Contents

1. Introduction 1

2. Monocrystalline Filaments (Whiskers) 4
2.1 Crystal Growth 4
2.2 Handling 4
2.3 Characteristic Properties 5

3. Low Temperature Techniques 9
3.1 General Features 9
3.2 ^{4}He Bath Cryostat (1.4 K - 4.2 K) 10
3.3 ^{4}He Overpressure Cryostat (3.0 K - 7.5 K) 10
3.4 ^{3}He Cryostat with Superfluid ^{4}He Bath (0.45 K - 1.4 K) 12

4. Basic Experimental Observations 14

5. Overview of Theories 17
5.1 Ginsburg-Landau Theory 18
5.2 BCS Ground State and Quasiparticle Excitations . . 21
5.3 Charge Imbalance and Quasiparticle/Pair Electrochemical Potentials 25
5.4 Relaxation of Charge Imbalance 34
5.5 Energy Mode 46
5.6 Collective Excitations 51
5.7 Dynamics of Charge Imbalance 54
5.8 Models for a Phase-Slip Center 59
5.8.1 The Phase-Slip Phenomenon 59
5.8.2 The RSM Model 62
5.8.3 The SBT Model 63
5.8.4 The KSS Model 69
5.9 Time-Dependent Ginsburg-Landau (TDGL) Theory . . 79
5.10 Final and Summarizing Remarks 95

6. Equilibrium Properties 99
6.1 Critical Current 99
6.2 Critical Temperature 103

7. Fundamental Properties of Phase-Slip Centers 107
7.1 Introductory Remarks 107
7.2 Quasiparticle Diffusion Length and Time Averaged Supercurrent 108
7.3 The Influence of High-Frequency Radiation 123
7.4 Localization of Phase-Slip Centers 138
7.5 Stabilization of Superconductivity by a Phase-Slip Center 142
7.6 Electrochemical Potentials of Pairs and Quasiparticles - Evidence for Collective Excitations . . 155

8. The Limit of Long Quasiparticle Relaxation Times . . . 168
8.1 Introductory Remarks 168
8.2 Experiments on Zn and Zn-Ag Whiskers 169
8.3 Interpretation by Comparison with Theoretical Work 173

9. The Limit of Short Quasiparticle Relaxation Times . . . 178
9.1 Introductory Remarks 178
9.2 Change from Weak to Strong Coupling Behaviour: Experiments on Whiskers of the In-Pb Alloy System 179
9.2.1 In-Rich Alloys 179
9.2.2 The Range of Substantial Alloy Contents . 182
9.2.3 Pure Pb 183
9.2.4 Pb with Small Impurity Concentrations of In (or Bi) 188
9.3 Interpretation within Phase-Slip Models and the TDGL Theory 189

10. Universal Behaviour of an Isolated Phase-Slip Center: Experiment and TDGL Theory 198

11. Hysteresis of the Critical Current 211
11.1 Introductory Remarks 211
11.2 Heat Transfer from a Metallic Filament into Helium - The Kapitza Resistance 216
11.3 Hysteretic Behaviour of a Tin Whisker 222

11.4 Phenomenological Hysteresis Model 224
11.4.1 A Model with Two Fitting Parameters . . 224
11.4.2 Comparison with Experiment 230
11.4.3 A Model without Fitting Parameters . . . 235
11.4.4 Comparison with Experiment 238
11.5 The Hysteresis in the TDGL Theory 241

12. Tunable Weak Links 245
12.1 Experiments 246
12.2 Interpretation 251

13. Remarks on Ongoing Work 256
13.1 Low-Temperature Behaviour of a Phase-Slip Center 256
13.2 Tunable Weak Links 258
13.3 Microcontacts 266
13.4 The Interaction of Phase-Slip Centers in Zn Whiskers 269

14. Conclusions 283

A. Appendix 287
A.1 Different Definitions of the Charge Imbalance . . . 287
A.2 Remarks on the Calculation of the Quasiparticle Chemical Potential 288
A.3 Inelastic Electron-Phonon Scattering Time 288
A.4 Remarks on the Derivation of the Charge Imbalance Wave Equation 295
A.5 Remarks on the Calculation of the Inelastic Electron-Phonon Scattering Time for In-Pb Alloy Whiskers 296

Final Note 299

References 301

List of Abbreviations 319

List of Symbols 321

Subject Index 335