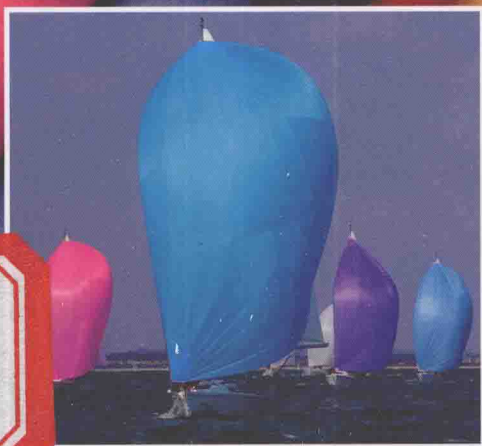


# The Chemistry of Textile Fibres

Robert R Mather and Roger H Wardman



RSC Publishing

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# Preface

Textiles are ubiquitous materials that many of us take for granted in our everyday lives. We rely on our clothes to protect us from the environment, for modesty, and to make us look good. Textiles also enhance our domestic lives, in the form of soft furnishings, such as carpets and curtains, as well as towels and bed linen, *etc.* Some people may also be aware of the uses of textiles in high-performance garments, such as waterproof breathable materials for outdoor wear, or performance sportswear, such as thermoregulating materials. Fewer are aware, however, of the applications of textiles outside of these areas, such as in transport, healthcare, building, marine uses and a whole range of other industrial uses.

What lies behind the fibres and fabrics that possess such a wide variety of properties is often a complex and demanding chemistry. Fibres are polymeric materials and the production of fibres that are suitable for their intended end uses depends not only on the successful optimisation of the formulation of the polymers, but also on their physical chemistry. In turn, the manufacture of many of the synthetic fibres has presented considerable challenges to both chemical and process engineers, and many of the fibres on the market today represent the successful integration of development work by chemists and engineers alike.

The journey – from the first efforts to produce man-made fibres by chemically modifying natural fibres (principally cotton), through the marketing in the 1940s of the first nylons, to the present day breeds of fibres, some of which are many times stronger than steel whilst being a good deal lighter – is a remarkable story. It is a story of chemistry at its

best, and moreover, one that involves all three of the classical branches of chemistry – organic, inorganic and physical chemistry.

What we have tried to do in this book is to give an overview of the various types of textile fibres that are available today – ranging from the natural fibres, right through to the high-performance fibres that are often very technologically advanced. Whilst the focus of the book remains the chemistry of the fibres, we will also investigate the reasons why some individual fibre types are more suitable for certain application than others. The book does not go into advanced detail about the chemistry of formation of the fibres or the intricate technicalities of their production. There are many specialised authoritative textbooks on the market that serve this purpose for the researcher or specialist user. In addition, it is not always possible to give much technical detail about production methods, since these are often kept confidential by the manufacturers. Instead this book is aimed at students following ‘A’ level courses, or equivalent, at school or technical college, and first-year undergraduate students following textile technology courses at university. A bibliography at the end of each chapter directs the reader to further sources of information.

In Chapter 1, we start with a description of the classes of fibres and indicate the relative quantities produced annually on a global basis. The requirements of polymers in order to have fibre-forming properties are then explained, as well as the general chemical and physical properties necessary for fibres to be commercially viable.

Chapter 2 deals with the natural cellulosic fibres, the so-called ‘vegetable’ fibres, which include the fibres that can be obtained from the stem, leaf or seed of plants, all of which are cellulosic in nature. Later chapters in the book will explain the sophisticated developments that have led to synthetic fibres with remarkable properties, but it is important not to forget that the humble cotton fibre is the second most produced fibre in the world and as such, still has a major role to play. Chapter 3 covers the other major class of natural fibres – the protein fibres of wool, hair and silk – which are also commercially important fibres in their own way.

The first man-made fibres were produced from naturally occurring polymers, chiefly cellulosic materials. Fibres from these sources were extracted by often complex chemical processes and some of these fibre types, the so-called ‘regenerated’ fibres, are still important today. These fibres are the subject of Chapter 4.

Synthetic fibres, the fibres made from chemicals derived from oil, are discussed in Chapters 5 and 6. Chapter 5 deals with the methods by which man-made fibres are formed, that is, how the polymers are extruded into the fine fibre filaments required for textile manufacture. It

goes on to cover the chemistry of the 'mainstream' synthetic fibres. In Chapter 6, we explain the chemical principles behind the development and manufacture of a selection of high-performance fibres. Chapter 7 covers other specialty fibres, fibres with specific functions, or what might be termed 'functional fibres'. This is an exciting area of development, one that is taking textile fibres into the areas of the so-called 'smart' or 'intelligent' textiles. Leading the way in this class are the nanofibres, but equally exciting in their own way are the electrically conducting fibres, optical fibres (for use in textiles) and electroluminescent fibres.

The point has been made above that the production of textile fibres involves all three classical disciplines of chemistry. The performance properties of textile fibres can be significantly modified by alteration of their surface characteristics and so surface chemistry has an important role to play. In Chapter 8, the techniques that are available for enhancing fibre performance by surface treatment are discussed and examples are given of the effects that can be produced.

Finally, blends of different fibre types are widely used, especially for apparel and for interior furnishings. Chapter 9 explains the reasons for blending different fibre types, typical blends used and their applications.

We are greatly aware of the need for an introductory book on textile fibre chemistry, particularly in light of the recent innovations taking place in this important sector of chemistry. We hope therefore that readers new to textiles will find the book stimulating, and will be inspired to read further. For this reason a short bibliography is given at the end of each chapter.

In the preparation of this book, we are much indebted to Mr Jim McVee, Instrument Technician, and to research students, Miss Uzma Syed and Mr Abdulhameed Abdrabbo of Heriot-Watt University, for their assistance in preparing microscopic images of fibres. We are especially grateful to Dr Josef Schmidtbauer and Mr Jim Taylor of Lenzing Fibres GmbH for their invaluable advice on viscose and Lyocell fibres. We have also valued the advice of Prof. John Wilson of Heriot-Watt University on photonic crystal fibres and Mr Gavin Dundas on the extent of chemical knowledge that may be expected of students following courses to 'A' level and equivalent standards.

Finally, we are extremely grateful to the Royal Society of Chemistry for giving us the opportunity to share our fascination of textile chemistry with the wider community of chemists. We sincerely hope we have risen to this challenge satisfactorily.

Robert Mather and Roger Wardman

Dr Mather gratefully acknowledges the support of his wife Rosemary.  
Prof. Roger Wardman dedicates the book to his late wife Rosemary.

# Contents

<b>Chapter 1</b>	<b>The Scope of Textile Fibres</b>	<b>1</b>
1.1	Introduction	1
1.2	Classification of Textile Fibres	2
1.3	Fibre Production Statistics	4
1.4	Characteristics of Textile Fibres	5
1.5	Requirements of Fibre-Forming Polymers	7
1.6	Properties of Textile Fibres	10
1.6.1	Mechanical Properties	11
1.6.2	Thermal Properties	13
1.6.3	Electrical Properties	14
1.6.4	Optical Properties	16
1.6.5	Surface Properties	19
1.6.6	Biological Properties	19
	Suggested Further Reading	21
<b>Chapter 2</b>	<b>Cellulosic Fibres</b>	<b>22</b>
2.1	Introduction	22
2.2	Seed Fibres	22
2.2.1	Growth and Morphology of Cotton	23
2.2.2	Chemical Composition of Cotton	26
2.2.3	Crystalline Structure of Cotton	29
2.2.4	Chemical Processing of Cotton	32
2.2.5	Chemical Reactions of Cellulose	33
2.2.5.1	Acid	33



2.2.5.2	Alkali	34
2.2.5.3	Oxidation	35
2.2.5.4	Action of Heat on Cotton	37
2.2.5.5	Other Important Reactions of Cellulose	38
2.2.6	Fibre Properties	41
2.2.7	'Green Cotton'	42
2.3	Bast Fibres	44
2.3.1	Flax	45
2.3.2	Hemp	50
2.3.3	Jute	51
2.3.4	Ramie	53
2.3.5	Bamboo	55
2.3.6	Nettles	56
2.3.7	Uses of Bast Fibres	57
2.4	Leaf Fibres	58
2.5	Other Polysaccharide Fibres	58
2.5.1	Alginate Fibres	58
2.5.2	Chitin and Chitosan Fibres	59
	Suggested Further Reading	60

### **Chapter 3 Protein Fibres 61**

3.1	Introduction	61
3.2	Wool	61
3.2.1	Origins and Morphology	61
3.2.2	Cuticle	63
3.2.3	Cortex	65
3.2.4	Cell Membrane Complex	66
3.2.5	Chemical Composition of Wool	66
3.2.6	Isolation and Location of Keratins	70
3.2.7	Processing of Wool Fleeces	72
3.2.8	Chemical Reactions of Wool	74
3.2.8.1	Introduction	74
3.2.8.2	Alkali	74
3.2.8.3	Acid	77
3.2.8.4	Reduction	78
3.2.8.5	Oxidation	81
3.2.8.6	Chlorination	82
3.2.8.7	Cross-Linking	83
3.2.8.8	Reactive Dyes	84
3.2.8.9	Action of Heat	85
3.2.8.10	Action of Light	86
3.2.9	Setting	87

3.2.10	Shrinkproofing	88
3.2.11	Fibre Properties	90
3.3	Speciality Mammalian Fibres	91
3.4	Silk	93
3.4.1	Introduction	93
3.4.2	Chemical Composition of Silk	94
3.4.3	Bleaching of Silk	96
3.4.4	Chemical Reactions of Silk	96
3.4.4.1	Introduction	96
3.4.4.2	Acid and Alkali	96
3.4.4.3	Oxidation	97
3.4.4.4	Cross-Linking	97
3.4.4.5	Reactive Dyes	98
3.4.4.6	Action of Light	98
3.4.5	Silk Weighting	98
3.4.6	Fibre Properties	98
	Suggested Further Reading	99

## **Chapter 4 Regenerated Fibres 100**

4.1	Regenerated Cellulosic Fibres	100
4.1.1	Viscose	102
4.1.2	Variants of Rayons	108
4.1.2.1	High Tenacity Rayons	108
4.1.2.2	Polynosic Rayons	109
4.1.2.3	High Wet Modulus Rayons	110
4.1.2.4	Modal	111
4.1.2.5	Flame Retardant Rayons	111
4.1.2.6	Other Variants of Rayons	111
4.1.3	Cuprammonium Rayon	113
4.1.4	Lyocell Fibres	115
4.1.5	Other Solvent-Based Processes	121
4.1.6	Cellulose Acetate Fibres	122
4.2	Regenerated Protein Fibres	126
	Suggested Further Reading	127

## **Chapter 5 Synthetic Fibres 128**

5.1	Processing of Synthetic Fibres	128
5.1.1	Introduction	128
5.1.2	Melt Spinning	130
5.1.3	Solution Spinning	131
5.1.4	Drawing	135
5.2	Polyamide Fibres	136
5.2.1	Introduction	136

5.2.2	Manufacture of Monomers	138
5.2.2.1	1,6-Hexandioic Acid (Adipic Acid)	138
5.2.2.2	1,6-Diaminohexane (Hexamethylene Diamine)	139
5.2.2.3	Caprolactam	140
5.2.3	Production of Nylon 6,6	141
5.2.4	Production of Nylon 6	142
5.2.5	Fibre Extrusion	143
5.2.6	Physical Structure	144
5.2.7	Chemistry of Polyamide Fibres	145
5.2.7.1	Introduction	145
5.2.7.2	Hydrolysis	145
5.2.7.3	Pyrolysis	145
5.2.7.4	Thermal Oxidation	146
5.2.7.5	Photodegradation	148
5.2.7.6	Stabilisation of Polyamide Fibres	148
5.2.8	Fibre Properties	150
5.3	Polyester Fibres	151
5.3.1	Introduction	151
5.3.2	Manufacture of Monomers	153
5.3.2.1	Terephthalic Acid	153
5.3.2.2	Dimethyl Terephthalate	153
5.3.2.3	Ethane-1,2-diol	153
5.3.2.4	Butane-1,4-diol	154
5.3.2.5	Propane-1,3-diol	154
5.3.2.6	Cyclohexanedimethanol	155
5.3.2.7	Naphthalene-2,6-dicarboxylic Acid	155
5.3.2.8	Dimethyl Naphthalene-2,6-dicarboxylate	156
5.3.3	Production of Polyesters	157
5.3.3.1	Production of PET	157
5.3.3.2	Production of PBT	158
5.3.3.3	Production of PTT	159
5.3.3.4	Production of PCT	159
5.3.3.5	Production of Polyethylene Naphthalate	159
5.3.4	Fibre Processing	160
5.3.5	Physical Structure	160
5.3.6	Chemistry of Polyester Fibres	161
5.3.6.1	Introduction	161
5.3.6.2	Hydrolysis	161
5.3.6.3	Thermal Degradation	162
5.3.6.4	Photodegradation	163
5.3.7	Fibre Properties	164

5.4	Acrylic and Modacrylic Fibres	165
5.4.1	Introduction	165
5.4.2	Manufacture of Acrylonitrile	168
5.4.3	Polymerisation of Acrylonitrile	169
5.4.4	Fibre Extrusion	171
5.4.5	Chemistry of Acrylic Fibres	173
5.4.5.1	Acids and Alkalis	173
5.4.5.2	Solvents	173
5.4.5.3	Oxidation	173
5.4.5.4	Action of Heat	174
5.4.6	Physical Properties of Acrylic Fibres	174
5.4.7	Uses of Acrylic Fibres	175
5.5	Polyolefin Fibres	176
5.5.1	Introduction	176
5.5.2	Manufacture of Monomers	178
5.5.3	Production of Polyolefins	178
5.5.4	Fibre Processing	181
5.5.5	Physical Structures	183
5.5.6	Chemistry of Polyolefin Fibres	184
5.5.6.1	Introduction	184
5.5.6.2	Pyrolysis	184
5.5.6.3	Thermal Oxidation	185
5.5.6.4	Photodegradation	186
5.5.6.5	Stabilisation of Polyolefin Fibres	186
5.5.7	Fibre Properties	187
5.6	Elastomeric Fibres	188
5.6.1	Introduction	188
5.6.2	Elastane Fibres	188
5.6.3	Elastodiene Fibres	196
5.6.4	Elastomultiester Fibres	198
5.6.5	Elastolefin Fibres	199
	Suggested Further Reading	199

## **Chapter 6 High-performance Fibres 200**

6.1	Introduction	200
6.2	Aramid Fibres	202
6.2.1	Introduction	202
6.2.2	Production of Aramid Fibres	202
6.2.2.1	<i>m</i> -Aramid Fibres	202
6.2.2.2	<i>p</i> -Aramid Fibres	203
6.2.3	Physical Structure	206
6.2.4	Chemistry of Aramid Fibres	208
6.2.4.1	Introduction	208
6.2.4.2	Hydrolysis	208

6.2.4.3	Photodegradation	208
6.2.5	Fibre Properties	210
6.3	Aromatic Polyester Fibres	210
6.3.1	Introduction	210
6.3.2	Production of Aromatic Polyester Fibres	211
6.3.3	Fibre Structure	213
6.3.4	Chemistry of Aromatic Polyester Fibres	214
6.3.5	Fibre Properties	214
6.4	Polybenzimidazole Fibres	214
6.4.1	Introduction	214
6.4.2	Production of PBI Fibres	215
6.4.3	Fibre Properties	216
6.5	Fluoropolymer Fibres	218
6.5.1	Introduction	218
6.5.2	Production of Fluoropolymer Fibres	218
6.5.3	Fibre Properties	219
6.6	Carbon Fibres	220
6.6.1	Introduction	220
6.6.2	Carbon Fibres from PAN Fibres	221
6.6.3	Carbon Fibres from Mesophase Pitch	221
6.6.4	Fibre Structure	222
6.6.5	Fibre Properties	224
6.6.6	Carbon Nanotube Fibres	224
6.7	Thermoset Polymer Fibres	227
6.7.1	Introduction	227
6.7.2	Melamine–Formaldehyde Fibres	227
6.7.3	Phenol–Formaldehyde Fibres	228
6.8	Ceramic Fibres	230
6.8.1	Introduction	230
6.8.2	Production of Silicon Carbide Fibres	230
6.8.3	Production of Alumina Fibres	231
6.8.4	Fibre Properties	231
	Suggested Further Reading	232

## **Chapter 7 Other Speciality Fibres 233**

7.1	Nanofibres	233
7.1.1	Introduction	233
7.1.2	Methods for Making Nanofibres	234
7.1.2.1	Electrospinning	235

7.1.2.2	Melt Blown Nanofibres	241
7.1.2.3	'Islands-in-the-Sea'	241
7.1.3	Uses of Nanofibres	243
7.2	Electrically Conducting Fibres	244
7.2.1	Introduction	244
7.2.2	Methods for Making Electrically Conductive Fibres	245
7.2.2.1	Very Fine Metal Wires	245
7.2.2.2	Inherently Conductive Polymers (ICPs)	247
	Polyaniline (PANI)	249
	Polypyrrole (PPy)	252
	Polythiophene (PT)	253
7.2.2.3	Coating Textile Fibres with an Electrically Conductive Layer	253
7.2.2.4	Incorporating Conductive Particles into Fibres	255
7.2.2.5	Polymer Blending	256
7.2.3	Inherently Conducting Nanofibres	257
7.3	Optical Fibres	257
7.3.1	Introduction	257
7.3.2	Glass Fibres	259
7.3.3	Polymer Optical Fibres (POFs)	262
7.3.4	Uses of Optical Fibres in Textiles	266
7.3.5	Photonic Crystal Fibres (PCFs)	269
7.4	Luminescent Fibres	272
7.4.1	Introduction	272
7.4.2	Photoluminescent Fibres	272
7.4.3	Electroluminescent Fibres	274
7.5	Biodegradable Fibres	276
7.5.1	Introduction	276
7.5.2	Polylactic Acid (PLA)	277
7.5.2.1	Introduction	277
7.5.2.2	Manufacture of PLA Fibres	278
7.5.2.3	Properties of PLA Fibres	282
7.5.2.4	Uses of PLA Fibres	283
7.5.3	Polycaprolactone (PCL)	283
7.5.4	Other Biodegradable Fibres	284
	Suggested Further Reading	285
	Nanofibres	285
	Electrically Conducting Fibres	286
	Optical Fibres	286
	Biodegradable Fibres	286

<b>Chapter 8</b>	<b>Enhancement of Fibre Performance by Surface Modification</b>	<b>287</b>
8.1	Introduction	287
8.2	Wetting and Wicking Properties of Textiles	287
8.2.1	Introduction	287
8.2.2	Wetting	289
8.2.3	Wicking	294
8.3	Surface Treatments	298
8.3.1	Plasma Treatment	299
8.3.1.1	Introduction	299
8.3.1.2	Methods for Generating Plasmas	299
8.3.1.3	Effects of Plasma Treatments	300
8.3.1.4	Characterisation of Plasma-Treated Textile Surfaces	303
8.3.1.5	Examples of Fibre/Fabric Treatments	305
8.3.1.5.1	Wool	305
8.3.1.5.2	Silk	306
8.3.1.5.3	Cotton	306
8.3.1.5.4	Nylon 6 and 6,6	307
8.3.1.5.5	Polyester	307
8.3.1.5.6	Polypropylene	308
8.3.1.6	Uses of Plasma Treatments	308
8.3.2	Enzyme Treatments	309
8.3.3	Chemical Finishing of Textiles	311
8.3.3.1	Introduction	311
8.3.3.2	Chemical Softeners	312
	Cationic Softeners	312
	Anionic Softeners	313
	Amphoteric Softeners	313
	Non-Ionic Softeners	314
8.3.3.3	Water Repellents	315
8.3.3.4	Soil-Release/Anti-Soiling Agents	318
	Carboxyl-Based Polymers	320
	Hydroxy-Based Polymers	320
	Ethoxy-Based Polymers	320
	Hybrid-Fluorocarbon Polymers	321
8.3.3.5	Antistatic Finishes	322
8.3.3.6	Flame Retardant Agents	324
8.3.3.6.1	Cellulosics	325
8.3.3.6.2	Wool	327
8.3.3.6.3	Synthetic Fibres	327
	Suggested Further Reading	328
	Wetting and Wicking	328

Surface Treatments	328
Chemical Finishes	328
<b>Chapter 9 Fibre Blends in Textile Fabrics</b>	<b>330</b>
9.1 Introduction	330
9.2 Making Blended Materials	331
9.2.1 Blended Yarns	331
9.2.1.1 Intimate Yarns	331
9.2.1.2 Non-Intimate (Core Spun) Yarns	334
9.2.1.3 Plied Yarns	335
9.2.2 Union Fabrics	335
9.2.3 Double Face Knitted Fabrics	336
9.3 Uses of Blended Fibres	337
Suggested Further Reading	337
<b>Appendices</b>	<b>338</b>
<b>Subject Index</b>	<b>347</b>



## CHAPTER 1

# The Scope of Textile Fibres

### 1.1 INTRODUCTION

There is a very wide range of textile fibre types available in the market-place. They vary not only in chemical type but also in physical characteristics, reflecting the wide variety of applications they have. Many people relate textiles to apparel and to materials for domestic uses, such as carpets, bedding and soft furnishings, but in fact textiles also have many specialised industrial applications. These textile products are referred to as 'technical textiles' and are produced mainly for their functional and technical performance, rather than their aesthetic characteristics. There are no clear distinctions between apparel and technical applications either, in the sense that the 'performance' apparel market, for which garments are produced to meet specific requirements in terms for example functionality or personal protection, is a hugely important one. Indeed, performance apparel in 2009 represented some 10% of the sportswear market and is forecast to be worth over US\$ 4.3 billion by 2012.

For centuries the textile industry was comprised exclusively of the natural fibres, particularly cotton, wool and silk. Indeed, in the UK the textile industry was dominated by wool, because it was not until the beginning of the eighteenth century that cotton began to be imported. Towards the end of the nineteenth century the first 'man-made' fibres were commercialised, these being the regenerated fibres, such as viscose rayon, based on cellulose. The textile industry then made considerable technological advances from the 1930s with the development of many types of commercially important synthetic polymers. In the period since

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