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Plastics Packaging

Properties, Processing, Applications, and Regulations

2nd Edition

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The Authors:
Professor Dr. Susan E.M. Selke, Michigan State Universitiy, School of Packaging, East Lansing, MI 48824-1223, USA
John D. Culter, President Advanced Materials Engineering Inc., Napels, Fl 34114-9232, Silver Lake Blvd. 1231, USA
Professor Ruben J. Hernandez (†)

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In memory of

Ruben J. Hernandez
1945-2002

Professor
School of Packaging
Michigan State University

Preface

This book is intended to provide a basic understanding of plastic packaging materials. It covers the properties of common packaging plastics, and relates these properties to the chemical structure of the polymers. Common processing methods for transforming plastic resins into packages are covered.

In this book we discuss the uses of plastics in packaging. Although this is not a course in chemistry nor in material science, we attempt to stress the relationship between chemical structure and packaging material properties. We expect the reader to have some knowledge of chemistry and physics. The major purpose of this book is to provide the students in the School of Packaging with reading material on plastics for packaging; however, we hope that it can also be useful to packaging professionals responsible for writing specifications, designing, fabricating, testing, and controlling the quality of plastic materials. We also hope to trigger the reader's curiosity to pursue further studies in the exciting world of packaging materials.

This second edition fixes some of the errors that, despite our best efforts, found their way into the first edition. Unfortunately, we're sure that we have not yet found them all! We have also expanded and updated the discussion of PET bottle production, retort pouches, polylactides, plastics recycling, and a variety of other topics.

We have deliberately included some information that goes well beyond what would normally be included in an introductory level packaging course, in order that it will be available for the more advanced student and for the practitioner. In the first edition, we attempted to identify this material by putting it inside grey boxes. We have abandoned that convention in this edition for a variety of reasons, the most compelling being that instructors vary in what they choose to incorporate in an introductory course. We decided that it is better to leave it up to individual instructors to tell students what sections, or portions of sections, to omit in their study of this text.

Contents

1 Introduction

1.1 Historic Note

The first man-made plastic, a form of cellulose nitrate, was prepared in 1838 by A. Parker and shown at the Great International Exhibition in London in 1862. It was intended to be a replacement for natural materials such as ivory and was called parkesine. In 1840, Goodyear and Hancock developed the "vulcanization" procedure that eliminated tackiness and added elasticity to natural rubber. The change in the properties of the natural rubber was obtained by the addition of sulfur powder that produced additional chemical bonds in the bulk of the rubber.

In 1851, hard rubber, or ebonite, was commercialized. In 1870 a patent was issued to J. Hyatt, of New York, for celluloid, a type of cellulose nitrate with low nitrate content produced at high temperature and pressure. This was the first commercially available plastic, and the only one until the development of Bakelite by Baekeland in 1907. Bakelite is the oldest of the purely synthetic plastics and consisted of a resin obtained by the reaction of phenol and formaldehyde.

The exact nature of plastics, rubber, and similar natural materials was not known until 1920, when H. Staudinger proposed a revolutionary idea: all plastics, rubber, and materials such as cellulose were polymers, or macromolecules. Before Staudinger's theory, the scientific community was very confused about the exact nature of plastics, rubbers and other materials of very high molecular weight. To most research workers in the 19th century, the finding that some materials had a molecular weight in excess of 10,000 g/mol appeared to be untrustworthy. They confused such substances with colloidal systems consisting of stable suspensions of small molecules.

Staudinger rejected the idea that these substances were organic colloids. He hypothesized that the high molecular weight substances known as polymers were true macromolecules formed by covalent bonds. Staudinger's macromolecule theory stated that polymers consist of long chains in which the individual monomers (or building blocks) are connected with each other by normal covalent bonds. The unique polymer properties are a consequence of the high molecular weight and long chain nature of the macromolecule. While at first his hypothesis was not readily accepted by most scientists,