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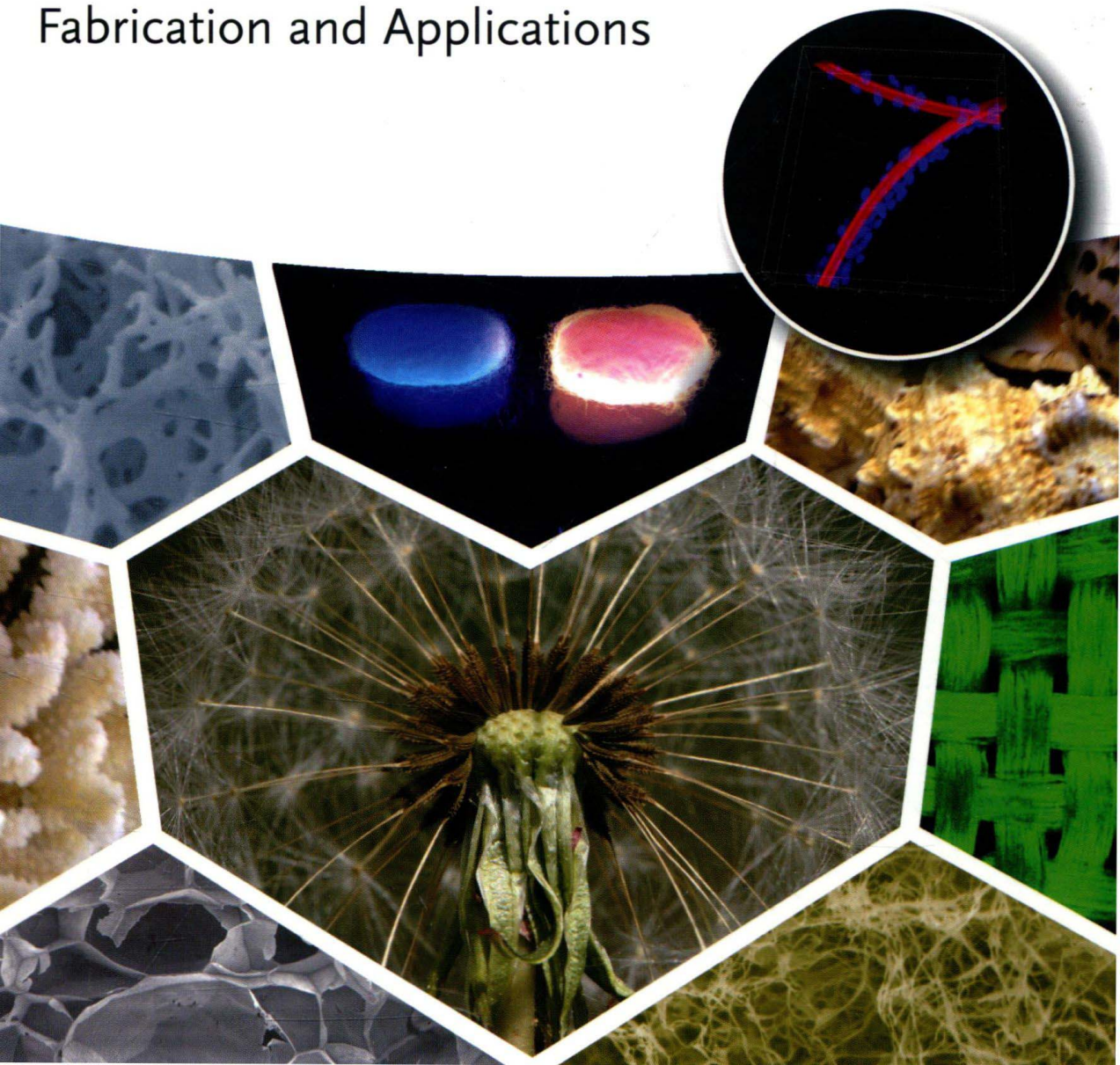
Soft Fibrillar Materials

Fabrication and Applications



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Preface

Nowadays, the advance of modern sciences and technologies depends to a large extent on the step changes in materials science. The research and engineering of materials have become one of the most exciting areas across physics, chemistry, biology, and engineering. Soft matter is a subfield of condensed matter comprising a variety of physical states that are easily deformed by thermal stresses or thermal fluctuations or under normal stress. They include liquids, colloids, polymers, foams, gels, granular materials, and a number of biological materials. These materials share an important common feature in that predominant physical behaviors occur at an energy scale comparable with room-temperature thermal energy.

In the area of materials science and engineering, three trends are of major research interest (Figure 1).

The *ultrafunctional materials* refer to those having some extraordinary properties. The materials entirely or partially appear to be superhard, superhydrophobic, superhydrophilic, superconducting, and so on. Spider dragline silk fibers can be considered one of the toughest materials in terms of energy versus density. It was estimated that a spider silk string a pencil-width thick can stop a Boeing 747 in flight. Lotus leaves turn out to be one of the common examples of superhydrophobicity, with the capability of self-cleaning. *Multifunctional materials* correspond to those having more than one major in-use properties/functions, an example being fluorescent silk. *Smart and responsive materials* are those that respond to some external stimuli in the way that particular properties of the materials change drastically and/or in opposition to conventional materials. Under some external stimuli, the color, optical properties, or conductivity of the materials change correspondingly. Shear responsive fluids, thermal responsive gels, and such materials belong to this type.

In comparison with conventional "hard materials," soft materials play a more important role in contemporary science and technology. It is the current tendency that many conventional "hard materials" are gradually replaced by soft materials due to the excellent performance, light weight, and broader applications. Subject to structural characteristics, the aforementioned three trends of research can be implemented more easily in soft materials. The increasing demand and broad applications of various special fibers and complex materials can be regarded as two such examples.

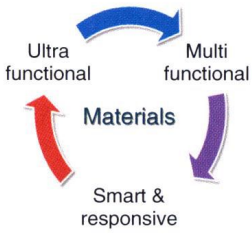

Figure 1 Three major trends in materials science and engineering.

Soft materials display combined solid and liquid properties, the so-called rheological properties. Correspondingly, the structures are normally complicated. This can be because soft materials consist of certain network structures. In many cases, these are fibrous network structures, ranging from nanoscale to microscopic scales. Therefore, the understanding on the formation of fibrous networks is the key to fabricate and engineer materials of this type.

This book deals with this type of important soft functional materials. We will take this opportunity to demonstrate a principle: *the elegant engineering of materials should be built on decent understanding*, which can be illustrated by the so-called engineering triangle (Figure 2). More specifically, the engineering of materials with some particular properties can be implemented by fabricating the structure of the materials, which can be achieved by controlling the formation kinetics. In detail, this concerns the establishment of the correlation between the structure and performance of the materials and the acquirement of formation kinetics of the materials. The latter should allow us to control the structure in order to acquire the materials with particular functionalities. In this regard, our aim is to demonstrate that based on the understanding of the formation mechanism of the materials, one can design and fabricate the materials of new functions and smartperformance/ultraperformance. The approaches described in this book will provide the readers with comprehensive knowledge and feasible approaches in designing and refining performance by tuning the network structure of the materials.

The book covers subjects related to important soft functional materials that have fibrous network structures. The materials include small-molecule physical

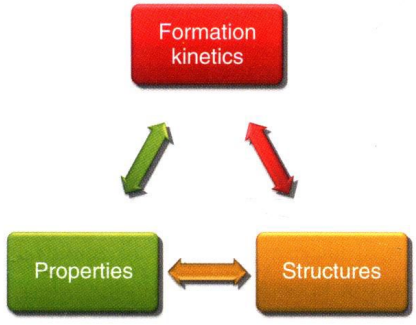

Figure 2 *Engineering triangle* from understanding to engineering: the engineering of materials with some particular in-use properties/performance is implemented by fabricating the structure of the materials. This can be achieved by controlling the formation kinetics.

gels, polymer gels, natural silk fibrous materials, and network materials based on nanofibrils, with respect to both the fundamentals, and the development and engineering methods. Their applications will concern drug delivery, home and personal care, macromolecule separation, catalysis, templating, tissue engineering, sensing, technical textiles and so on. It provides the reader with the necessary knowledge regarding chemical and physical formation mechanisms of these materials and demonstrates that one can rationally design and tune fibrillar networks so that the resulting materials exhibit desired functionalities. It also shows how materials from Nature, such as spider silk, can be adapted and functionalized for man-made applications and even mimicked in the laboratory.

The uniqueness of this book lies in the combination of the fundamentals of materials formation, engineering principles and approaches, and product design. The basic principles and sciences behind the technical approaches will be discussed in detail so that it is suitable to be adopted as a textbook for graduate students or specialists in this field. Numerous examples of applications and formulation based on the above engineering criteria are highlighted. Therefore, it can also serve as a comprehensive reference for the scientists and engineers working in related fields.

Xiang Yang Liu
Distinguished Professor

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