International Fiber Science and Technology Series/1

Handbook of Fiber Science and Technology: Volume I

Chemical Processing of Fibers and Fabrics

Fundamentals and Preparation

Part B

edited by
Menachem Lewin
Stephen B. Sello

about the book . . .

Continuing the outstanding coverage from *Part A,* the authoritative information in *Fundamentals and Preparation, Part B* rounds out the first comprehensive treatise on chemical processing of textiles. A systematic, single-source treatment of key topics in the field, this state-of-the-art work introduces major savings in time and cost to your work with fibers and fabrics . . . provides a foundation for projecting future developments . . . and guides you to useful further study with helpful, current references.

As new advances expand the scope of this field, each volume of *Handbook of Fiber Science and Technology* becomes an indispensable acquisition for researchers. Textile, fiber, polymer, organic, physical, and biological chemists; textile finishers and chemical manufacturers; research and development personnel in the polymer, fiber, chemical, and textile industries; plastics and chemical engineers; materials scientists; and wood and paper technologists will find them essential references. They are eminent sources for supplementary reading in graduate and advanced undergraduate courses including polymer, fiber, and textile chemistry and technology; chemical processing of fibers; chemical engineering; and polymer processing.

about the editors . . .

MENACHEM LEWIN is Director of the Israel Fiber Institute, Jerusalem. He received the M.Sc. degree in chemistry (1944) and Ph.D. degree in physical chemistry (1947) from the Hebrew University, Jerusalem, Israel. Dr. Lewin has authored or coauthored over 400 publications or technical reports and holds 25 patents in numerous areas of chemistry—including fiber structure, cellulose, flame retardancy, and bleaching—and has edited or coedited several books in fiber science. He received the Habif Prize of the University of Geneva, Switzerland (1959) for cellulose research, and was elected Fellow of the International Academy of Wood Science (1972). Among his recent honors, he was Program Co-Chairman of the IUPAC Symposium on Colloid and Surface Chemistry held in Jerusalem (1981). Dr. Lewin serves on the editorial boards of a number of journals, including *Journal of Wood Chemistry and Technology* (Marcel Dekker, Inc.) and *Journal of Applied Polymer Science.* He is also editor-in-chief of the *International Fiber Science and Technology* series (Marcel Dekker, Inc.).

STEPHEN B. SELLO is Manager of Finishing and Exploratory Chemistry at the J. P. Stevens & Co., Inc. Technical Center, Greenville, South Carolina. He received the Ph.D. degree in organic chemistry (1947) from Peter Pazmany University of Sciences, Budapest, Hungary. Dr. Sello has had a major role in such developments in textile science as washable wool, stretch wool, novel flame retardants, and no-iron 100% cotton fabrics. He has authored over 75 publications and holds 22 U.S. patents in textile chemistry. Dr. Sello is a member of the American Association of Textile Chemists and Colorists (AATCC), American Chemical Society, Fiber Society, and New York Academy of Sciences, and serves on the editorial board of *Polymer News.* He received the 1982 Olney Medal from AATCC. Dr. Sello is coeditor of *Handbook of Fiber Science and Technology,* Parts A and B (with Menachem Lewin, Marcel Dekker, Inc.).

Printed in the United States of America ISBN: 0–8247–7117–6

marcel dekker, inc./new york · basel

about the book . . .

Continuing the outstanding coverage from *Part A,* the authoritative information in *Fundamentals and Preparation, Part B* rounds out the first comprehensive treatise on chemical processing of textiles. A systematic, single-source treatment of key topics in the field, this state-of-the-art work introduces major savings in time and cost to your work with fibers and fabrics . . . provides a foundation for projecting future developments . . . and guides you to useful further study with helpful, current references.

As new advances expand the scope of this field, each volume of *Handbook of Fiber Science and Technology* becomes an indispensable acquisition for researchers. Textile, fiber, polymer, organic, physical, and biological chemists; textile finishers and chemical manufacturers; research and development personnel in the polymer, fiber, chemical, and textile industries; plastics and chemical engineers; materials scientists; and wood and paper technologists will find them essential references. They are eminent sources for supplementary reading in graduate and advanced undergraduate courses including polymer, fiber, and textile chemistry and technology; chemical processing of fibers; chemical engineering; and polymer processing.

about the editors . . .

MENACHEM LEWIN is Director of the Israel Fiber Institute, Jerusalem. He received the M.Sc. degree in chemistry (1944) and Ph.D. degree in physical chemistry (1947) from the Hebrew University, Jerusalem, Israel. Dr. Lewin has authored or coauthored over 400 publications or technical reports and holds 25 patents in numerous areas of chemistry—including fiber structure, cellulose, flame retardancy, and bleaching—and has edited or coedited several books in fiber science. He received the Habif Prize of the University of Geneva, Switzerland (1959) for cellulose research, and was elected Fellow of the International Academy of Wood Science (1972). Among his recent honors, he was Program Co-Chairman of the IUPAC Symposium on Colloid and Surface Chemistry held in Jerusalem (1981). Dr. Lewin serves on the editorial boards of a number of journals, including *Journal of Wood Chemistry and Technology* (Marcel Dekker, Inc.) and *Journal of Applied Polymer Science.* He is also editor-in-chief of the *International Fiber Science and Technology* series (Marcel Dekker, Inc.).

STEPHEN B. SELLO is Manager of Finishing and Exploratory Chemistry at the J. P. Stevens & Co., Inc. Technical Center, Greenville, South Carolina. He received the Ph.D. degree in organic chemistry (1947) from Peter Pazmany University of Sciences, Budapest, Hungary. Dr. Sello has had a major role in such developments in textile science as washable wool, stretch wool, novel flame retardants, and no-iron 100% cotton fabrics. He has authored over 75 publications and holds 22 U.S. patents in textile chemistry. Dr. Sello is a member of the American Association of Textile Chemists and Colorists (AATCC), American Chemical Society, Fiber Society, and New York Academy of Sciences, and serves on the editorial board of *Polymer News.* He received the 1982 Olney Medal from AATCC. Dr. Sello is coeditor of *Handbook of Fiber Science and Technology,* Parts A and B (with Menachem Lewin, Marcel Dekker, Inc.).

Printed in the United States of America ISBN: 0–8247–7117–6

marcel dekker, inc./new york · basel

Handbook of Fiber Science and Technology: Volume I

Chemical Processing of Fibers and Fabrics

FUNDAMENTALS AND PREPARATION

Part B

edited by

Menachem Lewin
Israel Fiber Institute
and Hebrew University
Jerusalem, Israel

Stephen B. Sello
J. P. Stevens & Co., Inc.
New York, New York
and Greenville, South Carolina

MARCEL DEKKER, INC. New York and Basel

Library of Congress Cataloging in Publication Data
(Revised for volume 1, part B)
Main entry under title:

Handbook of fiber science and technology.

(International fiber science and technology series ;
1-   )
Includes bibliographical references and indexes.
Contents: v. 1. Chemical processing of fibers and fabrics--fundamentals and preparation -- v. 2. Chemical processing of fibers and fabrics--functional finishes.
1. Textile finishing. I. Lewin, Menachem, [date]. II. Sello, Stephen B., [date]. III. Series: International fiber science and technology series ; 1, etc.
TS1510.H3 1983 677'.02825 83-7685
ISBN 0-8247-7010-2 (v. 1, pt. A)
ISBN 0-8247-7117-6 (v. 1, pt. B)

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

Current printing (last digit):
10 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF AMERICA

Handbook of Fiber Science and Technology: Volume I

Chemical Processing of Fibers and Fabrics

FUNDAMENTALS AND PREPARATION

Part B

INTERNATIONAL FIBER SCIENCE AND TECHNOLOGY SERIES

Handbook of Fiber Science and Technology: Volume I

Chemical Processing of Fibers and Fabrics
FUNDAMENTALS AND PREPARATION Part A

edited by Menachem Lewin and Stephen B. Sello

Chemical Processing of Fibers and Fabrics
FUNDAMENTALS AND PREPARATION Part B

edited by Menachem Lewin and Stephen B. Sello

Handbook of Fiber Science and Technology: Volume II

Chemical Processing of Fibers and Fabrics
FUNCTIONAL FINISHES Part A

edited by Menachem Lewin and Stephen B. Sello

Chemical Processing of Fibers and Fabrics
FUNCTIONAL FINISHES Part B

edited by Menachem Lewin and Stephen B. Sello

Other volumes in preparation

ABOUT THE SERIES

When human life began on this earth *food* and *shelter* were the two most important necessities. Immediately thereafter, however, came *clothing*. The first materials used for it were fur, hide, skin, and leaves—all of them sheetlike, two-dimensional structures not too abundantly available and somewhat awkward to handle. It was then—quite a few thousand years ago—that a very important invention was made: to *manufacture* two-dimensional systems—fabrics—from simple monodimensional elements—fibers; it was the birth of textile industry based on fiber science and technology. Fibers were readily available everywhere; they came from animals (wool, hair, and silk) or from plants (cotton, flax, hemp, and reeds). Even though their chemical composition and mechanical properties were very different, yarns were made of the fibers by spinning and fabrics were produced from the yarns by weaving and knitting. An elaborate, widespread, and highly sophisticated art developed in the course of many centuries at locations all over the globe virtually independent from each other. The fibers had to be gained from their natural sources, purified and extracted, drawn out into yarns of uniform diameter and texture, and converted into textile goods of many kinds. It was all done by hand using rather simple and self-made equipment and it was all based on empirical craftsmanship using only the most necessary quantitative measurements. It was also performed with no knowledge of the chemical composition, let alone the molecular structure of the individual fibers. Yet by ingenuity, taste, and patience, myriads of products of breathtaking beauty, remarkable utility, and surprising durability were obtained in many cases. *This first era* started at the very beginning of civilization and extended into the twentieth century when steam-driven machinery invaded the mechanical operations and some empirical procedures—mercerization of cotton, moth-proofing of wool and loading of silk—started to introduce some chemistry into the processing.

The second phase in the utilization of materials for the preparation and production of fibers and textiles was ushered in by an accidental discovery which Christian Friedrich Schoenbein, chemistry professor at the University of Basel in Switzerland, made in 1846. He observed that cotton may be converted into a soluble and plastic substance by the action of a mixture of nitric and sulfuric acid; this substance or its solution was extruded into fine filaments by Hilaire de Chardonnet in 1884.

Organic chemistry, which was a highly developed scientific discipline by that time, gave the correct interpretation of this phenomenon: the action of the acids on cellulose—a natural fiber former—converted it into a *derivative*, in this case into a cellulose nitrate, which was soluble and, therefore, spinnable. The intriguing possibility of manipulating natural products (cellulose, proteins, chitin, and others) by chemical action and thereby rendering them soluble, resulted in additional efforts which led to the discovery and preparation of several cellulose esters, notably the cellulose xanthate and cellulose acetate. Early in the twentieth century each compound became the basis of a large industry: viscose rayon and acetate rayon. In each case special processes had to be designed for the conversion of these two compounds into a fiber, but once this was done, the entire mechanical technology of yarn and fabric production which had been developed for the natural fibers was available for the use of the new ones. In this manner new textile goods of remarkable quality were produced, ranging from very shear and beautiful dresses to tough and durable tire cords and transport belts. Fundamentally these materials were not truly "synthetic" because a known natural fiber former—cellulose or protein—was used as a base; the new products were "artificial" or "man-made." In the 1920s, when viscose and acetate rayon became important commercial items polymer science had started to emerge from its infancy and now provided the chance to make *new fiber formers* directly by the polymerization of the respective monomers. Fibers made out of these polymers would therefore be "truly synthetic" and represent additional, extremely numerous ways to arrive at new textile goods. Now started the *third era* of fiber science and technology. First the basic characteristics of a good synthetic fiber former had to be established. They were: ready spinnability from melt or solution; resistance against standard organic solvents, acids, and bases; high softening range (preferably above 220°C); and the capacity to be drawn into molecularly oriented fine filaments of high strength and great resilience. There exist literally many hundreds of polymers or copolymers which, to a certain extent, fulfill the above requirements. The first commercially successful class was the *polyamides*, simultaneously developed in the United States by W. H. Carothers of duPont and by Paul Schlack of I. G. Farben in Germany. The *nylons*, as they are called commercially, are still a very important class of textile fibers covering a remarkably wide range of properties and uses. They were soon (in the 1940s) followed by the *polyesters*, *polyacrylics*, and *polyvinyls*, and somewhat later (in the 1950s) there were added the *polyolefins* and *polyurethanes*. Naturally, the existence of so many fiber formers of different chemical composition initiated successful research on the molecular and supermolecular structure of these systems and on the dependence of the ultimate technical properties on such structures.

As time went on (in the 1960s), a large body of sound knowledge on structure-property relationships was accumulated. It permitted embarkation on the reverse approach: "tell me what properties you want and I shall *tailor-make* you the fiber former." Many different techniques exist for the "tailor-making": graft and block copolymers, surface treatments, polyblends, two-component fiber spinning, and cross-section modification. The systematic use of this "macromolecular engineering" has led to a very large number of *specialty fibers* in each of the main classes; in some cases they have properties which none of the prior materials—natural and "man-made"—had, such as high elasticity, heat setting, and moisture repellency. An important result was that the new fibers were not content to fit into the existing textile machinery, but they suggested and introduced substantial modifications and innovations such as modern high-speed spinning, weaving and knitting, and several new technologies of texturing and crimping fibers and yarns.

This third phase of fiber science and engineering is presently far from being complete, but already a *fourth era* has begun to make its appearance, namely in fibers for uses *outside* the domain of the classical textile industry. Such new applications involve fibers for the reinforcement of thermoplastics and duroplastics to be used in the construction of spacecraft, airplanes, buses, trucks, cars, boats, and buildings; optical fibers for light telephony; and fibrous materials for a large array of applications in medicine and hygiene. This phase is still in its infancy but offers many opportunities to create entirely new polymer systems adapted by their structure to the novel applications outside the textile fields.

This series on fiber science and technology intends to present, review, and summarize the present state in this vast area of human activities and give a balanced picture of it. The emphasis will have to be properly distributed on synthesis, characterization, structure, properties, and applications.

It is hoped that this series will serve the scientific and technical community by presenting a new source of organized information, by focusing attention to the various aspects of the fascinating field of fiber science and technology, and by facilitating interaction and mutual fertilization between this field and other disciplines, thus paving the way to new creative developments.

Herman F. Mark

INTRODUCTION TO THE HANDBOOK

The Handbook of Fiber Science and Technology is composed of five volumes: chemical processing of fibers and fabrics; fiber chemistry; specialty fibers; physics and mechanics of fibers and fiber assemblies; and fiber structure. It summarizes distinct parts of the body of knowledge in a vast field of human endeavor, and brings a coherent picture of developments, particularly in the last three decades.

It is mainly during these three decades that the development of polymer science took place and opened the way to the understanding of the fiber structure, which in turn enabled the creation of a variety of fibers from natural and artificial polymeric molecules. During this period far-reaching changes in chemical processing of fabrics and fibers were developed and new processes for fabric preparation as well as for functional finishing were invented, designed, and introduced. Light was thrown on the complex nature of fiber assemblies and their dependence on the original properties of the individual fibers. The better understanding of the behavior of these assemblies enabled spectacular developments in the field of nonwovens and felts. Lately, a new array of sophisticated specialty fibers, sometimes tailor-made to specific end-uses, has emerged and is ever-expanding into the area of high technology.

The handbook is necessarily limited to the above areas. It will not deal with conventional textile processing, such as spinning, weaving, knitting, and production of nonwovens. These fields of technology are vast, diversified, and highly innovative and deserve a specialized treatment. The same applies to dyeing, which will be treated in separate volumes. The handbook is designed to create an understanding of the fundamentals, principles, mechanisms, and processes involved in the field of fiber science and technology; its objective is not to provide all detailed procedures on the formation, processing, and modification of the various fibers and fabrics.

Menachem Lewin

INTRODUCTION TO VOLUMES I AND II

Textiles have undergone wet chemical processing since time immemorial. Human ingenuity and imagination, craftmanship and resourcefulness are evident in textile products throughout the ages; we are to this day awed by the beauty and sophistication of textiles sometimes found in archaeological excavations.

The objectives of the chemical processing, while basically unchanged over the centuries, have in recent times been diversified and expanded. Comfort and esthetics, durability and functionality, safety from fire and health hazards, easy care performance, such as washability, soil release, water and oil repellency, and stability against biological attack are examples of the objectives of chemical treatments of fibers and fabrics. Before these treatments can be applied, the textile materials have to be prepared by appropriate chemical procedures such as sizing, desizing, scouring, bleaching, and mercerization.

The array of fibers used at present is highly diversified. The advent of polyester, nylon, acrylic, and polyolefin fibers in recent years has greatly increased the complexity of the treatments as well as the range of the chemicals used. It became clear that approaches such as those practiced until 3 decades ago cannot continue to serve the solution to the wide range of problems facing chemists and technologists in the industry today. This realization coincided with rapid developments in polymer science and technology and brought about a surge in research and development activities in textile chemistry.

The studies carried out in the last 3 decades yielded a staggering amount of new data and not only a better understanding of the fibers and fiber assemblies and of the chemical interactions and structural changes, but also a large number of innovative ideas were created and put forward. Many of these ideas were developed into new processes, machines, and instruments, and culminated in a remarkable reshaping of the textile industry.

In these books an attempt is made to review and summarize the most important developments in this field. The emphasis is placed on the chemical aspects of the problems discussed. While technological aspects as well as industrial applications of the processes are being dealt with, only a brief treatment is given to factory layouts and to the machinery used.

Chemical Processing of Fibers and Fabrics is divided into two major areas. The first area, the fundamentals underlying the chemical treatments of fibers and fabrics and the preparation processes, are presented in Vol. I, Parts A and B. The second area, the functional finishes of textiles, are discussed in Vol. II, Parts A and B.

The need for a new comprehensive book in the field of chemical processing of fibers and fabrics has been felt for a long time. The vast amount of information accumulated in recent years in this field necessitated the preparation of the present books. They are intended for scientists and technologists both in the field of textiles and polymers as well as for students and researchers in other fields of human endeavor.

It is hoped that these books will not only further the knowledge and understanding of the complex field of textile chemistry, but will also bring about an interaction between people dealing in this field and people of other disciplines and will trigger off new and innovative developments for the benefit of all humanity.

Menachem Lewin
Stephen B. Sello

PREFACE

This is the second of two parts on fundamentals and preparation. It reviews the chemistry and technology of the various phases of preparation in detail.

Warp sizing--especially of cellulosics with starch--has been carried out in the textile industry for centuries. This field is still of great interest to scientists and technologists and in recent years many efforts have been made to replace the empirical approaches previously used by techniques developed after systematic scientific studies. A relationship is being established between the characteristics of films cast from sizing polymers, the properties of sizing warp yarns, and weaving efficiency. The introduction of new fibers, fiber blends, and modern high speed looms made it necessary to develop new sizing polymers and slashing technologies. Desizing of textiles, including modern size recovery systems, is also discussed.

Subsequent chapters review the bleaching of cellulosic, wool and synthetic textiles and the application of fluorescent whitening agents. It is an objective of this book to lead the reader to a better understanding of the mechanism underlying the preparation procedures and to discuss the important recent developments in this field.

The editors wish to thank the editorial advisory board of the International Fiber Science and Technology Series, the contributors, and the editorial staff of Marcel Dekker for their cooperation and their contributions to this book.

Menachem Lewin
Stephen B. Sello

CONTRIBUTORS

Peter G. Drexler Research and Development Division, Chem-Mark, Inc., Middlesex, New Jersey

Raphael Levene Israel Fiber Institute, Jerusalem, Israel

Menachem Lewin Israel Fiber Institute, and School of Applied Science and Technology, Hebrew University, Jerusalem, Israel

Giuliana C. Tesoro* Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

*Present affiliation: Department of Chemistry, Polytechnic Institute of New York, Brooklyn, New York

CONTENTS OF OTHER VOLUMES