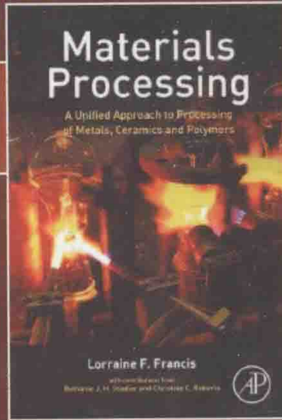
ELSEVIER

国际材料前沿丛书
International Materials Frontier Series



Lorraine F. Francis

金属、陶瓷和聚合物的加工方法

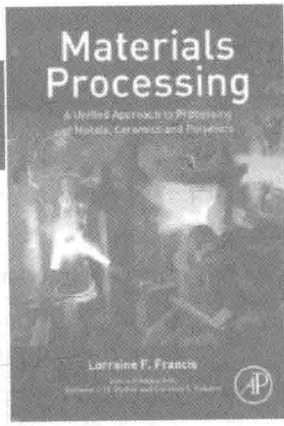
Materials Processing: A Unified Approach to Processing of Metals, Ceramics and Polymers

影印版

中南大學出版社
www.csupress.com.cn

ELSEVIER

国际材料前沿丛书
International Materials Frontier Series



Lorraine F. Francis

金属、陶瓷和聚合物的加工方法

Materials Processing: A Unified Approach to Processing of Metals, Ceramics and Polymers

影印版

中南大學出版社
www.csupress.com.cn
·长 沙·

图书在版编目(CIP)数据

金属、陶瓷和聚合物的加工方法：英文／(美)洛兰·弗朗西斯(Lorraine F. Francis)著. --长沙：中南大学出版社，2017.9

ISBN 978-7-5487-3019-4

Ⅰ.①金… Ⅱ.①洛… Ⅲ.①金属加工—英文 ②陶瓷—生产工艺—英文 ③聚合物—加工—英文 Ⅳ.①TG ②TQ174.6 ③TQ31

中国版本图书馆 CIP 数据核字(2017)第 239001 号

金属、陶瓷和聚合物的加工方法

JINSHU、TAOCI HE JUHEWU DE JIAGONG FANGFA

Lorraine F. Francis 著

□责任编辑 胡 炜
□责任印制 易建国
□出版发行 中南大学出版社
社址：长沙市麓山南路 邮编：410083
发行科电话：0731-88876770 传真：0731-88710482
□印 装 湖南众鑫印务有限公司

□开 本 720×1000 1/16 □印张 39.25 □字数 1017 千字
□版 次 2017 年 9 月第 1 版 □2017 年 9 月第 1 次印刷
□书 号 ISBN 978-7-5487-3019-4
□定 价 186.00 元

Materials Processing

A Unified Approach to Processing of Metals, Ceramics and Polymers

Lorraine F. Francis
University of Minnesota

With contributions from

Bethanie J. H. Stadler
University of Minnesota

Christine C. Roberts
Sandia National Labs

ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Academic Press is an imprint of Elsevier

AP

图字:18 -2017 -164 号

Materials Processing: A Unified Approach to Processing of Metals, Ceramics and Polymers
Lorraine F. Francis
ISBN: 9780123851321

Elsevier (Singapore) Pte Ltd.
3 Killiney Road
#08 -01 Winsland House I
Singapore 239519
Tel: (65) 6349 -0200
Fax: (65) 6733 -1817
First Published <2017>
<2017>年初版

内容简介

本书主要介绍金属、陶瓷和聚合物三种材料加工的基本原理，着重探讨加工的基本概念及其在典型工艺中的应用，主要内容包括材料加工概述、原材料、熔融加工固态法、粉末法、分散体与溶液法、气相法等。

本书采用的统一分类法是基于新形状形成时的物质状态。这种分类法有助于探究和应用先前已有的知识，帮助建立加工工艺和物质结构之间的联系。

本书可供材料、冶金等领域的科研人员、工程技术人员使用，同时也可作为高等院校材料、冶金等相关专业学生的参考书。

作者简介

Lorraine F. Francis 博士，美国明尼苏达大学教授，在明尼苏达大学任教25余年。主要研究方向是涂层、陶瓷和复合材料的材料科学与加工，研究重点是材料的加工及其微观结构的控制。1985年获得美国阿尔弗雷德大学纽约州立陶瓷学院的学士学位，1987年获得美国伊利诺伊大学厄巴纳－香槟分校陶瓷专业的硕士学位，1990年获得美国伊利诺伊大学厄巴纳－香槟分校陶瓷专业的博士学位。

序

材料加工是材料科学与工程领域的4个关键构成要素之一。材料的成形方式对其结构(即晶体结构、相、微观组织)相当重要，从而对其性能与服役表现相当重要。例如，冷变形工艺(如轧制)提高位错密度，从而提高金属的屈服强度。反之亦然，材料的结构与性能决定其用某种方法加工的难易程度。例如，典型的聚合物熔体黏度过高，不适宜用重力驱动流动的成形操作(如熔体铸造)，但非常适宜用压力驱动流动的成形操作(如挤压和注射成型)。加工－结构－性能的相互关系广泛存在于各种工程材料中。加工对决定最终产品的价格起重要作用，对材料选择和设计至关重要。因此，研究材料的加工自然而然地是为了弄懂结构－性能关系，是材料选择与设计的重要组成部分。

本书介绍材料加工的基本原理，广泛涉及材料科学与工程的基本原理及具体工艺细节。其目的当然并非涵盖所有的细节，而是探讨基本概念及说明其在典型工艺中的应用。这些典型工艺包括传统工艺(如金属的砂型铸造)和新型的加成工艺(如熔融沉积工艺，即3D打印)。本书涉及用于3类主要工程材料(即金属、陶瓷和聚合物)的加工基本原理。本书采用的统一分类法是基于新形状形成时的物质状态。例如，关于“熔体法”的章节探讨金属流动与凝固的基本方面及其在金属熔体铸造和聚合物注射成型中的应用。这种分类法有助于探究和应用先前已有的知识。

本书可供材料科学与工程及相关领域的本科生使用。完成了材料科学与工程专业的入门课程，以及微积分、物理学和化学课程的学生，便具备了学习本书所需的背景知识。例如，只要具备了上述必备知识，本书可直接用作大学一年级或二年级学生的课程教学，或者用作高年级学生的“旗舰”课程。研究生和实习工程师也可通过本书扩展其知识基础，增进其对基本概念的理解。

本书正文分为7章。第1章介绍材料加工涉及的领域，概述金属、陶瓷和聚合物的加工。第2章探讨用于加工的原材料的制备、成形和表征。其余5章分别介绍不同的加工工艺，根据最终

形状的材料性质可分为：熔体法、固体法、粉末法、分散体或溶液法以及气相法。重要的加工后处理操作（例如烧结）已融入各节中。每章包括材料科学与工程基本原理和工艺。工艺部分包括工艺描述、建模分析方法和实例。每章（除第1章外）以参考文献、习题和问题结束。

Materials Processing

A Unified Approach to Processing of Metals, Ceramics and Polymers

Academic Press is an imprint of Elsevier
125, London Wall, EC2Y 5AS.
525 B Street, Suite 1800, San Diego, CA 92101-4495, USA
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, USA
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

ISBN: 978-0-12-385132-1

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress.

For Information on all Academic Press publications
visit our website at http://store.elsevier.com/

Dedicated to Mark and Carolyn

Preface

Materials processing is recognized as one of the four key components of the field of Materials Science and Engineering (MSE). How a material is made into its final form has great importance to a material's structure (i.e., crystal structure, phases, microstructure) and therefore to its properties and performance. For example, cold deformation processes, such as rolling, increase the dislocation density and hence the yield strength of metals. The reverse is also true: a material's structure and properties determine its ability (or inability) to be processed easily by a given method. For example, the viscosity of a typical polymer melt is too high for forming operations involving gravity-driven flow, such as melt casting, but is well suited for processes involving pressure-driven flow, such as extrusion and injection molding. Processing-structure-property interrelationships abound in all types of engineering materials. Processing also plays a significant part in determining the cost of the final item, and is central to materials selection and design. Hence, the study of materials processing builds naturally from a base understanding of structure-property relationships and is an essential component of materials selection and design.

This book introduces the fundamentals of materials processing. The area is broad both in the scientific and engineering principles and in the details involved in the practical processes. The intent here is not to cover all the details, but to explore fundamental concepts and show their application in example processes. The examples range from traditional processes, such as sand casting of metals, to newer additive processes, such as fused deposition modeling (i.e., 3D printing). The book covers processing fundamentals that apply to the three main classes of engineering materials: metals, ceramics, and polymers. The unified approach used here considers processes in categories according to their state of matter as the new shape is formed. For example, the chapter on "melt processes" explores the fundamentals aspects of melt flow and solidification and applies them to processes such as metal melt casting and polymer injection molding. This approach lends itself to exploration and application of prior knowledge.

The book is intended for undergraduates in MSE and related fields. Students who have completed an introductory materials science and engineering course, as well as calculus, physics, and chemistry courses have the background needed for this book. For example, the book could be used in a course offered in the junior or even the sophomore year directly after these prerequisites are completed, or in a course for seniors as a capstone. Graduate students and practicing engineers may also find this book useful to broaden their knowledge base and add to their understanding of fundamental concepts.

There are seven chapters in this text. The first chapter introduces the field of materials processing and provides an overview of the processing of metals, ceramics, and polymers. The second chapter deals with the preparation, formulation, and characterization of the starting materials for processing. The remaining chapters are devoted to different processing routes. These routes are grouped by the nature of the material as the final form is created: melt, solid, powder, dispersion or solution, and vapor. Important post-processing operations, such as sintering, are integrated into these chapters. Each chapter includes sections dealing with scientific and engineering fundamentals, followed by sections on the processes, including descriptions, analytical approaches to process modeling and worked examples. Each chapter ends with a bibliography, review questions, and problems.

Acknowledgements

This book is the culmination of over 12 years of effort on and off. I would like to first thank God for providing strength and inspiration. There are many people to thank and acknowledge. I would like to thank my colleagues in the Department of Chemical Engineering and Materials Science at the University of Minnesota for encouraging the development of a course in materials processing (MatS 4301) and for supporting this book. I am especially grateful to Frank Bates, who was Department Head during the time when this book was initiated and most of it written, for his support and encouragement, and to Dan Frisbie, the current Department Head, for his support during the final push to finish. Thanks to all the students and teaching assistants in MatS 4301 for their questions and suggestions over the years. Their input has shaped and improved the text immensely; I am grateful for the opportunity to teach such wonderful students! Thanks to Chris Macosko, who taught MatS 4301 with me during its first offering, for his encouragement and valuable input on polymer processing. I would also like to acknowledge the late L. E. "Skip" Scriven, who taught me to think broadly about process fundamentals through our years of collaborating on coating processes. I am grateful to Beth Stadler for writing the chapter on vapor processes and Christine Roberts for her contributions to the chapter on dispersions and solution processes. Their expertise and contributions strengthened the book considerably and it was wonderful to work with them. Thanks also to Penn State University and Gary Messing for hosting a semester stay during the sabbatical that launched the project and for discussions about processing. I would like to acknowledge the L. E. Scriven Chair and the Taylor Professor Fund for support of my educational activities. Thanks to Tiffany Smith, Carolyn Francis, Tho Kieu, David Fischer, Connie Dong, Phil Jensen and Jacquelyn Hoseth for assistance with figures, references, and proof reading. Thanks also to Eray Aydil, Frank Bates, Marcio Carvalho, Xiang Cheng, Yuyang Du, Vivian Ferry, Bill Gerberich, Cindie Giummarra, Russ Holmes, Satish Kumar, Efie Kokkoli, Robert Lade, Chris Macosko, Ankit Mahajan, Sue Mantell, Michael Manno, Ashok Mennon, Alon McCormick, Luke Rodgers, Jeff Schott, Wieslaw Suszynski, Yan Wu, and Jenny Zhu for commenting on various sections and chapters of the book and providing information. Thanks to Steve Merken, Jeff Freeland, and Christina Gifford of Elsevier Publishing as well as Kiruthika Govindaraju and the Elsevier book production team for their patience and assistance. Lastly, very special thanks to family, especially my husband, Mark, and daughter, Carolyn, for their love and support.

Lorraine F. Francis
June 2015

目　录