , and Likhtenstein G.I. , Study of molecular mobility in biological membranes by two millimeter band EPR spectroscopy, Biofizika, 32, 59, 1987 (in Russian).
Krinichnyi, V.I. , Antsiferova, L.I. , Lubachevskaya, E.V. , Belonogova, O.V. , Grinberg, O. Ya. and Likhtenstein G.I. , 2-mm EPR spectroscopy of spin-labeled inverted micelles, Zh. Fiz. Khim., 63, 3015, 1989 (in Russian).
Krinichnyi, V.I. , Grinberg, O. Ya. , Jusupov, I.H. , Marupov, R.M. , Bo-bodjanov, P.H. , Likhtenstein, G.I. , and Lebedev, Ya. S. , Investigaton of spin-labeled cotton fiber by the 2-mm wave band EPR method, Biofizika, 31, 482, 1986 (in Russian).
Krinichnyi, V.I. , Ushakov, E.N. , Arutyunyan, Kh. A. , and Kostina N.V. , Study of microcrystalline cellulose by the 3-cm and 2-mm ranges EPR method, Biofizika, 36, 427, 1991 (in Russian).
Lassman, G. , Ebert, B. , Kuznetsov, A.V. , and Damerau W. , Characterization of hydrophobic regions in proteins by spin labeling technique, Biochim. Biophys. Acta, 310, 298, 1973.
Likhtenstein, G.I. and Bobodjanov P.H. , Investigation of structure and local conformational conversions of proteins and enzymes by the method of double paramagnetic labels, Biofizika, 13, 757, 1968 (in Russian).
Likhtenstein, G.I. , Determination of the topography of protein groups by the method of specific paramagnetic labels, Mol. Biol., 2, 234, 1968 (in Russian).
Likhtenstein, G.I. , Bogatyrenko, V.R. , and Kulikov A.V. , Study of mobility of free radicals connected with serum albumins at 30230 K, Biofizika, 28, 585, 1983 (in Russian).
Likhtenstein, G.I. , Akhmedov, Yu. D. , and Ivanov L.V. , Study of macromolecule of lysozyme by the method of spin label, Mol. Biol., 8, 48, 1974 (in Russian).
Schmidt, P.G. and Kuntz I.D. , Distance measurements in spin-labeled lyosozyme, Biochemistry, 23, 4261, 1984.
Kosman, D.J. , Electron paramagnetic resonance probing of macromolecules: a comparison of structure function relationships in chymotrypsinogen, - chymotrypsin and anhydrochymotrypsin, J. Mol. Biol., 67, 247, 1972.
Likhtenstein, G.I. , Water and dynamics of proteins and membranes, Stud. Biophys., 111, 89, 1986.
Frolov, E.N. , Likhtenstein, G.I. , Khurgin, Yu. I. , and Belonogova O.V. , On dynamic structure of active center of -chymotrypsin, Izv. Akad. Nauk SSSR, 1, 231, 1973 (in Russian).
Frolov, E.N. , Likhtenstein, G.I. , and Goldanskij V.I. , The dynamics structure of protein and water-protein interactions, in Proc. Int. Conf. on Moss-bauer Spectroscopy, Vol. 2, Krakow, Poland, 1975, 319.
208 Markus, R.A. and Sutin N. , Electron transfer in chemistry and biology, Biochim. Biophys. Acta, 811, 265, 1985.
McLendon G. , Long-distance electron transfer in proteins and model systems, Acc. Chem. Res., 21, 160, 1988.
Bystrjak, I.M. , Likhtenstein, G.I. , Kotelnikov, A.I. , Hankovsky, H.O. , and Xuder K. , Effect of solvent molecular dynamics on nitroxides photoreduction, Zh. Fiz. Khim., 60, 2796, 1986 (in Russian).
Rubtsova, E.T. , Vogel, V.R. , and Likhtenstein G.I. , Effect of protein environment molecular dynamics on the kinetics of intramolecular electron phototransfer, Biofizika, in press (in Russian).
Steitz, T.A. , Henderson, R. , and Blow D.M. , Structure of crystalline a-chymotrypsin. III. Crystallographic studies of substrates and inhibitors bound to the active site of -chymotrypsin,

J. Mol. Biol., 67, 247, 1969.
Chibisov, A.K. , The electron transfer in photochemical reactions, Usp. Khim., 50, 1169, 1981 (in Russian).
Lumry, R. and Gregory R.B. , Free energy movements in protein reactions: concepts, complications and compensation, in The Fluctuating Enzymes, Welch, G.R. , Ed., John Wiley & Sons, New York, 1986, 3.
Likhtenstein, G.I. , Spin Labeling Methods in Molecular Biology, John Wiley & Sons, New York, 1976, 159.
Cone, R.A. , Rotational diffusion of rhodopsin in the visual receptor membrane, Nature, 236, 39, 1972.
Smith, I.C.P. and Butler K.W. , Oriented lipid systems as model membranes, in Spin Labeling. Theory and Application, Vol. 1, Berliner, L. , Ed., Academic Press, New York, 1976, 441.
Koltover, V.K. , Kutlahmedov, Yu. A. , and Sukhorukov B.I. , The use of the method of spin probe in the study of membranes of cell organelles, Dokl. Akad. Nauk SSSR, 181, 730, 1968 (in Russian).
Schreier-Muccills, S. and Smith I.C.P. , Spin labels and probes in the organization of biological and model membranes, Prog. Surf. Membr. Sci., 9, 136, 1973.
Koltover, V.K. , Raikhman, L.M. , Jasaitis, A.A. , and Blumenfeld L.A. , Study of ATF-dependent conformational conversion in mitochondrial membranes by the spin probe method, Dokl. Akad. Nauk SSSR, 197, 219, 1971 (in Russian).
Menger, F.M. and Yamada K. , Enzyme catalysis in water pools, J. Am. Chem. Soc., 101, 6731, 1979.
Menger, F.M. , Donohue, J.A. , and Williams R.F. , Catalysis in water pools, J. Am. Chem. Soc., 95, 286, 1973.
Khmelnitskij, Yu. L. , Levashov, A.V. , Kljachko, N.L. , Chernjak, V. Ya. , and Martinek K. , The enzymes incorporated into reversed micelles of surfactants in organic solvents. Study of the protein-acrosol OT-H2O octane system by sedimentation analysis, Biokhimija, 47, 86, 1982 (in Russian).
Rabold, G.P. , Spin-probe studies. I. Application to latexes and micelle characterization, J. Polym. Sci., 7, 1187, 1969.
Meyer, K.H. and Misch L. , Positions des atomes dans le nouveau modele spatial de la cellulose; Sur la constitution de la partie crystallisee de la cellulose, Helv. Chem. Acta, 20, 232, 1937.
Dennis, D.P. and Preston R.D. , Constitution of cellulose microfibrils, Nature, 191, 667, 1961.
209 Frey-Wyssling, A. , The fine structure of cellulose microfibrille, Science, 119, 80, 1954.
Sharkov, V.I. , The modern views on overmolecular structure of cellulose, Usp. Khim., 36, 312, 1967 (in Russian).
Tarchevski, I.A. and Marchenko G.N. , Biosynthesis and Structure of Cellulose (in Russian), Nauka, Moscow, 1965.
Marupov, R. , Spectroscopy of Fiber-Forming Polymers (in Russian), Donish, Dushanbe, 1977.
Ershov, B.G. and Klimentov A.S. , Radiation chemistry of cellulose, Usp. Khim., 53, 2056, 1984 (in Russian).
Yusupov, I.K. , Bobodjanov, P.K. , Marupov, R. , Islomov, S. , Antsiferova, L.I. , Koltover, V.K. , and Likhtenstein G.I. , Study of molecular dynamics of cotton fiber by the spin label method, Vysokomol. Soedin., 26, 369, 1984 (in Russian).
Kostina, N.V. , Marupov, R. , and Antsiferova L.I. , The dependence of EPR spectral parameters of spin-labeled cotton fiber on viscosity and temperature in the liquid medium, Biofizika, 32, 496, 1987 (in Russian).
Kostina, N.V. , Marupov, R. , Antsiferova, L.I. , and Likhtenstein G.I. , Tumbling movement of spin label in the cotton fiber exposed by UV-radiation, Biofizika, 32, 660, 1987 (in Russian).
Johnson, M.E. , Vibrational motion of an immobilized spin label: hemoglobin spin labeled by a maleimide derivative, Biochemistry, 17, 1223, 1978.
Meier, H. , Application of the semiconductor properties of dyes: possibilities and problems, in Top. Curr. Chem., 61, 85, 1976.
Williams, J.M. , Ferraro, J.R. , Thorn, R.J. , Carlson, K.D. , Geiser, U. , Wang, H.H. , Kini, A.M. , and Whangboo, M.-H. , Organic Superconductors (Including Fullerenes): Synthesis, Structure, Properties and Theory, Prentice-Hall, Englewood Cliffs, NJ, 1992.
Day, P. Organic-inorganic molecular composites: photopolymerization of organic moieties in inorganic layer compounds, in Handbook of Conducting Polymers, Vol. 1, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 117.

Wnek, G.E. , Electrically conductive polymer composites, in Handbook of Conducting Polymers, Vol. 1, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 205.
Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Electronic Properties of Polymers and Related Compounds, Springer Series in Solid State Sciences, 63, Springer-Verlag, Berlin, 1985.
Scotheim, T.E. , Ed., Handbook of Conducting Polymers, Vol. 1, 2, Marcel Dekker, New York, 1986.
Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Springer-Verlag, Berlin, 1987.
Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Electronic Properties of Polymers, Springer, Berlin, 1992.
Zerbi, G. , Ed., Polyconjugated Materials, North-Holland, Amsterdam, 1992.
Baughmann, R.H. , Hsu, S.L. , Pez, G.P. , and Signorelli A.J. , The structures of cis-polyacetylene and highly conducting derivations, J. Chem. Phys., 68, 5405, 1978.
Fincher, C.R. , Chen, C.-E. , Heeger, A.J. , MacDiarmid, A.G. , and Hastings J.B. , Structural determination of the symmetry-breaking parameter in trans- (CH)x , Phys. Rev. Lett., 48, 100, 1982.
210 Elsenbaumer, R.L. and Shacklette L.W. , Phenylene-based conducting polymers, in Handbook of Conducting Polymers, Vol. 1, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 213.
Tourillon, G. , Polythiophene and its derivatives, in Handbook of Conducting Polymers, Vol. 1, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 293.
Street, G.B. , Polypyrrole: from powders to plastics, in Handbook of Conducting Polymers, Vol. 1, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 265.
Jozefowicz, M.E. , Laversanne, R. , Javadi, H.H.S. , Epstein, A.J. , Pouget, J.P. , Tang, X. , and MacDiarmid, A.G. , Multiple lattice phases and polaron-lattice-spinless-defect competition in polyaniline, Phys. Rev. B, 39, 12958, 1989.
Blakemore, G.S. , Solid State Physics, Cambridge University Press, Cambridge, 1985.
Su, W.P. , Schrieffer, J.R. , and Heeger A.J. , Solitons in polyacetylene, Phys. Rev. B, 22, 2209, 1980.
Chance, R.R. , Boudreaux, D.S. , Bredas, J.L. , and Silbey R. , Solitons, polarons and bipolarons in conjugated polymers, in Handbook of Conducting Polymers, Vol. 2, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 825.
Peierls, R.E. , Quantum Theory of Solids, Oxford University Press, London, 1955, 108.
Heeger, A.J. , Polyacetylene: new concepts and new phenomena, in Handbook of Conducting Polymers, Vol. 2, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 729.
Chien, J.C.W. , Polyacetylene: Chemistry, Physics and Material Science, Academic Press, Orlando, 1984.
Markowitsch, W. and Leising G. , Free carriers in heavily doped polyacetylene, Synth. Metals, 51, 25, 1992.
Markowitsch, W. , Kuchar, F. , and Seeger, K. , Reflectivity and magnetoreflectivity of iodine-doped polyacetylene, in Electronic Properties of Polymers and Related Compounds, Springer Series in Solid State Sciences, 63, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1985, 78.
Thomann, H. and Dalton L.R. , ENDOR studies of polyacetylene, in Handbook of Conducting Polymers, Vol. 2, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 1157.
Brdas, J.L. , Electronic structure of highly conducting polymers, in Handbook of Conducting Polymers, Vol. 2, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 859.
Brdas, J.L. , Chance, R.R. , Baughmann, R.H. , and Silbey R. , Ab initio effective Hamiltonian study of the electronic properties of conjugated polymers, J. Chem. Phys., 76, 3673, 1982.
Devreux, F. , Genoud, F. , Nechtschein, M. , and Villeret B. , On polaron and bipolaron formation in conducting polymers, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 270.
Brdas, J.L. , Themans, B. , Fripiat, J.G. , Andre, J.M. , and Chance R.R. , Highly conducting polyparaphenylene, polypyrrole, and polythiophene chains: an ab initio study of the geometry and electronic-structure modifications upon doping, Phys. Rev. B, 29, 6761, 1984.
Syed, A.A. and Dinesan M.K. , Review: polyaniline a novel polymeric material, Talanta, 38, 815, 1991.
211 Kivelson, S. , Electron hopping in a soliton band conduction in lightly doped (CH)x , Phys. Rev. B, 25, 3798, 1982.

Epstein, A.J. , AC conductivity of polyacetylene: distinguishing mechanisms of charge transport, in Handbook of Conducting Polymers, Vol. 2, Scotheim, T.E. , Ed., Marcel Dekker, New York, 1986, 1041.
Paasch, G. , Transport properties of new polyacetylene, Synth. Metals, 51, 7, 1992.
El Kadiri, M. and Parneix J.P. , Frequency-and temperature-dependent complex conductivity of some conducting polymers, in Electronic Properties of Polymers and Related Compounds, Springer Series in Solid State Sciences, 63, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1985, 183.
Parneix, J.P. and El Kadiri, M. , Frequency-and temperature-dependent dielectric losses in lightly doped conducting polymers, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 23.
Schfer-Siebert, D. , Budrowski, C. , Kuzmany, H. , and Roth S. , Influence of the conjugation length of polyacetylene chains on the DC-conductivity, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 38.
Schfer-Siebert, D. and Roth S. , Limitation of the conductivity of polyacetylene by conjugational defects, Synth. Metals, 28, D369, 1989.
Dos Santos, D.A. , Galvao, D.S. , Laks, B. , and dos Santos, M.C. , Poly(alkyl-thiophenes): chain conformation and thermochromism, Synth. Metals, 51, 203, 1992.
Hoogmartens, I. , Adriaensens, P. , Carleer, R. , Vanderzande, D. , Martens, H. , and Gelan J. , An investigation into the electronic structure of poly(isothia-naphthene), Synth. Metals, 51, 219, 1992.
Mott, N.F. and Davis E.A. , Electronic Processes in Non-Crystalline Materials, Clarendon Press, Oxford, 1979.
Isotalo, H. , Stubb, H. , and Saarilahti J. , Ion implantation of polythiophene, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 285.
Yueqiang, S. , Carneiro, K. , Ping, W. , and Renyuan Q. , Transport studies on polypyrrole films prepared from aqueous TsONa solutions of different concentrations, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 31.
Ehinger, K. , Bauhofer, W. , Menke, K. , and Roth S. , Electroconducting properties of the (CH)xJy , J. Phys., 44, C3115, 1983.
Kispert, L.D. , Files, L.A. , Frommer, J.E. , Shacklette, L.W. , and Chance R.R. , An EPR study on the reaction between poly(p-phenylene sulfide) and electron-acceptor dopants, J. Chem. Phys., 78, 4858, 1983.
Roth, H.-K. , Gruber, H. , Fanghnel, E. , and Trinh vuQuang , ESR on polymer semiconductors of poly(tetrathiafulvalene), Prog. Colloid Polym. Sci., 78, 75, 1988.
Roth, H.-K. , Brunner, W. , Volkel, G. , Schrdner, M. , and Gruber H. , ESR and ESE studies on polymer semiconductors of weakly doped poly(tetrathia-fulvalene), Macromol. Chem. Macromol. Symp., 34, 293, 1990.
Roth, H.-K. and Krinichnyi V.I. , ESR studies on polymers with particular electronic and magnetic properties, Macromol. Chem. Macromol. Symp., 72, 143, 1993.
212 Elsenbaumer, R.L. , Delannoy, P. , Muller, G.G. , Forbes, C.E. , Murthy, N.S. , Eskhardt, H. , and Baughman R.H. , Thermal enhancement of the electrical conductivities of alkali metal-doped polyacetylene complexes, Synth. Metals, 11, 251, 1985.
Epstein, A.J. , Rommelmann, H. , Druy, M.A. , Heeger, A.J. , and MacDiarmid, A.G. , Magnetic susceptibility of iodine doped polyacetylene: the effect of nonuniform doping, Solid State Commun., 38, 683, 1981.
Nechtschein, M. , Devreux, F. , Green, R.G. , Clarke, T.C. , and Street G.B. , One-dimensional spin diffusion in polyacetylene, (CH)x , Phys. Rev. Lett., 44, 356, 1980.
Park, Y.W. , Heeger, A.J. , Druy, M.A. , and MacDiarmid, A.G. , Electrical transport in doped polyacetylene, J. Chem. Phys., 73, 946, 1980.
Wada, Y. and Schrieffer J.R. , Brownian motion of a domain wall and the diffusion constants, Phys. Rev. B, 18, 3897, 1978.
Maki, K. , The soliton diffusion in the polyacetylene, Phys. Rev. B, 26, 2178, 2181, 1982.
Kivelson, S. , Electron hopping conduction in the solitone model of polyacetylene, Phys. Rev. Lett., 46, 1344, 1981.
Holczer, K. , Boucher, J.P. , Devreux, F. , and Nechtschein M. , Magnetic-resonance studies in undoped trans-polyacetylene, (CH)x , Phys. Rev. B, 23, 1051, 1981.

Nechtschein, M. , Devreux, F. , Genoud, F. , Gugleielmi, M. , and Holczer K. , Magnetic-resonance studies in undoped trans-polyacetylene, (CH)x. II, Phys. Rev. B, 27, 61, 1983.
Mizoguchi, K. , Kume, K. , Masubuchi, S. , and Shirakawa H. , Characterization of neutral soliton dynamics in pristine trans-polyacetylene by means of anisotropic ESR T1 and line width, Solid State Commun., 59, 465, 1986.
Mizoguchi, K. , Kume, K. , Masubuchi, S. , and Shirakawa H. , Neutral soliton diffusion and anisotropic T1 and T2 of ESR and NMR in stretch oriented t-polyacetylene, Synth. Metals, 17, 405, 1987.
Mizoguchi, K. , Komukai, S. , Tsukamoto, T. , Kume, K. , Suezaki, M. , Akagi, K. , and Shirakawa H. , Spin dynamics in undoped trans-(CH)x , Synth. Metals, 28, D393, 1989.
Mizoguchi, K. , Shimizu, F. , Kume, K. , and Masubuchi S. , Spin dynamics study in FSO 3-doped polyacetylene; conversion from metallic state to neutral soliton by degradation, Synth. Metals, 41, 185, 1991.
Shiren, N.S. , Tomkiewicz, Y. , Kazyaka, T.G. , Taranko, A.R. , Thomann, H. , Dalton, L. , and Clarke T.C. , Spin dynamics in trans-polyacetylene, Solid State Commun., 44, 1157, 1982.
Reichenbach, J. , Kaiser, M. , Anders, J. , Burne, H. , and Roth S. , Picosecond photoconductivity in (CH)x , Synth. Metals, 51, 245, 1992.
Mizoguchi, K. , Nechtschein, M. , Travers, J.P. , and Menardo C. , Spin dynamics in the conducting polymer, polyaniline, Phys. Rev. Lett., 63, 66, 1989.
Mizoguchi, K. , Nechtschein, M. , and Travers J.P. , Spin dynamics and conductivity in polyaniline: temperature dependence, Synth. Metals, 41, 113, 1991.
213 Epstein, A.J. , MacDiarmid, A.G. , and Pouget J.P. , Spin dynamics and conductivity of polyaniline, Phys. Rev. Lett., 65, 664, 1990.
Brazovskii, S.A. , Autocatalized excitations in the Peierls-Frelikh state, Zh. Eksp. Teor. Fiz., 78, 677, 1980 (in Russian).
Goldberg, I.B. , Crowe, H.R. , Newman, P.R. , Heeger, A.J. , and MacDiarmid, A.G. , Electron spin resonance of polyacetylene and F 5-doped polyacetylene, J. Chem. Phys., 70, 1132, 1979.
Grupp, A. , Hfer, P. , Kss, H. , Mehring, M. , Weizenhfer, R. , and Wegner G. , Pulsed ENDOR and TRIPLE resonance on trans-polyacetylene a la Durham route, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 156.
Zuravleva, T.S. , Studies of polyacetylene by magnetic resonance methods, Usp. Khim., 56, 128, 1987 (in Russian).
Bartl, A. , Frhner, J. , Zuzok, R. , and Roth S. , Characterization of segmented and highly oriented polyacetylene by electron spin resonance, Synth. Metals, 51, 197, 1992.
Rachdi, F. and Bernier P. , ESR study of metallic complexes of alkali-doped polyacetylene, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 160.
Leizing, G. , Kahlert, H. , and Leitner O. , Intrinsic anisotropic properties of trans-(CH)x , in Electronic Properties of Polymers and Related Compounds, Springer Series in Solid State Sciences, 63, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1985, 56.
Krinichnyi, V.I. , Pelekh, A.E. , Lebedev, Ya. S. , Tkachenko, L.I. , Kozub, G.I. , Barrat, A. , Brunei, L.G. , and Robert G.B. , Very high field EPR study of neutral polyacetylene, Appl. Magn. Reson., in press.
Traven, V.F. , Electronic Structure and Properties of Organic Molecules (in Russian), Khimija, Moscow, 1989.
Krinichnyi, V.I. , Pelekh, A.E. , Brezgunov, A. Yu. , Tkachenko, L.I. , and Kozub G.I. , The EPR study of undoped polyacetylene, Mater. Sci., 17, 25, 1991.
Krinichnyi, V.I. , Pelekh, A.E. , Tkachenko, L.I. , and Kozub G.I. , Study of spin dynamics in trans-polyacetylene at 2-mm wave band EPR, Synth. Metals, 46, 1, 1992.
Krinichnyi, V.I. , Pelekh, A.E. , Tkachenko, L.I. , and Kozub G.I. , The study of anisotropic spin dynamics in pristine trans-polyacetylene by means of 2-mm EPR spectroscopy, Synth. Metals, 46, 13, 1992.
Mank, V.V. and Lebovka N.I. , NMR Spectroscopy of Water in Heterogene Systems (in Russian), Naukova Dumka, Kiev, 1988.
Bartenev, G.M. and Frenkel, S. Ya. , Physics of the Polymers (in Russian), Khimija, Leningrad, 1990.
Uisem, J. , Linear and Non-Linear Waves (in Russian), Mir, Moscow, 1977.
Rebbi, C. , Solitons, Sci. Am., 240, 76, 1979.

Schrli, M. , Kiess, H. , Harbeke, G. , Berlinger, W. , Blazey, K.W. , and Mller K.A. , ESR of BF 4-doped poly(3-methylthiophene), in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 277.
214 Tourillon, G. , Gouriez, D. , Garnier, F. , and Vivien D. , Electron spin resonance study of electrochemically generated poly(thiophene) and derivatives, J. Phys. Chem., 88, 1049, 1984.
Krinichnyi, V.I. , Grinberg, O. Ya. , Nazarova, I.B. , Tkachenko, L.I. , Kozub, G.I. , and Khidekel M.L. , Investigation of organic conductors based on poly-thiofene and polyacetylene at 3-cm and 2-mm wave bands EPR, Izv. Akad. Nauk USSR, 2, 467, 1985 (in Russian).
Krinichnyi, V.I. and Nazarova I.B. , Study of spin dynamics in polythiophene synthesized from dithiophene at 3-cm and 2-mm wave bands EPR (to be published).
Qing, C. and Wang L.K. , Magnetic resonance experiments on undoped and doped poly(para-phenylene), Synth. Metals, 4950, 261, 1992.
Goldenberg, L.M. , Pelekh, A.E. , Krinichnyi, V.I. , Roshchupkina, O.S. , Zueva, A.F. , Lyubovskaya, R.N. , and Efimov O.N. , Investigation of poly-(p-phenylene) obtained by electrochemical oxidation of benzene in the BuPyCl-AlCl3 melt, Synth. Metals, 36, 217, 1990.
Goldenberg, L.M. , Pelekh, A.E. , Krinichnyi, V.I. , Roshchupkina, O.S. , Zueva, A.F. , Lyubovskaya, R.N. , and Efimov O.N. , Investigation of poly-(p-phenylene) obtained by electrochemical oxidation of benzene in the BuPyCl-AlCl3 melt and in organic solvents with oleum, Synth. Metals, 4143, 3071, 1991.
Audebert, P. , Binan, G. , Lapkowski, M. , and Limosin P. , Grafting, ionomer composites, and auto-doping of conductive polymers, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 366.
Pelekh, A.E. , Goldenberg, L.M. , and Krinichnyi V.I. , Study of doped polypyrrole by the spin probe method at 3-cm and 2-mm wave bands EPR, Synth. Metals, 44, 205, 1991.
Epstein, A.J. and MacDiarmid, A.G. , Polaron and bipolaron defects in polymers: polyaniline, J. Mol. Electron., 4, 161, 1988.
Menardo, C. , Genoud, F. , Nechtschein, M. , Travers, J.P. , and Hani P. , On the acidic functions of polyaniline, in Electronic Properties of Conjugated Polymers, Springer Series in Solid State Sciences, 76, Kuzmany, H. , Mehring, M. , and Roth S. , Eds., Springer-Verlag, Berlin, 1987, 244.
Lapkowski, M. and Genies E.M. , Evidence of two kinds of spin in polyaniline from in situ EPR and electrochemistry, J. Electroanal. Chem., 279, 157, 1990.
MacDiarmid, A.G. and Epstein A.J. , in Science and Application of Conducting Polymers, Salaneck, W.R. , Clark, D.T. , and Samuelson E.J. , Eds., Adam Hilger, Bristol, 1991.
Krinichnyi, V.I. , Eremenko, O.N. , Rukhman, G.G. , Geskin, V.M. , and Letuchy, Ya. A. , Polyaniline-based sensors for solution components, Synth. Metals, 41, 1137, 1991.
Lubentsov, B.Z. , Timofeeva, O.N. , Saratovskikh, S.V. , Krinichnyi, V.I. , Pelekh, A.E. , Dmitrenko, V.I. , and Khidekel M.L. , The study of conducting polymer interaction with gaseous substances. IV. The water content influence on polyaniline crystal structure and conductivity, Synth. Metals, 47, 187, 1992.
Lux, F. , Hinrichsen, G. , Christen, C. , Roth, H.-K. , Krinichnyi, V.I. , Nazarova, I.B. , Cheremisow, S.D. , and Pohl, M.-M. , Conducting islands concept for highly conductive polyaniline recent results of TEM, X-ray-diffraction, EPR, d. c. conductivity and magnetic susceptibility measurements, Synth. Metals, 53, 347, 1993.
215 Krinichnyi, V.I. , Nazarova, I.B. , Cheremisow, S.D. , Lux, F. , Hinrichsen, G. , Roth, H.-K. , and Lders K. , Dynamics of non-linear excitations in conducting polyaniline, Synth. Metals, in press.
Long, S.M. , Cromack, K.R. , Epstein, A.J. , Sun, Y. , and MacDiarmid, A.G. , High resolution ESR of pernigraniline base solution: the shape of neutral solitons, Synth. Metals, 55, 648, 1993.
Masters, J.G. , Ginder, J.M. , MacDiarmid A.G. , and Epstein A.J. , Thermochromism in the insulating form of polyaniline: role of ring-torsional conformation, J. Chem. Phys., 96, 4768, 1992.
Krinichnyi, V.I. , Pelekh, A.E. , Roth, H.-K. , and Lders K. , Spin relaxation studies on conducting poly(tetrathiafulvalene), Appl. Magn. Reson., 4, 345, 1993.
Krinichnyi, V.I. , Nazarova, I.B. , Cheremisow, S.D. , Roth, H.-K. , and Lders K. , Dynamics of non-linear excitations in pristine and doped poly(tetrathia-fulvalene), to be published.
Devreux, F. and Lecavelier H. , Evidence for anomalous diffusion in a conducting polymer, Phys. Rev. Lett., 59, 2585, 1987.

Madhukar, A. and Post W. , Exact solution for the diffusion of a particle in a medium with site diagonal and off-diagonal dynamic disorder, Phys. Rev. Lett., 39, 1424, 1977.
Silinsh, E.A. , Molecular polaron approach: impact on conductivity level energy spectra, charge carrier photogeneration and transport mechanisms in organic molecular crystals, in Proc. XI Symp. on Molecular Crystals, Lugano, Switzerland, 1985, 277.
Krinichnyi, V.I. , 2-MM EPR spectroscopy in the study of conducting and superconductive compounds (to be published).
Coulon, C. , Delhaes, P. , Flandrois, S. , Lagnier, R. , Bonjour, E. , and Fabre J. , A new survey of the physical properties of the (TMTTF)2X series. Role of the counterion ordering, J. Phys., 43, 1059, 1982.
Nelson, D.L. , Whittingham, M.S. , and George T.F. , Eds., Chemistry of High-Temperature Superconductors, American Chemical Society Symp. Ser. 351, State University of New York at Buffalo, 1987.
Van Duzer, T. and Taylor C.E. , Eds., Superconductivity, Proceedings of the IEEE, 77, No. 8, 1989.
Van Duzer, T. and Turner C.W. , Type-II superconductivity. Theory and technology, in Principles of Superconductive Devices and Circuits, Elsevier-North Holland, Amsterdam, 1981, chap. 8.
Chudnovsky, E.M. , Pinning by oxygen vacancies in high-Tc superconductors, Phys. Rev. Lett., 65, 3060, 1990.
Yeshurun, Y. and Malozemoff A.P. , Giant flux creep and irreversibility in YBaCuO crystals: an alternative to the superconducting glass model, Phys. Rev. Lett., 60, 2202, 1988.
Trauble, H. and Essman U. , Flux-line arrangement in superconductors as revealed by direct observation, J. Appl. Phys., 39, 4052, 1968.
Alers, P.B. , Structure of the intermediate state in superconducting lead, Phys. Rev. B, 105, 104, 1957.
Krinichnyi, V.I. , Grinberg, O. Ya. , Kozub, G.I. , and Lebedev, Ya. S. , Method of macrospin probe in the investigation of high-temperature superconducting materials, Khim. Fiz., 8, 423, 1989 (in Russian).
Govorkov, V.A. , Electrical and Magnetic Fields (in Russian), Svjazizdat, Moscow, 1951.
216 Kartsovnik, M.V. , Larkin, V.A. , Ryazanov, V.V. , Sidorov, N.S. , and Schegolev I.F. , The critical state and Hc1 field in YBaCuO single crystals, Pisma Zh. Eksp. Teor. Fiz., 47, 595, 1988 [JETP Lett., 47, 691, 1988].
Bezryadin, A.V. , Kopylov, V.N. , Krasnov, V.M. , Larkin, V.A. , Ryazanov, V.V. , Togonidze, T.G. , and Schegolev I.F. , Pinning and lower crystal field in TIBaCaCuO single crystals, Pisma Zh. Eksp. Teor. Fiz., 51, 147, 1990 [JETP Lett., 51, 167, 1990].
Maslov, S.S. and Pokrovsky M.E. , The first crystal field and locking-unlocking phase transition in layered superconductors, Europhys. Lett., 14, 591, 1991.