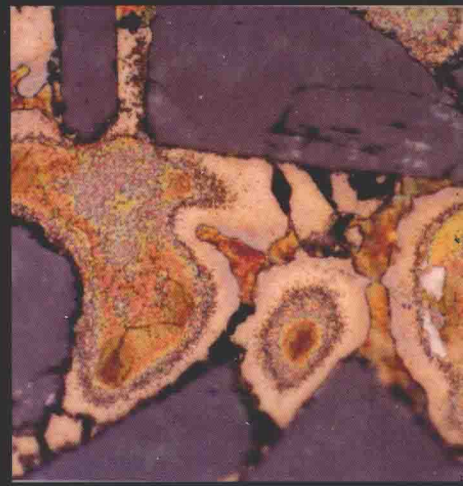
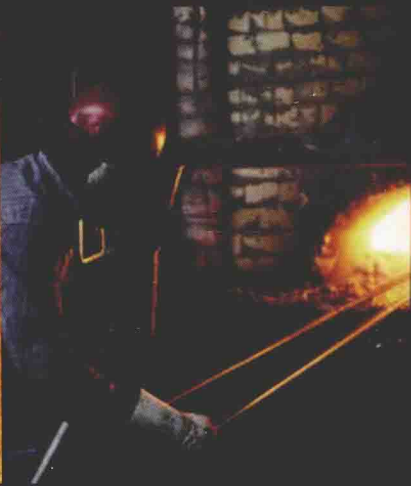


# MATERIALS SCIENCE *in* MANUFACTURING



RAJIV ASTHANA,  
ASHOK KUMAR *and* NARENDRA DAHOTRE



# Materials Processing and Manufacturing Science

Rajiv Asthana

Ashok Kumar

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Academic Press is an imprint of Elsevier



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30 Corporate Drive, Suite 400, Burlington, MA 01803, USA  
525 B Street, Suite 1900, San Diego, CA 92101-4495, USA  
84 Theobald's Road, London WC1X 8RR, UK

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**Library of Congress Cataloging-in-Publication Data: on file**

**British Library Cataloguing in Publication Data**

A catalogue record for this book is available from the British Library

ISBN 13: 978-0-7506-7716-5

ISBN 10: 0-7506-7716-3

For all information on all Academic Press publications  
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Printed in the United States of America  
05 06 07 08 09 10 9 8 7 6 5 4 3 2 1

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To our parents, spouses and children,  
and  
To students of materials processing everywhere.

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## Preface

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Competitive manufacturing relies on judicious selection of materials and processes to convert these materials into useful products, structures, and devices. Transforming materials into value-added products requires knowledge of manufacturing technology, processing science, and the material's response to external stimuli as it is coaxed to adopt the desired shape, structure, and other attributes.

This book focuses on the interrelationship among the “*structure and behavior of materials*” (materials science), the techniques of “*how to make things*” (manufacturing technology), and the “*theory of how things are made*” (processing science). It emphasizes a fundamental understanding of a range of processes used in manufacturing. This is important because diverse manufacturing techniques often exhibit an underlying commonality of process mechanics, the study of which aids premeditated design (as opposed to serendipitous development) of new techniques. Such understanding also aids in adapting current manufacturing practices to technological constraints imposed by the discovery of new materials.

In our assessment, most books that deal with the topics covered here tend to be either predominantly “vocational” or unabashedly “scientific.” They are written either for students majoring in the physics and chemistry of materials or for those training to become skilled craftspeople. Books that pursue a cross-disciplinary focus to processing usually become elementary surveys that sacrifice technical depth for greater breadth of coverage. Vocational books on manufacturing pay cursory attention to the process science knowledge base and at best view it as information that must be presented for the sake of completeness rather than as building blocks that are integral to the manufacturing enterprise. In contrast, most ‘science’-oriented books chiefly focus on the science of materials behavior and usually exclude any coverage of processing technology. The essential connectivity between materials science, processing science, and manufacturing technology is seldom emphasized.

The above is not to criticize the many eminently valuable books written to satisfy different objectives; such books have served and continue to serve students with varied academic backgrounds and career aspirations. This book is intended to fill a niche at the interface of materials science, processing science, and manufacturing technology. Fundamental materials phenomena are pervasive and manifest themselves in manufacturing processes in ways that are usually difficult to capture and assimilate using the knowledge base and paradigms specific to a single discipline. We believe that cultivating a mental orientation and habits of thought that permit

integration of concepts, theories, techniques, and visions from a multiplicity of disciplines can be learned, taught, and profitably used in solving materials problems. This book had its genesis in this premise.

In the past, concerns have been raised about a lack of integration in technical curricula. A National Academies Report\* states, "...*The area of synthesis and processing has suffered neglect in our universities and industry. A particularly compelling need is to provide undergraduates with a thorough grounding in the science and engineering of processing and its relation to manufacturing ... New courses and textbooks are needed at both the undergraduate and graduate levels ... These textbooks should also explicitly address the complementary approaches of physics, chemistry and engineering.*"

The book provides a contextual background in the elements of processing science and manufacturing technology. It customizes the content for diverse material classes and manufacturing processes. It is intended to cater to the needs of students who possess a basic, college-level background in physics, chemistry, and math through elementary calculus. It should also serve as a resource for those pursuing advanced graduate studies and research but possessing limited background in materials processing. The book does not follow an evolutionary approach usually needed for establishing the foundation of an undergraduate course, but it should be useful for in-depth treatment of selected topics. Above all, we hope that the book shall kindle students' interest to pursue advanced independent study in materials processing.

The book covers an expanded range of materials and processes in greater depth than has been customary in materials processing books. Chapter 1 reviews the foundational topics in materials science and engineering. The discussion is elementary and is intended to be a brief refreshment. An excessively discursive treatment has been avoided; in fact, the discussion is occasionally rather dense because prior knowledge of the content is assumed. Chapter 2 covers the industrial casting techniques and fundamental concepts of solidification science. Concepts in advanced solidification processing such as single crystal growth and semi-solid forming are also covered. Chapter 3 introduces the ceramic forming and powder metallurgy techniques. Wherever feasible, the underlying process physics is quantitatively described. Chapter 4 presents the basic concepts and elementary theory of selected surface, subsurface, and interface phenomena important in materials processing. Chapter 5 introduces the theory and practice of coating and surface modification technologies with emphasis on laser surface engineering. Chapter 6 focuses on the role of processing in the structure and properties of engineered composites, chiefly metal-matrix composites, particularly the high-temperature Ni-base composites. Chapter 7 introduces the theory and practice of semiconductor processing, including integrated circuits, silicon wafer manufacture, crystal growth, thermal oxidation, ion implantation, and lithography. The final chapter, written in a somewhat different key, covers emerging nanomaterials and their processing; because of the highly dynamic nature of the field, this chapter is written as a research report summarizing the latest findings. Overall, the book's topical coverage is not intended to be comprehensive, and the reader will note glaring omissions (metal working, polymer processing, etc.). The book, however, includes emerging materials and processes that are scantily covered in most similar books.

The book evolved out of lectures given over a decade or more by each author on one or more topics covered in the book, although some material derives from the scholarly writings for the professional community and from the authors' own research activities. Overall, the book is an

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\* Materials Science & Engineering for the 1990s: *Maintaining Competitiveness in the Age of Materials*, The National Academies Press, 1989 (<http://books.nap.edu/books/0309039282/html>).



outcome of the authors' combined teaching and scholarly efforts of nearly thirty-five years at different institutions. We are thankful to students from various disciplines whose educational needs in materials processing served as the driving force for this book. We hope that the book shall facilitate learning by the current and future generations of students.

We owe special gratitude to Elsevier's Senior Editor Joel Stein, Associate Editor Shoshanna Grossman, Production Editor Matt Heidenry, and Project Manager Brandy Lilly for their valuable help and guidance in completing this book, their patience with our pace of writing, and their encouragement at every activation barrier. We wish to thank the University of Wisconsin–Stout, the University of South Florida, and the University of Tennessee–Knoxville for institutional support. We are most indebted to our families—spouses, children, and parents—for their support and for the personal sacrifices that were mandated by this scholarly undertaking.

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Ashok Kumar  
Narendra B. Dahotre

# Acknowledgments

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The authors gratefully acknowledge the permission of the following organizations and publishers to use copyrighted materials from the cited sources.

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*American Ceramic Society Bulletin*

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*J. American Chemical Soc.*

*Macromolecules*

*Nano Letters*

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EPMA Educational Aid

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*Industrial Heating*: Journal of Thermal Technology, Industrial Heating, Manor Oak One, Suite 450, 1910 Cochran Road, Pittsburgh, PA 15220

*Phillips Plastics Corporation*, Metal Injection Molding, 422 Technology Drive East, Menomonie, WI 54751

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*American Foundry Society, Schaumburg, IL*  
*American Institute of Physics, Melville, NY*  
*American Society for Materials (ASM International), Materials Park, OH*  
*Amsted Industries, Chicago, IL*  
*Applied Science Publishers, Ltd., Barking Essex, U.K.*  
*Cast Metals Institute, Schaumburg, IL*  
*Chemical Society of Japan, Tokyo, Japan*  
*Chapman and Hall, London, U.K.*  
*CRC Press, Boca Raton, FL*  
*Elsevier, Boston, MA*  
*European Powder Metallurgy Association (Shrewsbury, England)*  
*Foundry Research Institute, Krakow, Poland*  
*Howard Taylor Trust, Boston, MA*  
*Institute of Materials, London, U.K.*  
*Investment Casting Institute, Montvale, NJ*  
*John-Wiley, New York, NY*  
*Materials Research Society, Warrendale, PA*  
*McGraw-Hill, New York, NY*  
*Metal Powder Industries Federation, Princeton, NJ*  
*Modern Casting, Schaumburg, IL*  
*Mir Publishers, Moscow, Russia*  
*National Physical Laboratory, London, U.K.*  
*Nature Publishing Group, CCC, Danvers, MA*  
*North American Die Casting Association, Wheeling, IL*  
*Pearson Education, Inc., Upper Saddle River, NJ*  
*Penton Media Inc., Cleveland, OH*  
*Phillips Plastics Corporation, Menomonie, WI*  
*Pratt & Whitney, East Hartford, CT*  
*Royal Society of Chemistry, Cambridge, U.K.*  
*Springer, New York, NY*  
*Taylor Knowlton, Ames, IA*  
*The Minerals, Metals & Materials Society, Warrendale, PA*  
*United States Steel Corporation, Pittsburgh, PA*

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