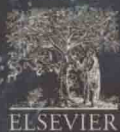


DOMINICK V ROSATO,
DONALD V ROSATO
& MATTHEW V ROSATO

Plastic Product Material & Process Selection Handbook



Plastic Product Material and Process Selection Handbook

江苏工业学院图书馆
藏书章

Dominick V. Rosato
Donald V. Rosato and
Matthew V. Rosato



UK Elsevier Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK
USA Elsevier Inc, 360 Park Avenue South, New York, NY 10010-1710, USA
JAPAN Elsevier Japan, Tsunashima Building Annex, 3-20-12 Yushima, Bunkyo-ku, Tokyo 113, Japan

© 2004 Elsevier Ltd.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic tape, mechanical, photocopying, recording or otherwise, without permission in writing from the publishers.

British Library Cataloguing in Publication Data

Rosato, Dominick V.

Plastic product material and process selection handbook

1. Plastics – Handbooks, manuals, etc.

I. Title II. Rosato, Donald V. (Donald Vincent), 1947–
668.4

ISBN 1 85617 431 X

Library of Congress Cataloging-in-Publication Data

Rosato, Dominick V.

Plastic product material and process selection handbook / Dominick Rosato, Donald Rosato
& Matthew Rosato.

p. cm.

Includes bibliographical references and index.

ISBN 1-85617-431-X

1. Plastics -- Handbooks, manuals, etc. 2. Engineering Design--Handbooks, manuals, etc.

I. Rosato, Donald V. II. Title

TA455.P5R65 2004

668/4--dc22

2004040457

No responsibility is assumed by the Publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein.

Published by

Elsevier Advanced Technology,

The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

Tel: +44(0) 1865 843000

Fax: +44(0) 1865 843971

Typeset by Land & Unwin (Data Sciences) Ltd, Bugbrooke

Printed and bound in Great Britain by Biddles Ltd, Guildford and King's Lynn

Preface, acknowledgement

This book is for people involved or to be involved in working with plastic material and plastic fabricating processes that include those concerned or in departments of material, processing, design, quality control, management, and buyers. The information and data in this book are provided as a comparative guide to help in understanding the performance of plastics and in making the decisions that must be made when developing a logical approach to fabricating plastic products to meet performance requirements at the lowest costs. Information and data can also be used when compromises have to be made in evaluating plastics and processes. The book is formatted to allow for easy reader access and this care has been translated into the individual chapter constructions and index.

This book has been prepared with the awareness that its usefulness will depend on its simplicity and its ability to provide essential information.

The information and data presented in this book are not intended to be used as a substitute for more up-to-date and accurate information on the specific plastics and processes. Such specific details can be obtained from in-house sources, testing laboratories, computer databases, material suppliers, data/information sources, consultants, and various institutions. References in this book represent examples for additional sources of plastics and processes.

This book was written to serve as a useful reference source for people new to plastics as well as providing an update for those with experience. It highlights basic plastic materials and processes that can be used in designing and fabricating plastic products. As with designing any material and/or using any process for plastic, steel, aluminum, wood, ceramic, and so on, it is important to know their behaviors in order to maximize product performance-to-cost efficiency. This book provides

information on the behaviors and processing of the different plastics and primary fabricating equipment including upstream and downstream auxiliary equipment. The information is interrelated between chapters so it is best to review more than one chapter to maximize your understanding the behavior of plastic materials and processes.

Designing to meet product performance and cost depends on being able to analyze the many diverse plastics and processes already existing. One important reason for this approach is that it provides a means to enhance the users' skills. It calls for the ability to recognize situations in which certain plastics and processing techniques may be used and eliminate potential problems.

Problems that are reviewed in this book should not occur. As explained they can be eliminated so that they do not effect the product performance when qualified people understand that the problems can exist. They are presented to reduce or eliminate costly pitfalls resulting in poor product performances or failures. With the potential problems or failures reviewed there are solutions presented. These failure/solution reviews will enhance the intuitive skills of those people who are already working in plastics. Cross-referencing of many pertinent behavior patterns is included so one will better understand the advantages and limitations that can develop with improper approaches.

Products reviewed range from toys to medical devices to cars to boats to underwater devices to containers to springs to pipes to buildings to aircraft to spacecraft and so on. The reader's product to be designed and/or fabricated can directly or indirectly be related to plastic materials, fabricating processes, and/or product design reviews in the book.

This book makes very clear the behavior of the 35,000 different plastics with the different behaviors of the hundreds of processes. It concentrates on the important plastics and processes used to fabricate products. The result is a complete logical approach to designing that involves the proper use of materials and fabricating processes.

Information contained and condensed in this book has been collected from many sources. Included is the extensive information assembled from worldwide personal experience, industrial, and teaching experiences of the two authors totaling over a century. Use was also made of worldwide information from industry (personal contacts, material and equipment suppliers, conferences, books, articles, etc.) and major trade associations. For someone to collect this information would require the person having familiarity in the many facets involved in the plastic industry worldwide.

The information contained in this book is not available on the Internet. The Internet contains an extensive amount of useful and important information that can be used but it is reviewed under many different subjects. However it does not contain all the information in this book.

Patents or trademarks may cover information presented. No authorization to utilize these patents or trademarks is given or implied; they are discussed for information purposes only. The use of general descriptive names, proprietary names, trade names, commercial designations, or the like does not in any way imply that they may be used freely.

While information presented represents useful information that can be studied or analyzed and is believed to be true and accurate, neither the authors nor the publisher can accept any legal responsibility for any errors, omissions, inaccuracies, or other factors. The authors and contributors have taken their best effort to represent the contents of this book correctly.

The Rosatos
2004

ACKNOWLEDGEMENT

Special and useful contributions in preparing practically all the figures and tables in this book were provided by David P. DiMattia. David is an experienced graphics art director specializing in marketing, product promotion, advertising, and public relations.

About the authors

Dominick V. Rosato

Since 1939 has been involved worldwide principally with plastics from designing-through-fabricating-through-marketing products from toys-through-commercial electronic devices-to-aerospace and space products worldwide. Experience includes Air Force Materials Laboratory (Head Plastics R&D), Raymark (Chief Engineer), Ingersoll-Rand (International Marketing Manager), and worldwide lecturing. Past director of seminars and in-plant programs and adjunct professor at University Massachusetts Lowell, Rhode Island School of Design, and the Open University (UK). Has received various prestigious awards from USA and international associations, societies (SPE Fellows, etc.), publications, companies, and National Academy of Science (materials advisory board). He is a member of the Plastics Hall of Fame. Received American Society of Mechanical Engineers recognition for advanced engineering design with plastics. Senior member of the Institute of Electrical and Electronics Engineers. Licensed professional engineer of Massachusetts. Involved in the first all plastics airplane (1944/RP sandwich structure). Worked with thousands of plastics plants worldwide, prepared over 2,000 technical and marketing papers, articles, and presentations and has published 25 books with major contributions in over 45 other books. Received BS in Mechanical Engineering from Drexel University with continuing education at Yale, Ohio State, and University of Pennsylvania.

Donald V. Rosato

Has extensive technical and marketing plastic industry business experience from laboratory, testing, through production to marketing, having worked for Northrop Grumman, Owens-Illinois, DuPont/

Conoco, Hoechst Celanese, and Borg Warner/G.E. Plastics. He has written extensively, developed numerous patents within the polymer related industries, is a participating member of many trade and industry groups, and currently is involved in these areas with PlastiSource, Inc., and Plastics FALLO. Received BS in Chemistry from Boston College, MBA at Northeastern University, M.S. Plastics Engineering from University of Massachusetts Lowell (Lowell Technological Institute), and Ph.D. Business Administration at University of California, Berkeley.

Matthew V. Rosato

Has a strong, Marine Corps influenced, skill set in information technology and software application areas, which has been helpful in constantly updating and keeping current the numerous plastic material and process selection reviews in this book. He is presently a bachelors candidate at Ohio State University, and is involved in technical marketing projects with Plastics Fallo.

Contents

<i>List of Figures</i>	xix
<i>List of Tables</i>	xxvi
<i>Preface, Acknowledgement</i>	xxix
<i>About the Authors</i>	xxxiii
Chapter 1 INTRODUCTION	1
Overview	1
Classifying plastic	3
Thermoplastic: crystalline or amorphous	4
Liquid crystalline polymer	7
Thermoset	7
Crosslinked plastic	8
Property and behavior	8
Molecular structure/property/process	10
Viscosity: Newtonian and Non-Newtonian	11
Rheology and viscoelasticity	12
Processing and thermal interface	13
Compounding and alloying	15
Introduction to property	16
Plastic behavior	17
Thermal behavior	17
Residence time	17
Plastic memory	25
Thermal conductivity	26
Specific heat	27
Thermal diffusivity	27
Coefficient of linear thermal expansion	27
Temperature index	28
Corrosion resistance	29
Chemical resistance	29

Fire property	30
Steel and plastic	30
Permeability	30
Radiation	31
Craze/crack	31
Drying plastic	31
Variable	34
Advantage and limitation	36
FALLO approach	37
Chapter 2 PLASTIC PROPERTY	40
Overview	40
Plastic performance	44
Thermoplastic	45
Polyolefin	45
Polyethylene	46
Linear polyethylene	48
Low density polyethylene	49
Ultra low density polyethylene	50
Linear low density polyethylene	51
High density polyethylene	51
Ultra high molecular weight polyethylene	52
Crosslinked polyethylene	52
Polyethylene wax	52
Chlorinated polyethylene elastomer	53
Polymethylpentene	53
Polyolefin elastomer	53
Polyolefin thermoplastic elastomer	54
Ethylene-propylene elastomer	54
Polypropylene	54
Polybutylene	55
Cyclic polybutylene terephthalate	56
Vinyl	56
Polyvinyl chloride	57
Ultra high molecular weight polyvinyl chloride	60
Polyvinyl acetate	60
Polyvinyl chloride acetate	61
Polyvinyl chloride, chlorinated	61
Polyvinyl alcohol	61
Polyvinyl butyral	62
Polyvinyl carbazole	62
Polyvinyl pyridine	62
Polyvinyl pyrrolidone	62

Polyvinylfluoride	62
Polyvinyl formal	62
Polyvinylidene chloride	62
Polyvinylidene fluoride	63
Polystyrene	63
Polystyrene copolymer	64
Polystyrene, expandable	64
Polystyrene maleic anhydride	64
Crystal clear polystyrene	64
Flame retardant polystyrene	65
Polystyrene film, heat-sealable	65
High gloss polystyrene	65
High impact polystyrene	65
Syndiotactic polystyrene	66
Polystyrene-acrylonitrile	66
Polystyrene-polyethylene blend	66
Polystyrene-polyphenylene ether blend	66
Advanced styrenic	66
Styrene-butadiene	67
Polyalphamethylstyrene	67
Acetal	67
Acrylic	67
Acrylic elastomer	68
Polymethacrylic acid	68
Polymethylacrylate	68
Polyethylmethacrylate	68
Polyglutarimide acrylic copolymer	68
Acrylonitrile	69
Acrylonitrile-butadiene rubber	69
Acrylonitrile-butadiene-styrene	69
Acrylonitrile-butadiene-styrene, transparent	70
Acrylonitrile-chlorinated polyethylene-styrene copolymer	70
Acrylonitrile-ethylene/propylene-styrene copolymer	70
Acrylonitrile-ethylene-styrene	70
Acrylonitrile-methylmethacrylate	71
Acrylonitrile-styrene	71
Acrylonitrile-styrene-acrylate	71
Polymethacrylonitrile	71
Polyvinylcyanide	71
Cellulosic	72
Chlorinated polyether	72

Ethylene-vinyl acetate	72
Ethylene-vinyl alcohol	72
Fluoroelastomer	73
Fluoroplastic	73
Polytetrafluoroethylene	74
Polychlorotrifluoroethylene	75
Polyhexafluoropropylene	76
Polyvinyl fluoride	76
Polyvinylidene fluoride	76
Fluorinated ethylene propylene	76
Chlorofluorohydrocarbon	76
Polyfluoroalkoxyphosphazene	77
Ionomer	77
Nylon (polyamide)	77
Parylene	79
Phoenix	79
Polyallomer	80
Polyamide	80
Polyamide-imide	80
Polyarylate	81
Polyaryletherketone	81
Polyarylsulfone	82
Polybutylene terephthalate	82
Polycarbonate	83
Polycyclohexylenedimethylene terephthalate	85
Polyelectrolyte	85
Polyester, thermoplastic	85
Polyester reinforced urethane	85
Polyester water-soluble	85
Polyetherketone	86
Polyetheretherketone	86
Polyether, chlorinated	87
Polyetherimide	87
Polyethylene naphthalate	88
Polyethylene terephthalate	88
Polyethylene terephthalate glycol	89
Polyhydroxybutyrate	89
Polyimidazole	90
Polyimide	90
Polyimide powder	91
Polyesterimide	91
Polyketone	92
Polyetheretherketone	92

Polyetheretherketoneketone	92
Poly lactide	92
Polyorganophosphazene	93
Polyoxymethylene	93
Polyparamethylstyrene	93
Polyperfluoroalkoxy	93
Polyphenylene ether	93
Polyphenylene oxide	94
Polyphenylene sulfide	95
Polyphosphazene	95
Polyphthalamide	95
Polysulfone	96
Polyethersulfone	97
Polyphenyl sulfone	97
Polyphenylethersulfone	98
Polyphthalamide	98
Polysaccharide	98
Polyterpene	98
Polythiophene	98
Polyurethane, thermoplastic	98
Polyurethane elastomer	99
Polyurethane isoplast	99
Polyurethane virtually crosslinked	100
Thermoset plastic	100
Alkyd	100
Allyl	100
Amino	101
Chlorosulfonated polyethylene elastomer	101
Crosslinked polyethylene	101
Diallyl phthalate	104
Epoxy	104
Epoxy vinyl ester	104
Fluorosilicone elastomer	104
Melamine formaldehyde	105
Neoprene	105
Phenol-formaldehyde	105
Polybenzimidazole	106
Polybenzobisoxazole	107
Polybutadiene	107
Polychloroprene	107
Polydicyclopentadiene	107
Polyester, thermoset	107
Polyester, water-soluble	109

Polyimidazopyrrolone	109
Polyisobutylene butyl	110
Polyisoprene	110
Natural rubber and other elastomer	110
Polynorbornene	110
Polysulfide	111
Polyurethane, thermoset	111
Rubber, natural	112
Rubber latex, natural	112
Silicone	113
Silicone elastomer	113
Styrene-butadiene elastomer	114
Urea-formaldehyde	114
Elastomer	115
Reinforced plastic	118
Recycled plastic	118
Plastic selection	119
 Chapter 3 FABRICATING PRODUCT	 130
Overview	130
Processing and patience	140
Processor certification	141
Processing fundamental	142
Machines not alike	149
Plastic processing performance	149
Plastic memory	151
Orientation	151
Reinforced directional property	153
Plastic deformation	154
Coextrusion/coinjection: fabricating multilayer	154
Plasticator melting operation	156
Screw	156
Feeding problem	160
Screw/barrel bridging	161
Multi-stage screw	162
Drying via venting	163
Barrier screw	163
Screw tip	163
Purging	164
Barrel	166
Downsizing machine	166
Upsizing machine	167
Rebuilding vs. Buying	167

Repair	168
Tooling	168
Process control	168
Overview	168
Sensor	171
Pressure sensor	172
Temperature sensor	173
Fuzzy logic	175
Temperature controller	175
Processing window	176
Control and monitoring	178
Process controller	184
Control choice	184
Intelligent processing	186
Intelligent setting and control	186
Program analysis	188
Fuzzy logic	189
Troubleshooting	190
Prototyping model	190
Safety	191

Chapter 4	INJECTION MOLDING	192
	Introduction	192
	Molding system	195
	Clamping design	197
	Tiebar	198
	Machine control	199
	Machine startup/shutdown	200
	Maximizing processing window control	204
	Coinjection molding	208
	Coinjection foam low pressure molding	209
	Gas-assist molding	209
	Gas-assist without gas channel molding	210
	Gas counterflow molding	211
	Water-assist molding	211
	Injection-compression molding	212
	Two-shot molding/over-molding	213
	In-mold molding	213
	Insert molding	214
	Thin-wall molding	215
	Soluble core molding	215
	Continuous molding	216
	Tandem machine molding	216

	Micro-molding	216
	Monosandwich molding	220
	Double-daylight molding	220
	Foamed gas counter pressure molding	221
	High pressure foam molding	221
	Low pressure foam molding	221
	Liquid molding	222
	Counterflow molding	222
	Melt flow oscillation molding	222
	Screwless molding	223
	Non-plastic molding	223
	Magnesium molding	225
	Thixotropic molding	225
	Summary	226
Chapter 5	EXTRUSION	227
	Introduction	227
	Component	231
	Extruder type/performance	235
	Operation	238
	Startup	238
	Shutdown	242
	Film and sheet	243
	Film	244
	Blown film	244
	Flat film	247
	Sheet	249
	Pipe and tube	252
	Profile	254
	Coating	257
	Wire and cable	261
	Fiber	263
	Coextrusion	267
	Orientation	269
	Blown film	271
	Flat film	273
	Fiber	274
	Other process	274
	Postforming	274
	Compounding	275
	Reclamation/recycling	275

Chapter 6	BLOW MOLDING	282
	Introduction	282
	Blow molding process	284
	Extrusion vs. Injection blow molding	288
	Extrusion blow molding	288
	Parison head	290
	Machine design	293
	Injection blow molding	295
	Stretch blow molding	297
	Dip blow molding	300
	Multiblow blow molding	300
	Sequential extrusion	301
	Blow/fill/seal	302
	Blow molding 3-d	302
	Blow molding with rotation	302
	Mold	304
Chapter 7	THERMOFORMING	308
	Introduction	308
	Mold	317
	Processing	320
	Vacuum forming	321
	Pressure forming	321
	Vacuum-air pressure forming	322
	Blow forming	322
	Drape forming	322
	Drape-vacuum forming	322
	Drape-vacuum assist frame forming	322
	Drape with bubble stretching forming	322
	Snap-back	323
	Plug assist forming	323
	Plug assist and ring forming	324
	Ridge forming	324
	Bilow forming	324
	Bilow plug assist forming	324
	Bilow-up vacuum snap-back	324
	Bilow snap-back forming	325
	Air slip forming	325
	Air slip plug assist forming	325
	Blister package forming	325
	Draw forming	326
	Dip forming	326
	Form, fill, and seal	326