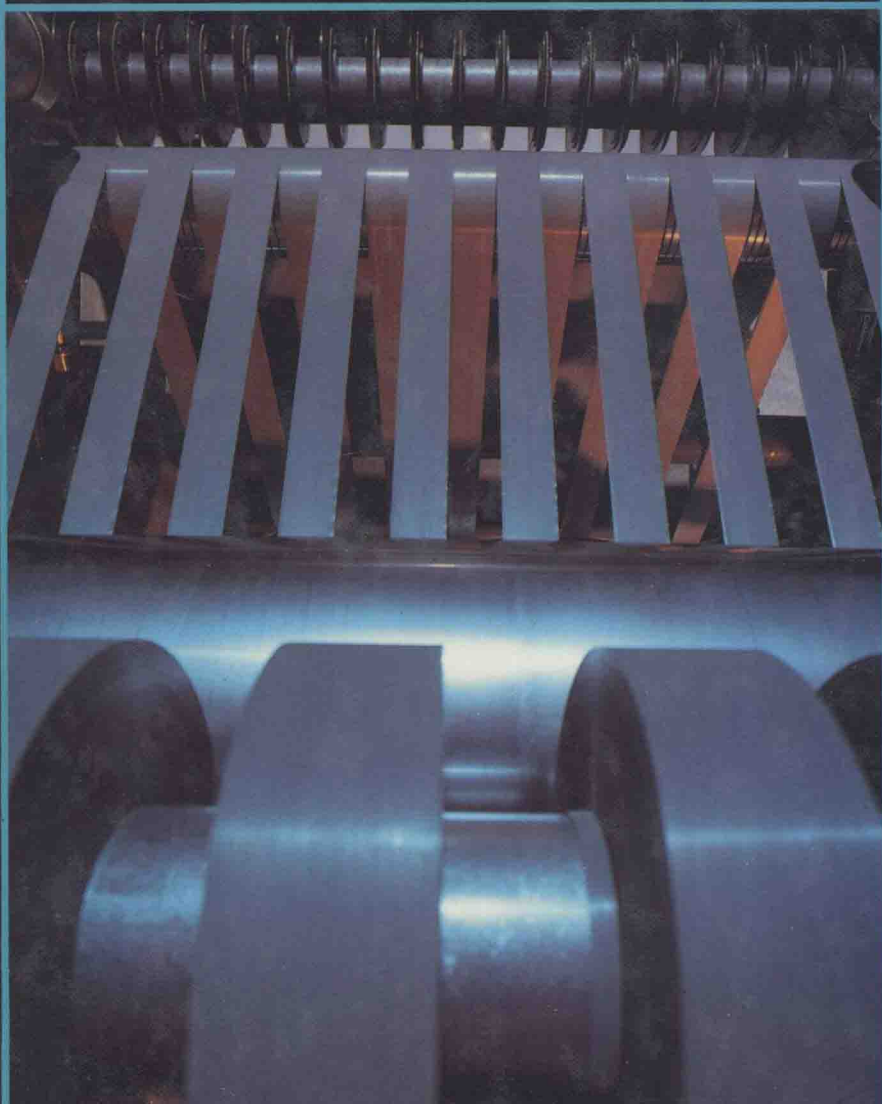


ENGINEERING POLYMER SOURCEBOOK

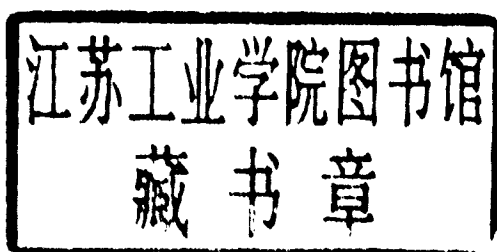
RAYMOND B. SEYMOUR



Engineering Polymer Sourcebook

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**Engineering
Polymer
Sourcebook**

Foreword

The advancement of polymers as materials of construction has been dependent, to a large extent, on the synthesis and modification of many different high-performance polymers which have been described in many outstanding books on this subject.

However, since many design engineers have not been trained in the field of polymer science and technology, their attempts to choose and use polymers are hampered by the absence of engineering-oriented polymer science reference books.

Fortunately, Professor Seymour has helped to fill this void by authoring this *Engineering Polymer Sourcebook*. I am impressed by the scope of the contents of this book and recommend it to those who are seeking more design information on these essential high-performance materials.

Herman F. Mark

Preface

Although they may not have been used for engineering applications, such as gears and structural members, many polymers used prior to World War II were low-grade engineering polymers. If we exclude strong, natural polymers, such as wood and cotton, the most noteworthy ancient derivative of natural polymers was leather, which has been called "the most historic of useful materials." The primitive techniques used several thousand years ago have been improved, but the modern tanning process is similar to that used by our ancestors a few millennia ago.

It has been recorded that bitumens, which were called slime, were used as caulking materials to waterproof Noah's Ark, Moses' basket, and ancient water tanks. These low-grade engineering applications may be overlooked today, but they were essential for survival of the inhabitants several thousand years ago.

Likewise, the vulcanization of rubber for the production of flexible and hard rubber and the plasticization (flexibilization) of cellulose nitrate for the production of moldable celluloid, cellulose nitrate coatings, and artificial fibers in the nineteenth century may not be considered engineering "break-throughs," but these products were essential for waterproofing textiles, protecting metal surfaces, providing molded articles, and for producing continuous filaments.

Some polymer technologists exclude thermosets in their list of engineering polymers. However, Glyptal, which was produced by the esterification of glycerol by phthalic anhydride, and Bakelite, which was produced by the reaction of phenol and formaldehyde, are thermosets which can definitely be classified as engineering polymers. Hence, both high-performance thermosets and high-performance thermoplastics will continue to have engineering applications and are discussed in this book.

Several good books, which emphasize the chemistry of engineering polymers, have been published. These are listed as references, and, of course, some chemistry is included in this book. However, the emphasis is on design, processing, fabrication, and application of these unique modern materials of construction.

Raymond B. Seymour

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About the Author

Raymond B. Seymour is Distinguished Professor of Polymer Science at the University of Southern Mississippi, and the 1989 winner of the prestigious International Award in Plastics given by the American Chemical Society, as well as numerous other awards and honors. He is a member of the American Chemical Society, Society of Plastics Engineers, Society of Coatings Technology, American Institute of Chemical Engineers, and a Fellow in the Texas, Tennessee, and Mississippi Academies of Science. Dr. Seymour has been awarded over 45 patents and over 100 foreign patents. He has published over 1500 technical articles in leading scientific journals and has 36 books published or in press.

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History of the Development of Engineering Polymers

1.1 Introduction—Scope

This book concerns engineering polymers, which may be thermoplastic or thermosetting polymers that maintain their dimensional stability and their major mechanical properties in the temperature range of 0 to 100°C.

Other criteria for engineering polymers include moldability and a good balance of mechanical properties which is maintained for a long time over a wide range of environmental conditions. These polymers, which may be natural or synthetic, are the counterparts of traditional engineering materials, such as metals and ceramics.

The term “engineering polymers,” which is interchangeable with the terms “high-performance polymers” and “engineering plastics,” is subject to a variety of other criteria and interpretations. The editorial steering committee of the American Society for Metals (ASM International) has defined the term “engineering plastics” as a synthetic polymer resin-based material that has load-bearing characteristics and high-performance properties which permit it to be used in the same manner as metals and ceramics. However, contrary to the ASM definition, some natural polymers are included in this book on engineering polymers. Engineering plastics have also been defined as plastics which lend themselves for use in engineering design, such as gears and structural members.

The major products produced by the polymer industry are general-purpose plastics, such as polyethylene, polypropylene, polyvinyl chloride, and polystyrene. Because of their relatively low strength and lack of re-

sistance to moderately high temperatures, these widely used plastics are not classified as engineering polymers. However, some copolymers of styrene do meet the criteria for low-grade engineering polymers.

1.2 Natural Polymers

High-performance polymers are not new. Nature has been generous in supplying us with abundant quantities of tropocollagen, which is the major component of skin, tendons, cartilage, bone, and teeth. Keratin, which is found in hooves, nails, and claws of animals, and in beaks of birds, and fibroin, which is the principal constituent of silk, have also served as moderately high performance polymers for thousands of years. Also, nucleoproteins, which are not defined as high-performance polymers, are essential for our very existence.

Wood, which is a composite of cellulose and lignin, is also a moderately high performance material. Fire, which ranks next to the wheel as humankind's most significant discovery, would have had little impact unless wood was available as fuel. A century ago, wood was still our major source of energy, and this renewable resource continues to be an important structural material.

There are very few other materials with the characteristic elasticity of natural rubber (NR; *Hevea brasiliensis*); hence, natural rubber should be classified as a high-performance polymer. Since many of today's high-performance polymers are blends, it is of interest to note that a blend of cis hevea rubber and trans gutta-percha plastic was patented and used as a cable coating in 1846. [The cis and trans prefixes describe the position of chain extensions on the ethylenic double bonds $-(CH=CHZ)-$ in polymeric dienes. Dienes contain two double bonds.]

1.3 Pre-World War I Polymers

Nelson Goodyear, a brother of Charles Goodyear, patented hard rubber (ebonite) in 1851. This pioneer inventor's manufactured thermoset was used for dental prosthetics, combs, and battery cases. (A thermosetting plastic is one that does not dissolve in solvents and is not softened when heated.) Cellulose nitrate, plasticized, i.e., flexibilized, by camphor, was the pioneer manufactured thermoplastic (Celluloid). It was patented by two brothers, I. S. and J. W. Hyatt, in 1870. (In contrast to the thermosets, thermoplastics are soluble in selected solvents and may be heated and cooled, reversibly, without decomposition.) Few of the early applications of cellulose nitrate were structural, but its subsequent use as an automotive lacquer (Duco) is a relatively high performance application.

Polyesters, which had potential as high-performance polymers,