J A BRYDSON

PLASTICS MATERIALS

Sixth Edition

A GENUINE MILESTONE IN REFERENCE WORKS

British Plastics And Rubber

PLASTICS MATERIALS

SIXTH EDITION

J. A. Brydson

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BUTTERWORTH HEINEMANN

Butterworth-Heinemann Ltd
Linacre House, Jordan Hill, Oxford OX2 8DP

A member of the Reed Elsevier plc group

OXFORD LONDON BOSTON
MUNICH NEW DELHI SINGAPORE SYDNEY
TOKYO TORONTO WELLINGTON

First published by Iliffe Books Ltd 1966
Second edition 1969
Reprinted 1970
Third edition 1975
Reprinted with revisions 1977
Reprinted 1979
Fourth edition published by Butterworth-Heinemann 1982
Reprinted 1985
Fifth edition 1989
Reprinted 1991, 1993
Sixth edition 1995

British Library Cataloguing in Publication Data
Brydson, J. A.
Plastics Materials. – 6Rev. ed
I. Title
668.4

ISBN 0 7506 1864 7

Library of Congress Cataloguing in Publication Data
Brydson, J. A.
Plastics materials – J. A. Brydson. – 6th ed.
p. cm.
Includes bibliographical references and index.
ISBN 0 7506 1864 7 (pbk.)
1. Plastics. I. Title
TP1120.B7 1995
668.4—dc20 94-44833
CIP

Composition by Genesis Typesetting, Laser Quay, Rochester, Kent
Printed and bound in Great Britain by Hartnolls, Bodmin

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Preface to the Sixth Edition

When I began preparation of the first edition of this book world production of plastics materials was of the order of 9 million tonnes per annum, while today it is more than ten times that value. Furthermore, at that time polypropylene, the acetals, the polycarbonates and ABS were newly arrived on the scene. In the first chapter of that edition I made the point that the likelihood of discovering new important general purpose polymers was remote but that special purpose materials would continue to be introduced. Although I was frequently told that I was being too pessimistic (with respect to new general purpose polymers) this prediction has stood the test of time. One of my main aims with the first edition was to try and explain the properties of plastics materials in terms of their structure and morphology. Whilst there have been enormous developments in polymer science in the past 30 years I have not felt it necessary to make many changes to the basic principles enunciated in the first edition.

Many new speciality materials have, however, appeared and wherever possible I have tried to discuss these in the context of relating structure to properties. I have continued this process into this edition.

For the first time since the third edition I have added extra chapters. One covers three groups of polymers (thermoplastic elastomers, biodegradable plastics and electrically conductive polymers) which I felt should be discussed as a group rather than as scattered sentences throughout the book. The second is an introduction to the subject of material selection. With hundreds of polymer species now on the market with, in some cases, hundreds of grades within a species, some attempt at rationalisation has been attempted. As a further aid to the reader I have also included after the preface, some lists of common abbreviations.

J. A. B
Brent Eleigh
Suffolk, 1995

Preface to the First Edition

There are at the present time many thousands of grades of commercial plastics materials offered for sale throughout the world. Only rarely are the properties of any two of these grades identical, for although the number of chemically distinct species (e.g. polyethylenes, polystyrenes) is limited, there are many variations within each group. Such variations can arise through differences in molecular structure, differences in physical form, the presence of impurities and also in the nature and amount of additives which may have been incorporated into the base polymer. One of the aims of this book is to show how the many different materials arise, to discuss their properties and to show how these properties can to a large extent be explained by consideration of the composition of a plastics material and in particular the molecular structure of the base polymer employed.

After a brief historical review in Chapter 1 the following five chapters provide a short summary of the general methods of preparation of plastics materials and follow on by showing how properties are related to chemical structure. These particular chapters are largely qualitative in nature and are aimed not so much at the theoretical physical chemist but rather at the polymer technologist and the organic chemist who will require this knowledge in the practice of polymer and compound formulation.

Subsequent chapters deal with individual classes of plastics. In each case a review is given of the preparation, structure and properties of the material. In order to prevent the book from becoming too large I have omitted detailed discussion of processing techniques. Instead, with each major class of material an indication is given of the main processing characteristics. The applications of the various materials are considered in the light of the merits and the demerits of the material.

The title of the book requires that a definition of plastics materials be given. This is however very difficult. For the purpose of this book I eventually used as a working definition 'Those materials which are considered to be plastics materials by common acceptance'. Not a positive definition but one which is probably less capable of being criticised than any other definition I have seen. Perhaps a rather more useful definition but one which requires clarification is

'Plastics materials are processable compositions based on macromolecules'. In most cases (certainly with all synthetic materials) the macromolecules are polymers, large molecules made by the joining together of many smaller ones. Such a definition does however include rubbers, surface coatings, fibres and glasses and these, largely for historical reasons, are not generally regarded as plastics. While we may arbitrarily exclude the above four classes of material the borderlines remain undefined. How should we classify the flexible polyurethane foams—as rubbers or as plastics? What about nylon tennis racquet filament?—or polyethylene dip coatings? Without being tied by definition I have for convenience included such materials in this book but have given only brief mention to coatings, fibres and glasses generally. The rubbers I have treated as rather a special case considering them as plastics materials that show reversible high elasticity. For this reason I have briefly reviewed the range of elastomeric materials commercially available.

I hope that this book will prove to be of value to technical staff who are involved in the development and use of plastics materials and who wish to obtain a broader picture of those products than they could normally obtain in their everyday work. Problems that are encountered in technical work can generally be classified into three groups; problems which have already been solved elsewhere, problems whose solutions are suggested by a knowledge of the way in which similar problems have been tackled elsewhere and finally completely novel problems. In practice most industrial problems fall into the first two categories so that the technologist who has a good background knowledge to his subject and who knows where to look for details of original work has an enhanced value to industry. It is hoped that in a small way the text of this book will help to provide some of the background knowledge required and that the references, particularly to more detailed monographs, given at the end of each chapter will provide signposts along the pathways of the ever thickening jungle of technical literature.

1965 J. A. B.

Acknowledgements for the Sixth Edition

The information provided in this volume is a distillation of the work of very many scientists, technologists, engineers, economists and journalists without which this book could not have existed.

For this edition I would, however, specifically like to thank Susan Davey, Librarian of the University of North London, and her colleague Matthew Hepburn, Tony Whelan, the Editorial Staff of *Plastics and Rubber Weekly* and the following companies for providing information: Arco Chemical, Bayer, Du Pont, Elf Atochem, Exxon, General Electric, Phillips Petroleum, RAPRA Technology, Rhône–Poulenc and Zeneca.

In addition I should acknowledge that I have drawn heavily from the journals *Kunstoffe, Kunstoffe Plast Europe, Modern Plastics International* and *Plastics and Rubber Weekly* for data on production and consumption statistics.

My thanks also go to the publishers Butterworth-Heinemann and particularly Sharon Cooper for their tolerance and considerable help.

Finally and most importantly I must express my thanks to Wendy, my wife, who has had to endure me writing editions of this volume at intervals for much of our married life.

Abbreviations for Plastics and Rubbers

Many abbreviations for plastics materials are in common use. Some of these have now been incorporated into national and international standards, including:

ISO 1043 (1978) Plastics–Symbols.

BS 3502 Common Names and Abbreviations for Plastics and Rubbers.
Part 1 Principal commercial plastics (1978).
(The 1978 revision was carried out in accordance with IS 1043 although the latter also deals with compounding ingredients.)

ASTM D 1600–83 Abbreviations of terms relating to plastics.

DIN 7728
Part 1 (1978) Symbols for terms relating to homopolymers, copolymers and polymer compounds.
Part 2 (1980) Symbols for reinforced plastics.

In *Table 1*, drawn up by the author, of abbreviations in common use those in **bold** type are in the main schedule of BS 3502. In this list the names given for the materials are the *commonly used scientific names*. This situation is further complicated by the adoption of a nomenclature by the International Union of Pure and Applied Chemistry for systematic names and a yet further nomenclature by the Association for Science Education which is widely used in British schools but not in industry. Some examples of these are given in *Table 2*. Because many rubbery materials have been referred to in this book, *Tables 3* and *4* list abbreviations for these materials.

Table 1 Common abbreviations for plastics

Abbreviation	*Material*	*Common name*
ABS	Acrylonitrile–butadiene–styrene polymer	ABS
ACS	Acrylonitrile–styrene and chlorinated polyethylene	
AES	Acrylonitrile–styrene and ethylene–propylene rubber	
ASA	Acrylonitrile–styrene and acrylic rubber	
CA	Cellulose acetate	Acetate
CAB	Cellulose acetate–butyrate	CAB, butyrate
CAP	Cellulose acetate–propionate	CAP
CN	Cellulose nitrate	Celluloid
CP	Cellulose propionate	CP, propionate
CPVC	Chlorinated polyvinyl chloride	
CTA	Cellulose triacetate	Triacetate
CS	Casein	Casein
DMC		Dough moulding compound (usually polyester)
EAA	Ethylene–acrylic acid	
EEA	Ethylene–ethyl acrylate	
EP	Epoxide resin	Epoxy
ETFE	Tetrafluoroethylene–ethylene copolymer	
EVAC	Ethylene–vinyl acetate	EVA
EVOH, EVAL, EVOL		Ethylene–vinyl alcohol
FEP	Tetrafluoroethylene–hexafluoropropylene copolymer	
FRP, FRTP	Thermoplastic material reinforced, commonly with fibre	
GRP	Glass-fibre reinforced plastic based on a thermosetting resin	
HDPE	High-density polyethylene	
HIPS	High-impact polystyrene	
LDPE	Low-density polyethylene	
LLDPE	Linear low-density polyethylene	
MBS	Methacrylate–butadiene styrene	
MDPE	Medium-density polyethylene	
MF	Melamine–formaldehyde	Melamine
PA	Polyamide	Nylon (some types)
PAI	Polyamideimide	
PBTP, PBT, PTMT	Polybutylene terephthalate	Polyester
PC	Polycarbonate	Polycarbonate
PETP, PET	Polyethylene terephthalate	Polyester
PCT	Poly-(1,4-cyclohexylenediaminemethylene terephthalate)	
PCTFE	Polychlorotrifluoroethylene	
PE	Polyethylene	Polythene
PEBA	Polyether block amide	
PEEK	Polyether ether ketone	

Table 1 Continued

Abbreviation	*Material*	*Common name*
PEEKK	Polyether ether ketone ketone	
PEG	Polyethylene glycol	
PEI	Polyetherimide	
PEK	Polyether ketone	
PES	Polyether sulphone	
PETP, PET	Polyethylene terephthalate	Polyester
PF	Phenol–formaldehyde	Phenolic
PFA	Tetrafluoroethylene–perfluoroalkyl (usually propyl) vinyl ether copolymers	
PI	Polyimide	
PIB	Polyisobutylene	
PMMA, PMM	Polymethyl methacrylate	Acrylic
PMMI	Polymethylmethacrylimide	
POM	Polyacetal, polyoxymethylene, polyformaldehyde	Acetal
PP	Polypropylene	Propylene, polyprop
PPG	Polypropylene glycol	
PPO	Polyphenylene oxide	
PPO	Polypropylene oxide	
PPS	Polypropylene sulphide	
PS	Polystyrene	Styrene
PS, PSU		Polysulphone
PTFE	Polytetrafluoroethylene	PTFE
PUR	Polyurethane	Polyurethane, urethane
PVA	Polyvinyl acetate	
PVA	Polyvinyl alcohol	
PVA	Polyvinyl acetal	
PVAC	Polyvinyl acetate	PVA
PVB	Polyvinyl butyral	
PVC	Polyvinyl chloride	PVC, vinyl
PVDC	Polyvinylidene chloride	
PVDF	Polyvinylidene fluoride	
PVF	Polyvinyl fluoride	
PVF	Polyvinyl formal	
PVP	Polyvinyl pyrrolidone	
P4MP1	Poly-4-methyl pentene-1	
RF	Resorcinol–formaldehyde	
SAN	Styrene–acrylonitrile	SAN
SI	Polysiloxane	Silicone
SMA	Styrene–maleic anhydride	
SMC		Sheet moulding compound (usually polyester)
TPS	Toughened polystyrene	
UF	Urea–formaldehyde	Urea
UP	Unsaturated polyester	Polyester
UPVC	Unplasticised PVC	
VLDPE	Very low density polyethylene	
XPS	Expanded polystyrene	

The Commission on Macromolecular Nomenclature of the International Union of Pure and Applied Chemistry has published a nomenclature for single-strand organic polymers (*Pure and Applied Chemistry*, **48**, 375 (1976)). In addition the Association for Science Education in the UK has made recommendations based on a more general IUPAC terminology, and these have been widely used in British schools. Some examples of this nomenclature compared with normal usage are given in *Table 2*.

Table 2

Normal usage	ASE	IUPAC
Polyethylene	Poly(ethene)	Poly(methylene)
Polypropylene	Poly(propene)	Poly(propylene)
Polystyrene	Poly(phenyl ethene)	Poly(1-phenyl ethylene)
Polyvinyl chloride	Poly(chloroethene)	Poly(1-chloroethylene)
Polymethyl methacrylate	Poly(methyl 2-methyl propenoate)	Poly[1-(methoxycarbonyl)-1-methyl ethylene]

In this book the policy has been to use *normal usage scientific terms*.

Table 3 Standard abbreviations for rubbery materials (based on ISO Recommendation and ASTM D 1418)

ABR	acrylate–butadiene rubber
ACM	copolymers of ethyl or other acrylates and a small amount of a monomer which facilitates vulcanization
ACSM	alkyl chlorosulphonated polyethylene
AECO	terpolymers of allyl glycidyl ether, ethylene oxide and epichlorohydrin
AEM	copolymers of ethyl or other acrylate and ethylene
AFMU	terpolymer of tetrafluoroethylene, trifluoronitrosomethane and nitrosoperfluorobutyric acid
ANM	copolymers of ethyl or other acrylate and acrylonitrile
AU	polyester urethanes
BIIR	bromo-isobutene–isoprene rubber (brominated butyl rubber)
BR	butadiene rubber
CFM	rubber with chlorotrifluoroethylene units in chain
CIIR	chloro-isobutene–isoprene rubber (chlorinated butyl rubber)
CM	chlorinated polyethylene
CO	epichlorhydrin rubber
CR	chloroprene rubber
CSM	chlorosulphonated polyethylene
ECO	ethylene oxide and epichlorhydrin copolymer
EAM	ethylene–vinyl acetate copolymer
EPDM	terpolymer of ethylene, propylene and a diene with the residual unsaturated portion of the diene in the side chain
EPM	ethylene–propylene copolymer
EU	polyether urethanes
FFKM	perfluororubbers of the polymethylene type, having all substituent groups on the polymer chain either fluoroperfluoroalkyl or perfluoroalkoxy
FKM	fluororubber of the polymethylene type, having substituent fluoro and perfluoroalkoxy groups on the main chain
FVMQ	silicone rubber having fluorine, vinyl and methyl substituent groups on the polymer chain
FZ	polyphosphazene with fluorinated side groups
GPO	polypropylene oxide rubbers

Table 3 Continued

IIR	isobutene–isoprene rubber (butyl rubber)
IM	polyisobutene
IR	isoprene rubber (synthetic)
MQ	silicone rubbers having only methyl substituent groups on the polymer chain
NBR	nitrile–butadiene rubber (nitrile rubber)
NIR	nitrile–isoprene rubber
NR	natural rubber
PBR	pyridine–butadiene rubber
PMQ	silicone rubbers having both methyl and phenyl groups on the polymer chain
PNR	polynorbornene rubber
PSBR	pyridine–styrene–butadiene rubber
PVMQ	silicone rubbers having methyl, phenyl and vinyl substituent groups on the polymer chain
PZ	polyphosphazene with phenolic side chains
Q	rubbers having silicon in the polymer chain
SBR	styrene–butadiene rubber
T	rubbers having sulphur in the polymer chain (excluding copolymers based on CR)
VMQ	silicone rubber having both methyl and vinyl substituent groups in the polymer chain
XNBR	carboxylic–nitrile butadiene rubber (carboxynitrile rubber)
XSBR	carboxylic–styrene butadiene rubber
Y	prefix indicating thermoplastic rubber
YBPO	thermoplastic block polyether–polyester rubbers

In addition to the nomenclature based on ISO and ASTM recommendations several other abbreviations are widely used. Those most likely to be encountered are shown in *Table 4*.

Table 4 Miscellaneous abbreviations used for rubbery materials

ENR	epoxidized natural rubber
EPR	ethylene–propylene rubbers (either EPM or EPDM)
EVA	ethylene–vinyl acetate copolymers (instead of EAM)
EVM	ethylene–vinyl acetate rubber (instead of EAM or EVA)
HNBR	hydrogenated nitrile rubber
PEBA	thermoplastic polyamide rubber, polyether block amide
SBS	styrene–butadiene–styrene triblock copolymer
SEBS	hydrogenated SBS
SIR	Standard Indonesian rubber
SIS	styrene–isoprene–styrene triblock copolymer
SMR	Standard Malaysian rubber
TOR	polyoctenamer
TPO	thermoplastic polyolefin rubber
TPU	thermoplastic polyurethane rubber

During the World War II the United States Government introduced the following system of nomenclature which continued in use, at least partially, until the 1950s and is used in many publications of the period.

GR-A	Government Rubber—Acrylonitrile	(modern equivalent NBR)
GR-I	Government Rubber—Isobutylene	(IIR)
GR-M	Government Rubber—Monovinyl acetylene	(CR)
GR-P	Government Rubber—Polysulphide	(T)
GR-S	Government Rubber—Styrene	(SBR)

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