

Contents

Chapter 1

Introduction to Highly Conducting One-Dimensional Solids

A. J. Berlinsky

1. Introduction	1
2. Some Preliminary Thoughts	1
3. Excitonic Superconductivity	3
4. TCNQ Salts and KCP	4
4.1. NMP-TCNQ	5
4.2. TTF-TCNQ	5
4.3. KCP	5
5. TTF-TCNQ and TSeF-TCNQ	6
5.1. Structural Transitions in TTF-TCNQ	7
5.2. Electromagnetic Properties of TTF-TCNQ	7
5.3. ESR and Alloys of TTF-TCNQ and TSeF-TCNQ	8
6. Theory	9
7. Some Concluding Thoughts	10
References	12
	13

Chapter 2

X-Ray and Neutron Scattering from One-Dimensional Conductors

R. Comès and G. Shirane

1. Introduction	17
1.1. Lattice Instabilities and Phonon Anomalies	17
1.2. X-Ray Diffuse Scattering	22
1.3. Neutron Scattering	27
2. Structural Studies of KCP and Related Platinum Chain Complexes	28
2.1. Structure and One-Dimensional Electrical Properties of KCP	29
2.2. X-Ray Diffuse Scattering from KCP	31
2.3. Neutron Scattering Studies of KCP	33
2.4. Study of Other Platinum Complexes	42
3. Structural Studies of Organic One-Dimensional Conductors	43
3.1. Structure and TTF-TCNQ Crystals	44
3.2. High-Temperature Precursor Scattering in TTF-TCNQ	46
3.3. The Modulated Phases of TTF-TCNQ	54

3.4. Spin Waves in TTF-TCNQ?	58
3.5. The Interpretation of the Sequence of Modulated Phases in TTF-TCNQ	59
3.6. Study of Other Organic One-Dimensional Conductors	61
4. Concluding Remarks	62
<i>References and Notes</i>	64

Chapter 3

Charge-Density Wave Phenomena in One-Dimensional Metals: TTF-TCNQ and Related Organic Conductors

A. J. Heeger

1. Introduction	69
2. Strength of Interactions; Bandwidth, Electron-Electron and Electron-Phonon Interactions	77
2.1. One-Electron Energies; Band Structure	77
2.2. Electron-Electron Interactions: Nuclear Magnetic Resonance and Magnetic Susceptibility	80
2.3. Electron-Phonon Interaction	87
3. The Peierls Instability in TTF-TCNQ: Structural Aspects and Phonon Softening	93
4. The Pseudogap: Optical Properties	97
5. Electrical Conductivity	105
5.1. DC Measurements	105
5.2. Microwave Measurements	120
6. The Transition Region $38^{\circ}\text{K} < T < 54^{\circ}\text{K}$	122
7. The Pinned Regime at Low Temperatures	127
8. Nonlinear Transport in TTF-TCNQ at Low Temperatures	131
9. Conclusion	138
<i>References and Notes</i>	140

Chapter 4

The Organic Metals $(\text{TSeF})_x(\text{TTF})_{1-x}\text{-TCNQ}$ —A Systematic Study

T. D. Schultz and R. A. Craven

1. Introduction	147
2. Preparation, Characterization, and Lattice Structure	149
3. Phase Diagram	154
4. Metallic Phase, $T > T_{c1}$	156
4.1. Transport Properties	156
4.2. Magnetic Properties	166
4.3. Phonon Anomalies	176
5. Metal-Semiconductor Phase Transition	183
5.1. Variation of Transition Temperature T_{c1} with Alloying	184
5.2. Thermodynamics and Critical Behavior of the Metal-Semiconductor Phase Transition	189
6. Semiconducting Phase, $T < T_{c1}$	196
6.1. Transport Properties in the Semiconducting Phase	197
6.2. Magnetic Properties	202
6.3. Superlattices and Phonon Anomalies	206

7. Summary	217
References and Notes	219

*Chapter 5***Perturbation Approach to Lattice Instabilities in
Quasi-One-Dimensional Conductors***L. J. Sham*

1. Introduction	227
2. The One-Dimensional Electron-Phonon System	228
3. Fluctuations in the One-Dimensional System	232
4. Effects of Intercolumn Coupling	236
5. Effects of Impurities	239
References and Notes	243

*Chapter 6***Theory of the One-Dimensional Electron Gas***V. J. Emery*

1. Basic Physics	247
1.1. Introduction	247
1.2. Phase Transitions and Long-Range Order	248
1.3. Mathematical Model	250
1.4. Strong Coupling	252
2. Spinless Fermions	255
2.1. Definition of the Continuum Limit	255
2.2. Boson Representations and the Free Energy	258
2.3. Boson Representations of Fermion Fields	263
2.4. Correlation Functions of the Interacting System	267
3. Large "On-Site" Interaction	271
3.1. Attractive Interaction	271
3.2. Repulsive Interaction	274
3.3. Correlation Functions	274
4. Continuum Limit—Energy Gaps	276
4.1. Separation of Charge and Spin Degrees of Freedom	277
4.2. Reduction to Spinless Fermions	278
4.3. Solution of the Spinless Fermion Problems	280
4.4. Correlation Functions	283
4.5. Relationship to Other Problems	286
5. Renormalization Group Method	289
5.1. Scaling Equations	290
5.2. Trajectories and Energy Scales	291
5.3. Low-Temperature Properties	294
5.4. Four-Particle Functions	297
Appendix A: Some Results That Are Useful for Working with Boson Representations	299
Appendix B: Anticommutation of Different Fermion Fields	300
Appendix C: Charge-Density Wave Gap and CDW Correlations	301
References	302

*Chapter 7***The Prospects of Excitonic Superconductivity***H. Gutfreund and W. A. Little*

1. Introduction	305
2. The Nature of Superconductivity	309
2.1. Background	309
2.2. Phonon Mechanism	310
2.3. Limitation on T_c	312
2.4. Isotope Effect	315
2.5. Exciton Mechanism	317
3. Problems of Superconductivity Unique to the Exciton Mechanism	319
3.1. Exchange	320
3.2. Apparent Limitation on $\lambda - \mu^*$	320
3.3. Vertex Corrections	322
3.4. Equation for T_c	323
3.5. The Kernel $U(p, k)$	326
3.6. Effects of the Phonons on the Exciton Mechanism	328
4. Effects of Limited Dimensionality	331
4.1. Effects of Fluctuations	333
4.2. Types of Order in a One-Dimensional Electron Gas	338
4.3. Relevance of "g-ology"	344
4.4. Interchain Coupling	345
4.5. Localization and Impurities	349
4.6. Effects of Screening	352
5. Real Models	356
5.1. Model of a Filamentary Excitonic Superconductor	357
5.2. Discussion	365
6. Summary	366
References	367

*Chapter 8***Recent Developments and Comments***John Bardeen*

1. Introduction	373
2. Nature of the Phase Transitions	378
2.1. Transition in KCP	379
2.2. Transitions in TCNQ Compounds	380
2.3. Transitions in TaS_3 , $NbSe_3$	382
3. Coulomb Interactions and Magnetic Susceptibility	382
3.1. Limitations of the Hubbard Model	382
3.2. Magnetic Susceptibility	384
3.3. Problem of TTF-TCNQ	385
3.4. Properties of NMP-TCNQ	386
4. Collective Transport	387
4.1. Superconductivity and One-Dimensional Fluctuations	388
4.2. Dielectric Properties	390

4.3. Transport above T_c	392
4.4. Nonlinear Field Dependence of Conductivity	398
5. Concluding Comments	401
<i>References</i>	402
<i>Author Index</i>	405
<i>Subject Index</i>	413