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F. L. Riley
Frontmatter
More information

STRUCTURAL CERAMICS: FUNDAMENTALS AND CASE STUDIES

This book provides an introduction to the structural ceramics, their processing and properties. Five important groups of materials – porcelain, alumina, silicon carbide, silicon nitride and zirconia – are presented as case studies. Historical developments, the properties of constituent components, and relationships between production methods, resulting microstructures, and materials properties, are explained.

The structural ceramics have many commercial applications, ranging from high voltage insulation and fuel cells, to metal machining tools and surgical implants. These applications depend on combinations of chemical, physical and mechanical properties, which include structural stability over wide temperature ranges, strength, hardness, and resistance to wear.

Over 200 diagrams and photographs provide visual aids to learning, and end-of-chapter summaries pull together key points. With numerous review questions to test understanding of the topics covered, and extensive referencing, this book is ideal for those studying materials science and engineering, or starting research in the structural ceramics area.

FRANK RILEY was Professor of Ceramic Processing (and is now Emeritus Professor) at the University of Leeds where he researched and taught for over 30 years. He is a Fellow of the Institute of Materials, Minerals and Mining. He has directed two NATO Advanced Study Institutes, is editor of several conference proceedings, and has authored many research publications and review articles.

STRUCTURAL CERAMICS

Fundamentals and Case Studies

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Contents

Preface

The technical ceramics can be divided into *electroceramics*, which, by and large, make use of the materials' electrical or magnetic properties, and the *structural* ceramics, with applications mainly (though not entirely) dependent on mechanical properties. The structural ceramics providing the case studies for this book have been chosen because they illustrate well the characteristic features of the class of structural ceramics as a whole. They have a wide range of properties, and they are of considerable technical importance. The five studies are intended to introduce the reader to this large class of materials, and the rôle they play in today's world. Each of the materials (more precisely, groups of materials) is examined systematically to provide an outline of its history and a simple picture of its development, how it can be fabricated, details of key physical and mechanical properties, and a summary of the principal applications based on these properties.

Because all the ceramics reviewed here have very high melting points, components are normally made by processing powders. Some appreciation of this aspect of the subject will be helpful before any examination of individual materials takes place. Chapter 1 therefore introduces the fundamental features of the powder sintering route to a ceramic, and the development of microstructure. Ceramics have a reputation for brittleness and a rather marked tendency to break if dropped, though in fact the best of the structural ceramics can have strengths comparable with those of the high tensile steels. Aspects of strength, fracture toughness and the general properties of ceramic materials important for the engineer and designer are also introduced here. The following chapters then examine each of the five materials in turn to identify distinguishing features, and those properties which are common to the structural ceramics as a class of material.

The oldest of the structural ceramics, by several thousand years, are the various types of what is usually termed "pottery", originally used for storage of grain, oil, and wine. Development of rudimentary production processes gradually led to refinements in quality, particularly aesthetic appeal, and strength, resulting in the development of the translucent, but strong, materials generally called "porcelain", or "china". Industrial porcelain, a "traditional" ceramic, is reviewed in Chapter 2, and although it is not particularly strong it provides a very useful introduction to some of the important features of the structural ceramics, and a standard by which the property values of the others can be judged. The more modern, or "technical", high-strength ceramics are then examined in the following four chapters. These studies show how limits on a material's properties can be determined by the fundamental nature of the components of the material itself, and assess the extent to which it might be possible to vary the properties or obtain improvements. The alumina, silicon carbide, silicon nitride and zirconia groups of materials have been developed as high-grade structural ceramics only during the last 40 years or so (though their history is actually very much longer). Alumina, discussed in Chapter 3, is by far the most widely used, but silicon carbide discussed in Chapter 4, and silicon nitride in Chapter 5, also have very important and expanding application areas. Zirconia in Chapter 6 is in one way the odd one out, because its markets at present are very much smaller than those of the others. It is included because the zirconia group of materials provides some of the highest strength and toughness ceramics yet seen outside of the ceramic composites area. In this respect therefore zirconia materials might be considered to be the best of the structural ceramics, though, as will be seen, they are not completely perfect. Chapter 7 summarises these case studies, and provides an overview of the development of the five groups of material, and their present areas of application.

This book could not have been written without the stimulus and willing cooperation of a very large number of people, who freely made available illustrations, photographs and technical information. I am particularly indebted to John Bailey, Jake Beatson, John Briggs, Rik Brydson, Francis Cambier, Dusan Galušek, Gren Goldstraw, Christine Hahn, Harry Hodgson, Peter Johnson, Heiner Knoch, Brian Lines, Roger Morrell, Trevor Page, Susan Payne, Günter Petzow, Vladimir Sida, Lance Snead, and Chongmin Wang, for help with background information, photographic illustrations and original diagrams.

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