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Dielectric Properties of Heterogeneous Materials

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Editor:
A. Priou
O.N.E.R.A.–C.E.R.T.
Microwaves Department
Toulouse Cedex, France

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PREFACE

Composite materials for aeronautics, space and telecommunication applications has become one of the great challenges of recent years.

The composite materials are, generally made of a fiber-reinforced thermosetting resin or spherical or non-spherical particles embedded in a resin matrix. Other combinations of dielectrics, conductors and conducting or non conducting polymer products of various shapes and sizes have been studied. Various multilayered materials have been designed and realized by using composite layers as described above.

In keeping with the overwhelming interest in electromagnetic properties of composite materials during the last ten years, as evidenced at various meetings and conferences around the world, a special volume of Progress in Electromagnetics Research (PIER) on this topics appears timely. The papers in this volume also demonstrate that this is an active field of research.

The objective is to present the background information, current state of the art, and future trends in dielectric modeling and characterization of heterogeneous materials. In this volume, an attempt is made to collect all the theoretical models created for heterogeneous materials to better explain their behavior and predict their electromagnetic properties. New concepts for prediction of the effective permeability are added, because in some applications dielectric-ferrite or more complex situations are encountered. Measurement techniques must be associated with theoretical models to both validate these models for or furnish experimental data on composite media.

In this volume, the first two chapters provide an overview of microwave material interactions and mixture laws.

In Chapter 1, W. R. Tinga reviews the fundamental principles of microwave material interactions in some detail including microwave heating models and their applications. The treatment is intended to give physical insight into the electromagnetic material interaction phenomena without going into rigorous mathematical details.

In Chapter 2, J. L. Greffe and C. Grosse review all the existing static theories to describe emulsion mixtures. They compare different theories and bring out their self-consistence. A general comparison with experimental results is presented to allow emphasis on the most important parameters that contribute to the complex permittivity.

They are followed by two other chapters providing the fundamental basis for the polarizability modeling of heterogeneous media and effective permeability of mixtures.

The contribution from A. Sihvola and I. V. Lindell, as Chapter 3, describes the low-frequency dielectric properties of inhomogeneous media. The authors establish the connection between the effective permittivity of a mixture and polarizabilities of inclusions constituting the mixture. The polarizabilities are calculated for homogeneous, layered, and radially continuous spherical and ellipsoidal inclusions. Different mixing formulas for dense mixtures are introduced and applied to some composite media.

In Chapter 4, A. Sihvola and I. V. Lindell describe the macroscopic behavior of heterogeneous materials that are composed of magnetically different components. The duality of magnetostatic and electrostatic problems allows them to derive mixing formulas as they did in the previous chapter. However, because of the special properties of magnetic media, magnetic mixtures need special attention.

In a Chapter 5, L. Tsang describes dense media radiative transfer equations for dense discrete random media with particles of multiple species (different sizes and permittivities). The dense media radiative transfer equations are developed from quasicrystalline approximation with coherent potential and the correlated ladder approximation and take into account correlated scattering between scatterers. These equations for both active and passive remote sensing media are derived.

In the five following chapters, authors use previous mentioned theories to analyze various kinds of heterogeneous media.

In Chapter 6, S. Nelson deals with an estimation of permittivities of solids from measurements on pulverized or granular materials. A simple method has been developed for extrapolation of permittivity measurement data on pulverized materials. This chapter is rich in experimental data on numerous pulverized materials at various frequencies in the microwave range. The author has undoubtedly a most important library on dielectric properties of various materials.

In Chapter 7, T. A. Ezquerra, F. Kremer and G. Wegner review the ac electrical properties of insulator-conductor composites in the frequency range from 10 to 10^{10} Hz. The experimental results are discussed in the light of the Effective Medium Theory (EMT) and the Percolation Theory (PT). Results for carbon black composites and conducting polymer composites are presented.

In Chapter 8, V. K. Varadan, Y. Ma, A. Lakhtakia and V. V. Varadan show how to implement the multiple scattering theory for the prediction of the electrical properties of porous ceramics during microwave sintering. Comparison with experimental results are given.

In Chapter 9, Y. Ma, V. K. Varadan and V. V. Varadan review two multiple scattering dependent expressions for the effective permittivity and the permeability of microwave composite materials to predict the electromagnetic properties of ferrite composites. Several cases involving a lossy/lossless matrix and magnetic inclusions are presented.

In Chapter 10, V. K. Varadan, Y. MA and V. V. Varadan examine the effects of chirality on the propagation of electromagnetic waves through a non chiral medium containing randomly distributed particles made of chiral materials. The multiple scattering formalism is employed to obtain a dispersion equation for the chiral composite media. Computed results of microwave properties of chiral composite media are presented.

This volume will not be complete without a chapter addressing the measurement techniques for composite materials.

In Chapter 11, M. Maurens, A. Priou, P. Brunier, S. Aussudre, M. Lopez and P. Combes, after an introduction dealing with an intensive work in the area of the modeling and characterization of heterogeneous structures, describe a free-space microwave measurement technique for composite materials. Experimental results on various composite materials are presented.

As Guest Editor, I wish to thank Professor J. A. Kong for his guidance and constant encouragement throughout this endeavor. Also I wish to express my appreciation to the authors for their efforts and to the reviewers for their prompt and careful reviews of the manuscripts. Finally I would like to thank especially Dr. I. Chenerie for valuable and intensive assistance in reviewing all the papers of this volume.

A. Priou

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CONTRIBUTORS TO PIER 6

S. Aussudre, *O.N.E.R.A-C.E.R.T.*
310055 Toulouse Cedex, France

P. Combes, *Paul Sabatier Sciences University*
31062 Toulouse Cedex, France

T. A. Ezquerra, *Instituto de Estructura de la Materia, CSIC*
Serrano 119, 28006 Madrid, Spain

J. L. Greffe, *LSGC - ENSIC*
Nancy Cedex, France

C. Grosse, *Universidad Nacional de Tucuman*
Tucuman, Republica Argentina

F. Kremer, *Max-Planck-Institut fur Polymerforschung*
D-6500 Mainz, Germany

A. Lakhtakia, *Pennsylvania State University*
University Park, PA 16802, USA

I. V. Lindell, *Helsinki University of Technology*
Espoo, Finland

M. Lopez, *O.N.E.R.A-C.E.R.T.*
310055 Toulouse Cedex, France

Y. Ma, *Pennsylvania State University*
University Park, PA 16802, USA

M. Maurens, *O.N.E.R.A-C.E.R.T.*
310055 Toulouse Cedex, France

S. O. Nelson, *United States Department of Agriculture*
Athens, GA 30613, USA

A. Priou, *O.N.E.R.A-C.E.R.T.*
310055 Toulouse Cedex, France

A. Sihvola, *Helsinki University of Technology*
Espoo, Finland

W. R. Tinga, *University of Alberta*
Edmonton Alberta, Canada

L. Tsang, *University of Washington*
Seattle, WA 98195, USA

V. K. Varadan, *Pennsylvania State University*
University Park, PA 16802, USA

V. V. Varadan, *Pennsylvania State University*
University Park, PA 16802, USA

G. Wegner, *Max-Planck-Institut fur Polymerforschung*
D-6500 Mainz, Germany

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