



THIRD EDITION

PLASTICS FILMS

JOHN · H · BRISTON

LONGMAN SCIENTIFIC & TECHNICAL IN ASSOCIATION
WITH THE PLASTICS AND RUBBER INSTITUTE.

Plastics Films

Third edition

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in association with
The Plastics and Rubber Institute

Longman Scientific & Technical
Longman Group UK Limited
Longman House, Burnt Mill, Harlow
Essex CM20 2JE, England
and Associated Companies throughout the world.

Copublished in the United States with
John Wiley & Sons Inc., 605 Third Avenue, New York, NY 10158

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First published in 1974 by Iliffe Books, an imprint of the Butterworth Group
Second edition 1983 by George Godwin
Reprinted by Longman Scientific & Technical 1986, 1987
Third edition 1989
Reprinted 1990

British Library Cataloguing in Publication Data

Briston, J. H. (John Herbert)
Plastics films.—3rd ed.
1. Plastics films
I. Title II. Katan, L. L. (Leonard L.)
668.4'95

ISBN 0-582-01490-5

Library of Congress Cataloging in Publication Data

Briston, J. H. (John Herbert)
Plastics films/J. H. Briston: with two chapters by L. L. Katan. —
— 3rd ed.
p. cm.
Includes bibliographies and index.
ISBN 0-470-21149-0 (Wiley)
1. Plastic films. I. Katan, Leonard L. II. Plastics and Rubber
Institute. III. Title.
TP1183.F5B74 1989
668.4'95--dc19

Produced by Longman Singapore Publishers (Pte) Ltd.
Printed in Singapore

Plastics Films

Preface to the Second Edition

Since the first edition of this book there have been many advances in the field of plastics films. There is also a greater awareness of the socio-economic consequences of the use of plastics films, particularly in packaging.

The unified approach of the original book seemed to meet with general approval so this has been retained but a great deal of new material has been added to keep it up-to-date and to deal with some of the issues now being raised by governments and consumer groups. Three new chapters have been added, for example, covering Choice Criteria, Plastics and Energy, and Degradability, Recycle and Re-use. In addition, the two chapters on Health Safety and Odour and Taint, have been largely re-written. In terms of Odour and Taint there have been remarkable strides in the assessment of organoleptic effects. There have also been some developments in the science of Health Safety but the main changes have been in legislation, particularly on the subject of monomers. This emphasis on monomers arose from the vinyl chloride monomer storm that blew up during the two editions of this book.

New material has also been added on the more recent plastics (including linear low density polyethylene, polyvinylidene fluoride, parylene and acrylonitrile/methyl acrylate copolymer), stretch wrapping, and the ultra-violet and infra-red drying of printing inks.

The sections on extrusion and calendering have been expanded and summaries have been added to the chapters on Properties in order to emphasise the importance of the various properties on the packaging operation and the end-use performance of the film.

As in the first edition the needs of students in both the plastics and the packaging industry have been kept clearly in mind but the book should also be valuable to the converter and user of plastics films.

Preface to the Third Edition

This edition has been extensively revised and updated in order to take account of advances in materials and conversion processes. The section on vacuum and gas packaging, for example has been expanded to include work on controlled/modified atmosphere packaging while the chapter on thermoforming has also been expanded and rewritten, with extra sections on control of wall thickness, automatic operation and solid phase pressure forming.

The chapter on health safety has been completely rewritten. The theory and the legislative aspects have both been updated, while new aspects include microwave cooking, irradiation and modified atmosphere packaging. The chapter on organolepsis has been extensively updated, particularly on newer techniques involving computers.

Finally, a new section has been appended on additives for plastics films in order to give a technological background to complement the health safety factors of additives.

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1

Introduction

Although the title of this book is 'Plastics Films' the subject of regenerated cellulose film has also been included because of its historical and present day importance. Regenerated cellulose is not a 'plastic' because at no stage in its manufacture is it capable of being moulded to shape. However, as a film it has a great deal in common with plastics films and it acts as an excellent reference point when properties and applications of plastics films are discussed.

The borderline between film and sheet may also need some clarification. There appears to be no hard and fast rule, but a convenient and widely accepted definition is that film comprises material up to $250\text{ }\mu\text{m}$ (0.010 in) in thickness whereas thicknesses above that figure refer to sheet. Some people tend to look on rigid material as sheet and flexible material as film but this is not so satisfactory as a practical definition. Materials such as unplasticised PVC and cellulose nitrate are fairly rigid even at thicknesses down to $70\text{ or }80\text{ }\mu\text{m}$ (around 0.003 in), whereas low-density polyethylene is not really rigid even at thicknesses around $300\text{ }\mu\text{m}$ (0.012 in).

The subject of plastics film is already vast and is still growing rapidly so that a great deal of selection and condensation has been necessary to keep the subject within the bounds of this volume. Its aim has been to provide as full a background as possible to the student of plastics so that he may be in a position to consult the extensive literature on the subject. It is also intended to be a guide to the user or prospective user of plastics films, and to the worker in other fields of polymer technology.

1.1 HISTORICAL BACKGROUND

The first commercially successful plastics film was cellulose nitrate. It had some excellent properties, such as clarity, strength, resistance to moisture and dimensional stability but it also had one serious drawback, namely, flammability. As a film it has now been displaced by newer materials although as a sheet it still has at least one large application, namely, table tennis balls.

The most important development in films was the production of regenerated cellulose. The first process for dissolving cellulose and subsequently regenerating it was discovered by Schweitzer and formed the basis of his cuprammonium rayon fibre process. Cuprammonium films have also been made but are not so important commercially as those made by the Xanthate process. This was discovered in 1892 by three English chemists, Cross, Bevan and Beadle. A method for coagulation and regeneration of xanthated cellulose was patented by Stearn in 1898 and small commercial quantities of film were produced by John Chorley in Manchester a year later. However, the person chiefly responsible for the commercial development of equipment for the continuous production of cellulose film was J. E. Brandenberger, a Swiss chemist, and patents were first issued to him in 1911.

First applications for regenerated cellulose film were as decorative wrappings for luxury or semi-luxury goods. The development of heat sealable and moisture-proof grades (by means of coatings) meant that the film could be used as a protective wrapper and from then on its growth rate increased by leaps and bounds.

Cellulose acetate film was developed first, in 1909, as a 'safety' photographic film because of the dangers attached to the use of cellulose nitrate. Since then it has developed as a wrapping film where 'breathability' is required (as in fresh produce packaging), in print lamination for the covers of journals, maps, etc., and in the manufacture of window cartons.

Of the films so far mentioned, regenerated cellulose was the almost unchallenged leader up to about 1950 since cellulose acetate was too expensive for the large tonnage packaging uses. The first film to challenge the supremacy of cellulose film was polyethylene but other, more recent, films such as polypropylene, PVC and polyethylene terephthalate have also either eroded cellulose film's markets or developed new ones of their own.

A calendered grade of polyethylene mixed with polyisobutylene was produced as early as World War II and was used for the packaging of Mepacrine tablets for the Services. In 1946, an

extrusion process was developed, followed by a chill roll casting method in 1948. The latter had a better gloss and transparency than the extruded grades then available but was unsuitable for bag making purposes because of a serious tendency to block. A year later, a blown tubular film was made available which could be converted into bags although its clarity was poor by today's standards. Initial applications were mainly confined to industrial packaging, such as covers for equipment packed inside wooden crates, the packaging of electrical resistors and as drum liners. The development of prepackaging for fresh produce gave a boost to the use of polyethylene film because of its combination of transparency and high strength. When, eventually, high clarity grades of polyethylene film were developed, new markets opened up in the fields of display packaging such as textiles, woollens, soft toys and similar items. During this time, polymer costs were steadily falling and eventually polyethylene film became the cheapest transparent film available. Today, one of the largest tonnage outlets for polyethylene film is the heavy duty sack for fertilisers, peat, polymer granules and various chemicals. The strength of polyethylene is exemplified by the fact that a sack for 50 kg (1 cwt) of fertiliser has a thickness of only 200 μm (0.008 in).

Although it has many advantages, low-density polyethylene film is limp compared with regenerated cellulose film and special machinery had to be developed before it could be used for high-speed packaging. A more challenging competitor to regenerated cellulose was polypropylene with its good clarity and stiffness as well as good barrier properties. This film was introduced around 1959.

Other plastics films have made their debut since then but none of them has had the impact of polypropylene, mainly because of their high price relative to polypropylene. However, many have established their own special niche in the market place by virtue of some special property or other. The importance of plastics films today can be seen from the *Table 1.1* which gives consumption figures for some of the main films in the U.K. in 1979.

Up to the beginning of the 1970s the story of plastics films was one of steadily reducing prices, leading to a gradual replacement of more traditional packaging materials such as paper. Since 1973 the continuing heavy increases in oil prices have sharply reversed the downward spiral of polymer prices and have greatly reduced the rate of increase in plastics consumption. The growth of plastics films has not been halted completely, however, because there are valid technical reasons, in addition to economic ones, for using them in a wide variety of applications. When considered from a performance

Table 1.1

<i>Film</i>	<i>Consumption (tonnes)</i>
Low-density polyethylene	300 000*
High-density polyethylene	22 000
Polypropylene	34 000†
PVC	40 000
Regenerated cellulose	47 000

* includes heavy duty sacks (65 000 tonnes).

† includes film tape used for woven sacks (9000 tonnes).

point of view plastics are still competitively priced in relation to other materials.

1.2 SOCIO-ECONOMIC CONSIDERATIONS

Reference has already been made to the economics of plastics films but there is also a socio-economic consideration which is becoming more important as time goes on. This is the use of energy in manufacturing processes. More strictly this should be looked at in terms of a total energy equation involving the energy used to produce the article to be packaged, the possible percentage loss if the product was sold in the unpackaged state and the energy used to produce the particular protective package. Such equations tend to show that in most cases the energy used in producing the packaging material is fully justified. In addition, the energy used in producing a plastics film bag or wrap is an order of magnitude less than that of a glass container (first use), a tinplate can or an aluminium container (to package an equivalent weight of foodstuff). As an example of the justification for packaging, 1 kg (2.2 lb) of potato crisps is estimated to consume 10 MJ (0.095 therms) of energy in its manufacture. Coated, oriented polypropylene bags, or bags made of coated cellulose film (to contain 1 kg—2.2 lb of crisps), would probably consume only about 0.3 to 0.35 MJ (0.003 to 0.0035 therms). The spoilage of unpackaged crisps would be 100% within a very short space of time and thus the packaging is fully justified. The energy consumption for a glass bottle (also able to hold 1 kg—2.2 lb of foodstuff) would be nearer 9 MJ (0.085 therms) on initial manufacture but this drops to about 0.5 MJ (0.005 therms) for subsequent reuse (reflecting the energy used in washing).

Another factor which has a bearing on economics is availability. Most plastics are derived from oil and, as this is a non-renewable resource, prices must obviously rise as the resources dwindle.

However, not all plastics are derived from oil. Cellulose (from trees and other plant life) forms the starting point for a range of plastics including regenerated cellulose and cellulose acetate films. Attention is also being directed increasingly towards a wide range of renewable resources including seaweed, sewer waste, field crops, etc. One important monomer—ethanol—can be derived, via the fermentation of sugars, from plant juices, cellulose and starch, while methanol (an important source of formaldehyde) can be obtained from agricultural residues or from municipal solid waste. Sugar itself has also been investigated as a feedstock for plastics. Economics is still a major barrier but this will change as the non-renewable sources become even more scarce.

It should not be forgotten that oil is not the only non-renewable resource available for plastics manufacture. Coal was widely used once and may well be again, so giving more time to develop renewable resources.

1.3 LEGISLATION

A large percentage of plastics films is used in packaging and this means that plastics films are widely affected by an increasing amount of legislation. One aspect of legislation is dealt with in Chapter 11 but there is also increasing pressure from consumer groups and governments concerning the impact of packaging on the environment. In the E.E.C., the Environment and Consumer Protection Service has set up a Packaging Working Group. This has already shown a very anti-packaging bias and although its initial attention has been concentrated on the use of returnable and one-trip containers for beverages it will probably move to other areas of packaging (including films) in due course. In the U.K. a Waste Management Advisory Council (WMAC) was set up in 1974 and went on to form a Packaging and Containers Working Group. WMAC was disbanded late in 1980 but not before the Working Group had produced an excellent report on returnable and non-returnable beverage containers. In order to present a coherent reply from industry to the growing criticism, leading U.K. packaging manufacturers, producers of packaged goods and retail organisations formed the Industry Committee for Packaging and the Environment (INCPEN) in 1974. Later, in 1976, the Waste Management Advisory Council indicated to INCPEN that, to avoid legislation, industry should consider producing a draft code of practice for packaging. INCPEN eventually produced a draft U.K. Code which was then discussed with the CBI, various consumer and

environmentalist organisations, Pira (Research Organisation for the Paper, Printing and Packaging Industries) and observers from various government departments. The final Packaging Code was published in May 1978. The Code has eight points, the last of which reads: 'The package should be designed with due regard to its possible effect on the environment, its ultimate disposal and to possible recycling and reuse where appropriate.' The operation of the Code is supervised by the Packaging Council which includes members representing manufacturers of packaging, packers of consumer goods, distributors, consumer organisations, environmentalists and trade unions, meeting under an independent chairman.

Some of the main factors concerned with the packaging film/environment interface are discussed in Chapter 25.