BOOK REVIEWS

Mullite and Mullite Ceramics

Reviewed by R. G. Munro, Ceramics Division, National Institute of Standards and Technology, Gaithersburg, MD 20899.

REFERENCE: Schneider, H., Okada, K., and Pask, J., *Mullite and Mullite Ceramics*, John Wiley & Sons, Chichester, England, 1994, ISBN: 0-471-94249-9, 251 pp., $85.

Mullite is a ceramic material that is important to both traditional ceramics and advanced ceramics. While its occurrence in nature is rare, mullite is a principal constituent of traditional clay-based ceramics such as pottery, porcelains, bricks, and tiles, due to reactions of alumina and silica during firing. Thus, mullite has been used, if not recognized explicitly, for thousands of years. More deliberate applications today include components for kilns, heat exchangers, and turbine engines, heat- and corrosion-resistant parts for chemical processing apparatus, and electronic packaging materials.

In general, "mullite ceramics" may be represented by the formula $Al_{4+2x}Si_{2-2x}O_{10-x}$, and in specific instances as $mAl_2O_3 \cdot nSiO_2$ for integers m and n. The specific term "mullite" refers to the composition with $x = 0.25$ or $m/n = {}^3/_2$ $(3Al_2O_3 \cdot 2SiO_2)$. Within the last two decades, high-quality mullite, sillimanite ($x = 0$, $m/n = 1/1$, $Al_2O_3 \cdot SiO_2$), and other ceramics of the general mullite formula have been studied as advanced structural materials because of their desirable thermal and mechanical properties and high-temperature stability. The authors have made significant contributions to those studies, and their combined experience is well reflected in the quality of their book.

The subject is approached in a very systematic manner. In the six chapters following the introduction, the authors discuss crystal chemistry, phase equilibria, synthesis, processing, properties, and uses. Each chapter is essentially self-contained and may be read gainfully without prior knowledge of the other chapters.

The chapter on crystal chemistry discusses both the crystal structure and the microstructure of mullite. Subsection 2.1, "Real Crystal Structure of Mullite," which discusses the crystallography of mullite, was contributed by special guest writer S. H. Rahman. An unusual feature of this section is its attempt to understand and model the defects and imperfections that may be observed in the material's microstructure. The chapter continues with several sections that provide an extensive discussion of the role of impurities, particularly transition metal oxides, and how they are incorporated into the structure. The issue of solubility leads naturally into the next chapter on phase equilibria.

The two chapters on synthesis and processing form the heart of the book. While neither chapter is written in an expository format, both address the critical issues of methodologies and processing variables. Three synthesis routes for producing mullite powders are described under the general classifications of sinter-mullite (solid state reaction), fused-mullite (melt processing), and chemical-mullite (sol-gel, precipitation, hydrolysis, spray pyrolysis, and chemical vapor deposition). Especially noteworthy are the numerous descriptive models of the mechanisms of "mullitization" during the processing of the starting powders into polycrystalline mullite ceramics.

Thermal and mechanical properties are presented in the next-to-last chapter. As is usual for engineering ceramics, the primary emphasis is on the mechanical properties, *viz.*, elastic modulus, flexural strength, fracture toughness, hardness, and creep. The dependencies of strength and toughness on composition, of course, receive the most thorough review. As is also common for engineering ceramics, a more superficial discussion of the thermal properties is given, except for thermal expansion which can be derived from crystallography data.

The book concludes with a brief discussion of the industrial uses of mullite. The emphasis in this chapter is on the more advanced applications such as heat exchangers, electronic packaging, and windows for infrared and visible light transmission. In each case, the basis for using mullite in the subject area is discussed, and practical examples and illustrations are given.

The authors indicate that the purpose of their book is to present an overview of recent results on mullite. In doing so, they hope to provide a guide to future efforts and a basis for a better understanding of the material. I suspect, however, that this book will be viewed rather more as a significant reference on the chemistry and characterization of mullite than as a modest overview of the topic.

Design Against Fire: An Introduction to Fire Safety Engineering Design

Reviewed by Andrew J. Fowell, Chief, Fire Safety Engineering Division, National Institute of Standards and Technology, Gaithersburg, MD 20899.

REFERENCE: *Design Against Fire: An Introduction to Fire Safety Engineering Design*, P. Stollard and L. Johnston, Eds., E&FN Spon, Chapman and Hall, London, 1994, ISBN: 0-419-18170-9, 172 pp., $44.95.

This book is based on the keynote papers, prepared by leading fire scientists, engineers, and consultants in the United Kingdom, in a continuing professional development course in fire engineering held at the Queens University, Belfast. The course was designed to train architects, building control officers, and fire prevention officers, and is not intended for inexperienced students. The text is therefore a short introduction to fire safety, giving some of the principles of fire safety design. It is not a fire safety engineering handbook and does not provide fire safety engineering design calculation procedures.

The primary focus is on building fire safety requirements in Northern Ireland and the rest of the United Kingdom. Each of the authors of the papers is a well-known leader in the fire safety field. D. Drysdale, in his chapter introducing fire science, does a good job of presenting the basic concepts of fire safety, stressing the importance of prevention of ignition and prevention or delay of flashover. He also endorses modern thinking that fire test methods should be designed to reflect real-life scenarios and provide useful product performance information that can be used in fire safety engineering calculations. P. Stollard identifies the tactics and their components that are addressed in reaching the two primary fire safety objectives: life safety and property protection. L. Johnston

identifies architectural design features that can be used to address the threat of arson, the greatest cause of fire loss in the United Kingdom in the 1990s. J. Northley lists the various heat, smoke, and radiation flame detectors and points the reader to the parts of British Standard 5839 for installation requirements.

Recent research in escape behavior in fires is reviewed in some depth by J. Sime who makes a case for the use of this information in building design. He provides useful design examples of a nurses' residence hall fire, a department store fire, and the evacuations of a lecture theater and an underground station. He also provides an extensive bibliography of people movement and human behavior in fire situations. J. Abrahms briefly explains some principles for designing escape routes for buildings with special uses. The paper by H. L. Malhotra explains the principles of fire containment through separation and compartmentation. He describes the fire resistance requirements contained in the British regulations. H. Morgan summarizes the work performed at the Fire Research Station in the United Kingdom on smoke control in shopping malls and atria. The text surprisingly fails to mention *Design of Smoke Management Systems,* published by the American Society of Heating, Refrigeration and Air Conditioning Engineers and the Society of Fire Protection Engineers [*1*].

The final chapter provides useful lists of British and international standards, building regulations in the various parts of the United Kingdom, and fire consulting and advisory associates throughout the United Kingdom.

Reference

[*1*] Klote, J. H. and Milke, J. A., *Design of Smoke Management Systems,* ASHRAE, Atlanta, GA, 1992.

Composite Materials: Engineering and Science

Reviewed by Haig M. Vahradian, graduate assistant and doctoral candidate, Department of Industrial Technology, University of Northern Iowa, Cedar Falls, IA.

REFERENCE: Matthews, F. L. and Rawlings, R. D., *Composite Materials: Engineering and Sciences,* Chapman and Hall, London, 1994, ISBN: 0-412-55960-9, 470 pp., $105.95.

One of the major advances in materials technology is the introduction of composite materials as a mainstream alternative. This book focuses on the science and engineering fundamentals and performance characteristics of composite materials. It covers the production processes and reinforcement of metal, ceramic, and polymer matrix composites. The book concentrates primarily on polymer matrix composites because of their wide-ranging use in industry. A considerable portion of the book is dedicated to calculating statics and strengths of unidirectional composite laminates (complete with formulas). Also included are sections on fracture mechanics, toughening mechanisms, and environmental effects, making this book a fine reference for those working with composites. Regrettably, there is only limited coverage on methods of joining and nondestructive testing of composite materials.

Generally, *Composite Materials: Engineering and Science* is an excellent reference guide for engineers, technicians, and technologists interested in composite materials. It is well written and includes many informative illustrations, photos, tables, and electron micrograph scans. This book would serve as a superb text for upper-division undergraduate and graduate engineering or advanced materials students who are its target audiences.