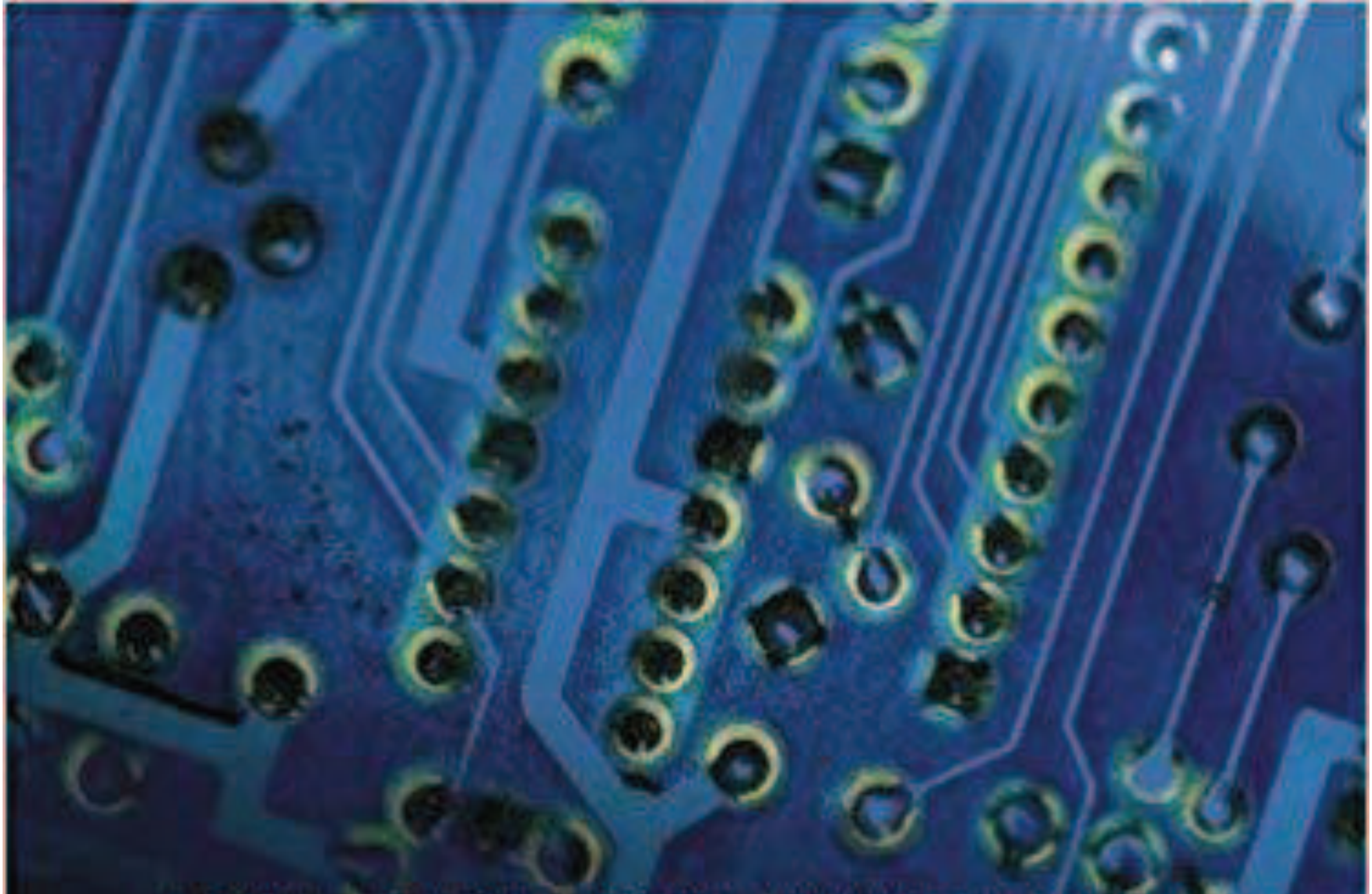

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Contents

Preface

Microwave materials have been widely used in a variety of applications ranging from communication devices to military satellite services, and the study of materials properties at microwave frequencies and the development of functional microwave materials have always been among the most active areas in solid-state physics, materials science, and electrical and electronic engineering. In recent years, the increasing requirements for the development of high-speed, high-frequency circuits and systems require complete understanding of the properties of materials functioning at microwave frequencies. All these aspects make the characterization of materials properties an important field in microwave electronics.

Characterization of materials properties at microwave frequencies has a long history, dating from the early 1950s. In past decades, dramatic advances have been made in this field, and a great deal of new measurement methods and techniques have been developed and applied. There is a clear need to have a practical reference text to assist practicing professionals in research and industry. However, we realize the lack of good reference books dealing with this field. Though some chapters, reviews, and books have been published in the past, these materials usually deal with only one or several topics in this field, and a book containing a comprehensive coverage of up-to-date measurement methodologies is not available. Therefore, most of the research and development activities in this field are based primarily on the information scattered throughout numerous reports and journals, and it always takes a great deal of time and effort to collect the information related to on-going projects from the voluminous literature. Furthermore, because of the paucity of comprehensive textbooks, the training in this field is usually not systematic, and this is undesirable for further progress and development in this field.

This book deals with the microwave methods applied to materials property characterization, and it provides an in-depth coverage of both established and emerging techniques in materials characterization. It also represents the most comprehensive treatment of microwave methods for materials property characterization that has appeared in book form to date. Although this book is expected to be most useful to those engineers actively engaged in designing materials property–characterization methods, it should also be of considerable value to engineers in other disciplines, such as industrial engineers, bioengineers, and materials scientists, who wish to understand the capabilities and limitations of microwave measurement methods that they use. Meanwhile, this book also satisfies the requirement for up-to-date texts at graduate and senior undergraduate levels on the subjects in materials characterization.

Among this book's most outstanding features is its comprehensive coverage. This book discusses almost all aspects of the microwave theory and techniques for the characterization of the electromagnetic properties of materials at microwave frequencies. In this book, the materials under characterization may be dielectrics, semiconductors, conductors, magnetic materials, and artificial materials; the electromagnetic properties to be characterized mainly include permittivity, permeability, chirality, mobility, and surface impedance.

The two introductory chapters, Chapter 1 and Chapter 2, are intended to acquaint the readers with the basis for the research and engineering of electromagnetic materials from the materials and microwave fundamentals respectively. As general knowledge of electromagnetic properties of materials is helpful for understanding measurement results and correcting possible errors, Chapter 1 introduces the general properties of various electromagnetic materials and their underlying physics. After making a brief review on the methods for materials properties characterization, Chapter 2 provides a summary of the basic microwave theory and techniques, based on which the methods for materials characterization are developed. This summary is mainly intended for reference rather than for tutorial purposes, although some of the important aspects of microwave theory are treated at a greater length. References are cited to permit readers to further study the topics they are interested in.

Chapters 3 to 8 deal with the measurements of the permittivity and permeability of low-conductivity materials and the surface impedance of high-conductivity materials. Two types of nonresonant methods, reflection method and transmission/reflection method, are discussed in Chapters 3 and 4 respectively; two types of resonant methods, resonator method and resonant-perturbation method, are discussed in Chapters 5 and 6 respectively. In the methods discussed in Chapters 3 to 6, the transmission lines used are mainly coaxial-line, waveguide, and free-space, while Chapter 7 is concerned with the measurement methods developed from planar transmission lines, including stripline, microstrip-, and coplanar line. The methods discussed in Chapters 3 to 7 are suitable for isotropic materials, which have scalar or complex permittivity and permeability. The permittivity of anisotropic dielectric materials is a tensor parameter, and magnetic materials usually have tensor permeability under an external dc magnetic field. Chapter 8 deals with the measurement of permittivity and permeability tensors.

Ferroelectric materials are a special category of dielectric materials often used in microwave electronics for developing electrically tunable devices. Chapter 9 discusses the characterization of ferroelectric materials, and the topics covered include the techniques for studying the temperature dependence and electric field dependence of dielectric properties.

In recent years, the research on artificial materials has been active. Chapter 10 deals with a special type of artificial materials: chiral materials. After introducing the concept and basic characteristics of chiral materials, the methods for chirality measurements and the possible applications of chiral materials are discussed.

The electrical transport properties at microwave frequencies are important for the development of high-speed electronic circuits. Chapter 11 discusses the microwave Hall effect techniques for the measurement of the electrical transport properties of low-conductivity, high-conductivity, and magnetic materials.

The measurement of materials properties at high temperatures is often required in industry, scientific research, and biological and medical applications. In principle, most of the methods discussed in this book can be extended to high-temperature measurements. Chapter 12 concentrates on the measurement of the dielectric properties of materials at high temperatures, and the techniques for solving the problems in high-temperature measurements can also be applied for the measurement of other materials property parameters at high temperatures.

In this book, each chapter is written as a self-contained unit, so that readers can quickly get comprehensive information related to their research interests or on-going projects. To provide a broad treatment of various topics, we condensed mountains of literature into readable accounts within a text of reasonable size. Many references have been included for the benefit of the readers who wish to pursue a given topic in greater depth or refer to the original papers.

It is clear that the principle of a method for materials characterization is more important than the techniques required for implementing this method. If we understand the fundamental principle underlying a measurement method, we can always find a suitable way to realize this method. Although the advances in technology may significantly change the techniques for implementing a measurement method, they cannot greatly influence the measurement principle. In writing this book, we tried to present the fundamental principles behind various designs so that readers can understand the process of applying fundamental concepts to arrive at actual designs using different techniques and approaches. We believe that an engineer with a sound knowledge of the basic concepts and fundamental principles for materials property characterization and the ability apply to his knowledge toward design objectives, is the engineer who is most likely to make full use of the existing methods, and develop original methods to fulfill ever-rising measurement requirements.

We would like to indicate that this text is a compilation of the work of many people. We cannot be held responsible for the designs described that are still under patent. It is also difficult to always give proper credits to those who are the originators of new concepts and the inventors of new methods. The names we give to some measurement methods may not fit the intentions of the inventors or may not accurately reflect the most characteristic features of these methods. We hope that there are not too many such errors and will appreciate it if the readers could bring the errors they discover to our attention.

There are many people to whom we owe many thanks for helping us prepare this book. However, space dictates that only a few of them can receive formal acknowledgements. But this should not be taken as a disparagement of those whose contributions remain anonymous. Our foremost appreciation goes to Mr. Quek Gim Pew, Deputy Chief Executive (Technology), Singapore Defence Science & Technology Agency, Mr. Quek Tong Boon, Chief Executive Officer, Singapore DSO National Laboratories, and Professor Lim Hock, Director, Temasek Laboratories, National University of Singapore, for their encouragement and support along the way. We are grateful to Pennsylvania State University and HVS Technologies for giving us permission to include the HVS Free Space Unit and the data in this book. We really appreciate the valuable help and cooperation from Dr. Li Zheng-Wen, Dr. Rao Xuesong, and Mr. Tan Chin Yaw. We are very grateful to the staff of John Wiley & Sons for their helpful efforts and cheerful professionalism during this project.

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