# Preface

The liquid crystal and the polymer are two different disciplines of science and technology. They meet together producing the liquid crystalline polymer or, if you prefer, the polymeric liquid crystal. The liquid crystalline polymer combines mesogenic units and high molecular weight, and thus exhibits excellent anisotropic physical properties while possessing the advantage of easy processing and convenient molecular tailoring. The liquid crystalline polymer not only possesses the individual properties of each of its parents, but also exhibits intrinsic features that its parents do not have. In such a sense, the liquid crystalline polymer is a new state of matter.

Both the liquid crystal and the polymer are of about the same age, but the polymer has successfully penetrated every walk of human life. On the other hand, the liquid crystal had kept itself quiet for a half century until the early 70's. Since then, it has caught the vast interest of both science and industry. It has been applied especially in the display industry, such as in portable TVs and notebook and desktop computers. Two important events symbolized the liquid crystal's coming of age: Professor P. G. de Gennes, a French physicist, won the Noble Prize in 1991 and Professor G. W. Gray, a British chemist, was awarded the Kyoto Prize in 1995.

In tracing back the history of the liquid crystalline polymer itself, the German scientist D. Vorlander should be mentioned. It was he who first pointed out that the long shape of the polymer does not prevent the polymer from exhibiting liquid crystallinity. The polymeric liquid crystallinity was first found in the tobacco mosaic virus in solution around 1940, and later found in the poly-peptide solution. The initial theoretical basis for the rigid liquid crystalline polymer is attributed to the efforts of Onsager and Flory, both Noble Prize laureates. The liquid crystalline polymer has been a constant challenge to theoretical scientists to fully explain and exactly predict the behaviors of it and its substantial members, *i.e.*, network and gel. In addition, the understanding of liquid crystalline polymers may provide an insight into biological systems.

S. L. Kwolek, a woman scientist of DuPont, invented the liquid crystal aromatic polyamides which eventually paved the way to the first commercial liquid crystalline polymer product—poly-p-phenyleneterephthalamide under the trade name Kevlar. She recently recalled, "When I dissolved the PBA (poly-p-aminobenzamide) polymer at 10% concentration in tetramethylurea with 6.5% LiCl, the solution was unusually fluid, turbid, stir-opalescent, and butter-milk-like in appearance." The fiber that was spun turned out to be extremely strong with a modulus of 430 gpd! This discovery in 1964 remains a milestone of this field. In recognition of her contribution, the American Society of Chemistry Industry awarded Kwolek the 1997 Perkin Medal.

The liquid crystalline polymer has since developed far beyond imagination that a decade ago. The liquid crystalline polymer family has so far included the main chain-, side chain-, and crosslinked- (*i.e.* network or elastomer) types, and their solutions and gels. The liquid crystal phases cover nematic, cholesteric and smectics. Although the science of the liquid crystalline polymer is not fully mature, it has attracted significant research interests and has already made tremendous progress. As investments and human resources continue, the liquid crystalline polymer is expected to have an even brighter future.

The liquid crystalline polymer industry now covers diverse products, from high modulus rope to high strength composite, from the tennis racket to the radial tire cord, from the cover layer of the optical fiber to the microwave oven, from the bullet-proof vest to thermal insulated clothing, and from the electro-optic display to non-linear optical material, *etc.*

The authors, X. J. Wang (XJW), a condensed matter physicist, and Q. F. Zhou (QFZ), a polymer chemist, have found joint research interest in this fascinating material since the middle of the 80's. They have collaborated on several projects. In 1994, they successfully organized an IUPAC conference on liquid crystalline polymers in Beijing. XJW is now working as a senior research scientist in Avery Research Center, Avery Dennison Company, USA. While QFZ is working as a professor in the Department of Polymer Science and Engineering, Peking University, China.

This book consists of six chapters. The first chapter highlights the concept of liquid crystals, including chemical structure, phase classification, defect and texture, and continuum theory. This chapter is carefully prepared in order to meet the needs of readers who are not specialized in liquid crystals. The second chapter is associated with the theoretical descriptions of liquid crystalline polymers, networks, and gels which deal with subjects such as the formation of liquid crystallinity in polymer system, phase transition and phase diagram, the molecular weight effect, chain conformation, physics properties, *etc.* In Chapter 3, the molecular engineering of liquid crystalline polymers is introduced. The molecular composition and the molecular weight play essential roles in the molecular design, which are reviewed in detail. In addition, some unusual liquid crystalline polymers are discussed in the chapter. Chapter 4 is devoted to the phase identification of liquid crystalline polymers. The techniques involved cover polarizing microscopy, thermal analysis, X-ray diffraction and others. Chapters 5 and 6 summarize the properties and applications of liquid crystalline polymers. Chapter 5 deals mainly with mechanical performance in fiber and composites. Chapter 6 introduces the elasticity and viscosity and rheology of liquid crystalline polymers, as well as other important properties.

XJW would like to thank Professor M. Warner who has been one of pioneers in the theoretical aspect of liquid crystalline polymers. The collaboration of XJW with Professor Warner has continued for more than a decade at Oxford and Cambridge, UK. Some contexts in Chapter 2 are in fact based on their joint research. Thanks are also due to Professors J. A. Zhao and A. J. Leadbetter for introducing him into this fascinating area when XJW studied liquid crystals in Tsinghua University, China, and the Rutherford Appleton Laboratory, UK. The assistance of C. H. Wang in the diagrams is also acknowledged by XJW. Special thanks of QFZ are given to Professors X. D. Feng, R. Y. Qian, R. W. Lenz, and J. I. Jin for introducing him into the sciences of polymer and polymeric liquid crystals. QFZ also acknowledges the assistance of D. Zhang, Y. G. Ma and X. H. Wan. Our families are worth special mention. We are indebted for their encouragement—that is what we need.

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