Preface

Polymer gels, which have both solid- and liquid-like properties, are an astonishing and fascinating material. At a first glance, they are just composed of a cross-linked polymer network and interstitial fluid. The ability of cross-linked water-soluble polymers to absorb large amounts of water and to form hydrogels makes them ideal vehicles for the storage or transport of active ingredients. Polyelectrolyte gels have been developed as superabsorbent materials in diapers and for moisture control. These gels can contain over 99% water. The water uptake, the swelling process, is associated with a respective volume change. Hydrogels became part of our workaday life. Applications of hydrogels have become extraordinarily widespread, notably in food processing, cosmetics, pharmaceuticals, bio-technology, agriculture, and paint manufacturing.

Apart from the swelling, two other properties make hydrogels attractive.

First, a strong volume change can be excited by a large spectrum of different physical and chemical factors such as temperature, electrical voltage, pH, concentration of organic compounds in water, and salt concentrations. The possibility of a first-order volume phase transition in gels was suggested by K. Dušek and D. Patterson in 1968 based on an analysis of Flory–Rehner theory. It took ten years for the phenomenon to be experimentally observed after prediction. It was found by T. Tanaka that, when a critical amount of an organic solvent was added to a water-swollen poly(acrylamide) gel, the gel collapses. Many gels of synthetic and natural polymers have been studied. Subsequent experiments showed that a volume phase transition (swelling/collapse) could also be brought about by changes in other environmental parameters such as pH, ionic strength, and temperature.

Second, volume change due to these physical or chemical stimuli is reversible. Hence, hydrogels are chemomechanical transducers converting chemical energy into mechanical energy and vice versa. This offers a huge potential for new sensor and actuator principles especially for applications in all fields where aqueous solutions play a decisive role, e.g., in process engineering, fluidics, chemistry, cell biology, and drug delivery, and makes them real “smart” materials. Artificial muscles are another field where ionic hydrogels are getting more and more attention.

Most of the authors of this book are scientists from the Technische Universität Dresden, having been involved in the “hydrogel business” for many years. One of the roots for that was the Collaborative Research Center “Reactive Polymers” (spokesman: Prof. Hans-Jürgen Adler) established in 1996 at the TU Dresden and funded by the German Research Foundation (DFG Deutsche Forschungsgemeinschaft). One of the foci of this centre was to investigate the chemistry and the physics of hydrogels, their synthesis, and their integration into engineering solutions. The close collaboration between chemists, physicists, and engineers was the prerequisite to get a profound understanding of the complex interactions within smart hydrogels and their prospects for new sensor and actuator systems.

Undoubtedly, a single institution is not capable of dealing with all aspects of such a complex matter. This is the reason why we were strongly interested in enlisting colleagues from the Universities of Stuttgart and Freiburg as well as from the Max Bergmann Centre, Dresden, as experts for several aspects with important relevance to hydrogel sensors and actuators. We are deeply indebted to them.

The book is organized in the following manner. After a short introduction of the general properties of hydrogels, Chap. 2 discusses the fabrication of hydrogels. Afterward, Chap. 3 introduces the thermodynamic processes down to the molecular level taking place in hydrogels during swelling and shrinkage. Since Chaps. 2 and 3 describe the complex chemical, physical, and physicochemical properties of hydrogels, their number of pages is larger than that of the following chapters. We did not take them to pieces to show the interactions and relationships in its complexity, but we structured the text in subchapters such that each of them has its own reference list.

Based on the understanding of the chemical and physical effects, the chemo-electro-mechanical coupling in hydrogels will be presented in Chap. 4. To predict the functioning of hydogel-based devices, models are needed to describe the complexity of occurring interactions and to enable the simulation of technical devices. The following three chapters (Chaps. 5–7) focus on the application of hydrogels in chemical and biosensors and for actuators. Finally, Chap. 8 shows a particular application of hydrogels in cell biology as cell culture carriers.

The editors of this book hope that the contents depict the most recent progress in hydrogel research for sensor and actuator devices. As it can be seen, it still needs a lot of efforts to bridge the gap between state-of-the-art research and existing demands for a future market introduction. However, there are plenty of ideas to overcome the still remaining problems. Let the book be an inspiration to all the colleagues involved in hydrogel research and development!

We thank all our coauthors who have contributed their comprehensive knowledge with their particular competence to this book. We also thank those companies and institutions that allowed us to use figures and material and which are named in the captures of the individual figures. Furthermore, we thank Springer-Verlag and in particular Thomas Lehnert and Ulrike Butz for the cordial cooperation and also for the patience when faced with repetitive delays due to the authors’ workload. We are deeply grateful to the Springer staff for their support during the entire process, from the first idea all the way through to the final book.

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