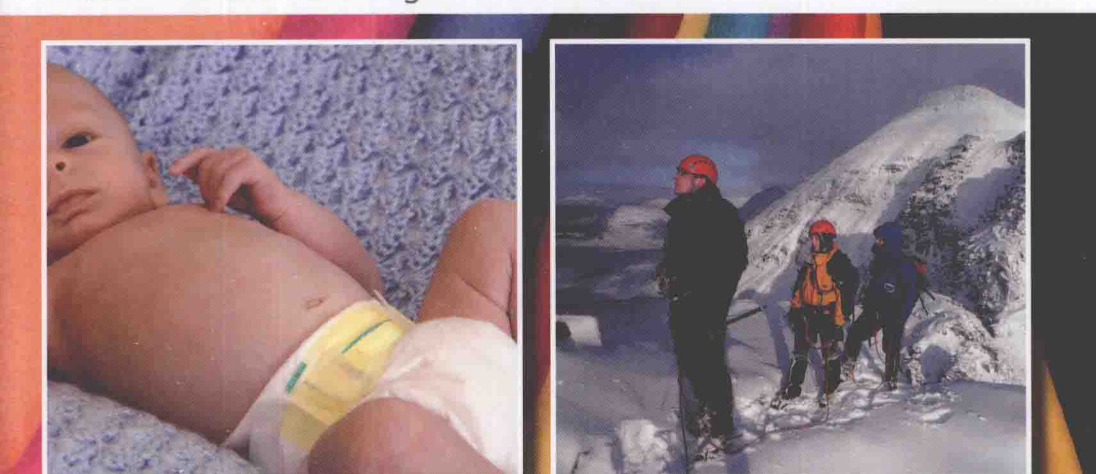
The Chemistry of Textile Fibres

Robert R Mather and Roger H Wardman



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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

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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 Abdulalhameed 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.

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CHAPTER 1
The Scope of Textile Fibres

1.1 INTRODUCTION

There is a very wide range of textile fibre types available in the marketplace. 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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