Preface

Progress in the rapidly developing area of nanoscience and nanotechnology will introduce new concepts and new scientific paradigm. The importance of injection and incorporation of new knowledge should not be excluded for the materials science. The integration of biomolecules with synthetic chemical methodology to form novel materials would be important as viewed from creation of functional devices and systems of the next era. In fact, general and active scientific effort is directed to the coupling of biological functions with synthetic materials trying to assemble intelligent processing devices that are anticipated to act as "artificial organs" with emergent functions.

The objective of this book is to provide biologists the comprehensive perspective of the science of polymer gels—"soft and wet matter"—and vise verse and invite materials scientists to the world of cytoskeletal proteins as bio-originated novel materials. Conjunction of biomolecules with the polymer science would yield novel hybrid devices with unique functions that provide fascinating scientific and technological interests.

Materials which consist of a cross-linked network of macromolecules with water filling the interstitial spaces of the network are called *hydrogels*. The important thing is that it is a comprehensive state of matter and shows both solid-like and liquid-like properties depending on the relaxation time and observation time.

Hydrogels are solids on the macroscopic level: they have definite shapes and do not flow. At the same time, they behave like fluid on the microscopic scale: water soluble molecules can diffuse through the network of the hydrogels. This important and unique characteristic of the gel is originated from the fact that the network polymer shows highly swelling property which, in turn, makes the network spaces penetrate water and give the viscoelastic mechanical responses. Regulated transportation of water, ions, and other physiological active substances and controlled viscoelastic properties are intrinsic to sustain the vital activity. This unique nature of the gel is the reason why the body of a living organism largely consists of soft tissue which is a state of hydrogel. In fact, various kinds of biopolymers consisting of proteins and

polysaccharides entangle, penetrate, and cross-link covalently each other to form the network structure. The network is useful to fill the water in its interstitial spaces and organizes the soft tissue of a living organism.

In accordance with these features of the polymer gel with soft tissue, gel researchers are actively developing synthetically derived tissue replacement technologies using hydrogels, both for temporary and permanent implants including cartilage, some artificial organs, and various medical devices. When implanted either blood- or tissue- contact implantation in vivo, they give good performances and the rapid progress is going on.

The application of hydrogels in the biomedical field is just a small example, and those especially prepared from synthetic polymer networks have numerous wide industry applications including food, pharmaceutical, chemical, and electronical industries. Superabsorbents which are widely used as a diaper consist of ionic polymer network and are able to absorb water several hundred to thousand times in weight. In addition, modulation of swelling forces in gel by chemical and physical stimuli enables dynamic control of hydration and diffusion of solutes, and therefore, a variety of bio-inspired soft and wet devices has recently been developed. The junction between polymer science and bio-inspired functions is introduced in Chap. 6 exemplifying various types of functional gels.

In this book newly obtained research results of hydrogels of cytoskeletal proteins performed by the project entitled "Molecular and System Life Science" at RIKEN are included. Considering the possible perspectives as novel materials, instead of intermediate fibers tropomyosin which is categorized as another cytoskeletal protein is highlighted together with actin and tubulin.

The book consists of seven chapters. The first and second chapters are dedicated to fundamental knowledges of hydrogels. The importance of the gel state of cytoskeletal proteins in living organism is also described (Y. Osada).

The following three chapters are dedicated to the procedure of preparation, basic structure, and behaviors of actin gel (K. Sano), microtubule gel (R. Kawamura), and tropomyosin gel (K. Sano), respectively. Detailed protocol of gel preparation, specified method of structure investigation, and unique functions of each cytoskeletal protein gel are explained. Dynamic studies of self-healing and autonomous oscillating functions of actin gel, integrated and synchronized motilities of microtubule gel, and enhanced cell-permeating properties of modified tropomyosin gel will be introduced emphasizing their emergent functions. As described in these chapters, the gels made from cytoskeletal proteins belong to the new family of biopolymer gels, and they are totally different from the common synthetic polymer gels from various aspects: they undergo reversible sol–gel transition polymerizing and depolymerizing upon environment, and they have multi-scale hierarchical structure with supramacromolecular size. Through the chapters the importance of multi-scale hierarchical structure will be emphasized to exert *emergent functions* that are critical for a living organism.

Many of the results described in this book were newly obtained by the research performed by Drs. R. Kawamura and K. Sano. They are the experts—biologists—invited together to RIKEN and who joined the research team "Molecular and System

Life Science Unit." This research was made possible by the strong financial supports of RIKEN and Toyota Motor Company from 2007 to 2011. The main purpose of this project was to open the door leading to establish a new biomaterials science and obtain a new class of hydrogels with emergent functions. We know that such attempt to open a new materials science requires much time to mature. If a steady and long-term continuing financial support by RIKEN and Toyota Motor Company were not made, this fundamental and pioneering study would not have been possible. We here express sincere thanks for their support. We are deeply indebted to Dr. Koji Kaya, the former director of Central Research Institute (RIKEN), who gave us the possibility to study this field and continuously encouraged and advised us. We would also like to thank all the research members of the "Molecular and System Life Science Unit" with whom I enjoyed the science.

This book is aimed to attract, to spark the imagination, to encourage scientists, and to step into this new materials science. Authors are happy if the collection of the different chapters will provide readers with a comprehensive perspective of this pioneering field.

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