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Copper Oxide Superconductors*

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Electromagnetic Absorption in the Copper Oxide Superconductors

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Preface to the Series

Since its discovery in 1911, superconductivity has been one of the most interesting topics in physics. Superconductivity baffled some of the best minds of the 20th century and was finally understood in a microscopic way in 1957 with the landmark Nobel Prize-winning contribution from John Bardeen, Leon Cooper, and Robert Schrieffer. Since the early 1960s there have been many applications of superconductivity including large magnets for medical imaging and high-energy physics, radio-frequency cavities and components for a variety of applications and quantum interference devices for sensitive magnetometers and digital circuits. These last devices are based on the Nobel Prize-winning (Brian) Josephson effect. In 1987, a dream of many scientists was realized with the discovery of superconducting compounds containing copper – oxygen layers that are superconducting above the boiling point of liquid nitrogen. The revolutionary discovery of superconductivity in this class of compounds (the cuprates) won Georg Bednorz and Alex Mueller the Nobel Prize.

This series on Selected Topics in Superconductivity will draw on the rich history of both the science and technology of this field. In the next few years we will try to chronicle the development of both the more traditional metallic superconductors as well as the scientific and technological emergence of the cuprate superconductors. The series will contain broad overviews of fundamental topics as well as some very highly focused treatises designed for a specialized audience.

Preface

In 1987 a major breakthrough occurred in materials science. A new family of materials was discovered that became superconducting above the temperature at which nitrogen gas liquifies, namely, 77 K or -196°C . Within months of the discovery, a wide variety of experimental techniques were brought to bear in order to measure the properties of these materials and to gain an understanding of why they superconduct at such high temperatures. Among the techniques used were electromagnetic absorption in both the normal and the superconducting states. The measurements enabled the determination of a wide variety of properties, and in some instances led to the observation of new effects not seen by other measurements, such as the existence of weak-link microwave absorption at low dc magnetic fields.

The number of different properties and the degree of detail that can be obtained from magnetic field- and temperature-dependent studies of electromagnetic absorption are not widely appreciated. For example, these measurements can provide information on the band gap, critical fields, the H–T irreversibility line, the amount of trapped flux, and even information about the symmetry of the wave function of the Cooper pairs. It is possible to use low dc magnetic field-induced absorption of microwaves with derivative detection to verify the presence of superconductivity in a matter of minutes, and the measurements are often more straightforward than others. For example, they do not require the physical contact with the sample that is necessary when using four-probe resistivity to detect superconductivity. Also, there is no limit on the form of the samples required for electromagnetic absorption studies since sintered and granular materials, crystals, and thin films are all equally acceptable.

The purpose of this volume is to provide an introduction to electromagnetic absorption measurements in superconductors, with an emphasis on the new superconducting materials, showing the variety of basic properties that can be delineated by such measurements. The volume is not intended to be a detailed review of all

the work done in the area, but rather an introduction to the field supplemented by an outline of the theory and discussions of relevant experimental results. The focus is on qualitative aspects and experimental measurements rather than on detailed theoretical considerations so that the reader can obtain a basic understanding and appreciation of the wealth of information provided by electromagnetic absorption measurements, as well as insights into the mechanisms of absorption. Thus the references cited are not meant to be comprehensive lists of work in the field but collections of representative articles. The level of presentation is such that the volume can be used as a supplementary text for a graduate course in solid state physics, materials science, or superconductivity.

The book is intended to be self-contained in that it starts with an elementary introduction to superconductivity, with an emphasis on those properties that are germane to understanding electromagnetic absorption of the superconducting state. Then we provide an overview of the properties of the copper oxide and fullerene superconductors, followed by a chapter on experimental techniques and another on electromagnetic absorption in the normal state. Our attention then turns to microwave absorption in a zero magnetic field and in low magnetic fields; this is followed by an explication of the role played by vortex motion. Absorption in the infrared and optical regions is then treated, and the book ends with a discussion of applications.

Acknowledgment

One of us (CPP) would like to thank his son Michael for drawing several of the more difficult figures.

Frank J. Owens and Charles P. Poole, Jr.

Contents

Chapter 1. The Superconducting State

1.1. Zero Resistance	1
1.1.1. The Superconducting Gap	2
1.1.2. Cooper Pairs	4
1.2. The Meissner Effect	7
1.2.1. Magnetic Field Exclusion	7
1.2.2. Temperature Dependencies	12
1.2.3. Applied and Internal Fields	14
1.2.4. Type I and Type II Superconductors	17
1.2.5. Quantization of Flux	23
1.2.6. Vortex Configurations	24
1.2.7. Flux Creep and Flux Flow	25
References	29

Chapter 2. The New Superconductors

2.1. The Copper Oxides	31
2.1.1. Lanthanum and Neodymium Superconductors	31
2.1.2. The Yttrium Superconductor	34
2.1.3. Bismuth and Thallium Superconductors	36
2.1.4. Mercury Superconductors	38
2.1.5. Infinite-Layer Phases	39
2.1.6. Ladder Phases	40
2.2. General Properties of Copper Oxide Superconductors	42
2.2.1. Commonalities of the Cuprates	44
2.2.2. Energy Bands	47
2.2.3. Cooper Pair Binding	49
2.3. Perovskite Superconductors	50
2.4. Carbon-60 Superconductors	51
References	54

Chapter 3 . Experimental Methods and Complementary Techniques

3.1. Radio Frequency Measurements Using LC Resonant Circuits	55
3.2. Microwave Measurements Using Cavity Resonators	59
3.3. Electron Paramagnetic Resonance	62
3.4. Paramagnetic Probes	65
3.5. Stripline and Parallel Plate Microwave Resonators	66
3.6. Nuclear Magnetic Resonance	68
3.7. Nuclear Quadrupole Resonance	69
3.8. Muon Spin Relaxation	69
3.9. Positron Annihilation	70
3.10. Mössbauer Resonance	70
3.11. Photoemission and X-Ray Absorption	71

Chapter 4 . Electromagnetic Absorption in the Normal State

4.1. Metallic State	75
4.1.1. Electrical Conductivity	75
4.1.2. Surface Resistance	78
4.1.3. Power Dissipation	79
4.1.4. Temperature Dependencies	81
4.2. Semiconductors	82
4.3. Metal–Insulator Transition	83
4.4. Antiferromagnetic Transition	83
4.5. Ferromagnetic Transition	84
4.6. Magnetoresistance	89
References	94

Chapter 5 . Zero Magnetic Field Microwave Absorption

5.1. Electromagnetic Absorption and the Two-Fluid Model	95
5.2. Surface Impedance	97
5.3. Electromagnetic Absorption in the BCS Theory	99
5.4. Copper Oxides	102
5.4.1. Penetration Depth Measurements	102
5.4.2. Surface Resistance Measurements	105
5.4.3. Penetration Depth Measurements as a Probe of s- and d-Wave Symmetry	107
5.4.4. Electromagnetic Absorption Due to Fluctuations	107
References	112

Chapter 6. Low Magnetic Field-Induced Microwave Absorption

6.1. Introduction	113
6.2. Properties of Low Magnetic Field Absorption Derivative	114

6.3. Properties of Low-Field Direct Microwave Absorption 120

6.4. Origin of Low Magnetic Field Derivative Signal 125

6.4.1. Loops and Josephson Junctions 125

6.4.2. Absorption Mechanism 128

6.5. Magnetic Field Absorption in Alternating Applied Fields 132

6.6. Low Magnetic Field Derivative Signal as a Detector of
Superconductivity 136

References 137

Chapter 7. Electromagnetic Absorption Due to Vortex Motion

7.1. Theory of Electromagnetic Absorption Due to Vortex Dissipation 139

7.1.1. Penetrating Fields 139

7.1.2. Flux Creep, Flux Flow, and Irreversibility 140

7.1.3. Coffey–Clem Model 142

7.2. Experimental Results 145

7.2.1. RF Penetration Depth Measurements 145

7.2.2. Microwave Bridge Measurements 148

7.2.3. Strip Line Resonator Measurements 153

7.3. Concluding Remarks 156

References 156

Chapter 8. Infrared and Optical Absorption

8.1. Absorption in the Infrared 159

8.2. Detecting Molecular and Crystal Vibrations 160

8.3. Soft Modes 163

8.4. Dielectric Constant and Conductivity 164

8.5. Reflectivity 165

8.6. Kramers–Kronig Analysis 166

8.7. Drude Expansion 166

8.8. Plasma Oscillations 169

8.9. Energy Gap 169

8.10. Absorption at Visible and Ultraviolet Frequencies 172

References 174

Chapter 9. Applications

9.1. Thin Films 175

9.2. Delay Lines 178

9.3. Stripline Resonators 178

9.4. Cavity Resonators 181

9.5. Transmission Lines 184

9.6. Superconducting Antennae 186

9.7. Infrared and Optical Sensors 188

9.8. Magnetometers 190

References 192

Index 193