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Deborah D. L. Chung

Composite Materials

Science and Applications

Second Edition

Springer

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In Celebration of the 20th Anniversary of the Composite Materials Research Laboratory, University at Buffalo, State University of New York

With thanksgiving for the past twenty years and excitement for the future, I dedicate this book to the Composite Materials Research Laboratory, which I founded at the University at Buffalo, State University of New York, in 1989. With the highly appreciated involvement of a large number of researchers, including students, postdoctoral associates, visiting scholars, faculty members and industrial participants, the Laboratory has made advances in the science and technology of composite materials, as shown by 400 peer-reviewed journal publications that cover composites with polymer, cement, and metal matrices, including those for aerospace, automotive, civil, electronic, energy and thermal applications. The Laboratory has emphasized material development that is application driven and process oriented, as partly described in this book. Our most notable breakthroughs relate to smart concrete, vibration damping materials, cement-based pn-junctions, thermoelectric materials, multifunctional structural materials, carbon nanofiber applications, electromagnetic interference shielding materials, electronic packaging materials and thermal interface materials. The graduation of over 30 doctoral students is particularly heartwarming. Special appreciation is extended to Mr. Mark A. Lukowski, for twenty years of technical support.

In further celebration of the anniversary, the Laboratory has commissioned Kenneth C.K. Yip (composer) and I (lyrics and narration writer) to write a musical that merges science and music. The piece is entitled *Materials Are Needed to Make Anything*, and is for performance by a chorus and two vocal soloists and percussion accompaniment. This is the first musical work that centers on engineering materials! Choirs interested in performing this 30-minute piece are welcome to contact me.

Deborah D.L. Chung
Director and Professor
Composite Materials Research Laboratory
Buffalo, NY
June 1, 2009

Preface to the Second Edition

The field of composite materials has progressed greatly over the last few decades, as shown by the widespread use of fibrous composite materials for airframes, sporting goods and other lightweight structures. Enabling this technological progress is scientific understanding of the design and mechanics of composite materials that involve continuous fibers as the reinforcement.

Current challenges in the field of composite materials are associated with the extension of the field of composite materials from structural composites to functional and multifunctional composites, the development of composite materials for electrical, thermal and other functional applications that are relevant to current technological needs, and the improvement of composite materials through processing. Examples of functions are joining (e.g., brazing), repair, sensing, actuation, deicing (as needed for aircraft and bridges), energy conversion (as needed to generate clean energy), electrochemical electrodes, electrical connection, thermal contact improvement and heat dissipation (i.e., cooling, as needed for microelectronics and aircraft). Processing includes the use of additives (which may be introduced as liquids or solids), the combined use of fillers (including discontinuous ones) at the micrometer and nanometer scales, the formation of hybrids (such as organic–inorganic hybrids), the modification of the interfaces in a composite, and control over the microstructure. In other words, the development of composite materials for current technological needs must be application driven and process oriented. This is in contrast to the conventional composites engineering approach, which focuses on mechanics and purely structural applications.

The second edition is aimed at providing in an organized manner the concepts and technical details for addressing the challenges mentioned above. Compared to the first edition, the second edition has been greatly expanded (with hundreds of illustrations added), extensively reorganized and almost totally rewritten.

As a part of a comprehensive treatment of composite tailoring methods, numerous examples of methods, in addition to data and micrographs that support their effectiveness, have been added to the second

edition. Topics added to the second edition include vibration damping, degradation, durability, mechanical joining, electrical connection and nanocomposites. Composites with polymer, cement, metal and carbon matrices are covered in terms of the structure, properties, fabrication and applications. Up-to-date information on lightweight structural materials and civil infrastructure materials is provided. Materials for structural, electrical and thermal applications are comprehensively covered with much information that is not in the first edition. The emphasis on process-oriented composite design, application-oriented functional properties and multifunctional structural materials makes this book different from all other books on composite materials.

Due to the large amount of up-to-date and down-to-earth information, the book is also suitable for use as a reference book for students and professionals that are interested in the development of composite materials. Due to the tutorial style, basic concept coverage, example problems and review questions, the book is also suitable for use as a textbook for undergraduate and graduate students that have had a semester of an introductory materials science course. The relevant academic disciplines include materials, chemical, mechanical, aerospace, electrical and civil engineering.

Deborah D.L. Chung
Buffalo, NY
April 16, 2009
http://alum.mit.edu/www/ddlchung

Preface to the First Edition

Books on composite materials are essentially limited to addressing the fabrication and mechanical properties of these materials, because of the dominance of structural applications (such as aerospace applications) for traditional composite materials. However, nonstructural applications are rapidly increasing in importance due to the needs of the electronic, thermal, battery, biomedical and other industries. The scientific concepts that guide the design of functional composites and that of structural composites are quite different, as both the performance and cost requirements are different. Therefore, this book is different from related books in its emphasis on functional composite materials. The functions addressed include structural, thermal, electrical, electromagnetic, thermoelectric, electromechanical, dielectric, magnetic, optical, electrochemical and biomedical functions. The book provides the fundamental concepts behind the ability to provide each function, in addition to covering the fabrication, structure, properties and applications of the relevant composite materials.

Books on composite materials tend to emphasize polymer-matrix composites, though cement-matrix composites are the most widely used structural materials, and metal-matrix, carbon-matrix and ceramic-matrix composites are rising in importance. In contrast, this book covers composite materials with all of the abovementioned matrices.

The most common approach for books on composite materials is to emphasize mechanics issues, due to the relevance of mechanics to structural applications. A less common approach for books on composite materials is to categorize composite materials in terms of their matrices and cover the composites in accordance with their matrix materials. In contrast, this book takes a new approach, namely the functional approach—covering composites in accordance with their functions. The functional approach allows the readers to appreciate how composites are designed for the needs of various industries. Such appreciation is valuable for students who are preparing themselves for industrial positions (most students are) and for professionals working in various industries. Moreover, the functional approach allows

an organized presentation of numerous scientific concepts other than those related to mechanical behavior, thereby enabling a wide scientific scope to be covered.

The book is tutorial in style, but it is up-to-date, and each chapter includes an extensive list of references. The readers need to have taken a course on introductory materials science. They do not need to have taken any prior course on composite materials. Therefore, the book is suitable for use as a textbook for upper-level undergraduate students and for graduate students. It is also suitable for use as a reference book for students, engineers, technicians, technology managers and marketing personnel.

Because of the wide scientific scope enabled by the functional approach, the book is expected to be useful to all kinds of engineers (including electrical, thermal, chemical and industrial engineers). In contrast, the conventional approach that emphasizes mechanical behavior limits the readership to materials, mechanical, aerospace and civil engineers.

Deborah D.L. Chung
Buffalo, NY
April 1, 2002

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