Preface

Shape-memory polymers (SMP) are an emerging class of intelligent polymers, which are able to change their shape in a predefined way upon appropriate stimulation. Once processed into their permanent shape, SMP can be deformed and temporarily fixed in a second, temporary shape. This temporary shape is retained until the shaped body is exposed to an appropriate stimulus, which induces the recovery of the original shape. In this way SMPs remember a “memorized” shape. In the last decade, the interest in these smart materials rose enormously. On the one hand the technological significance of this technology became apparent because of its very broad applicability, ranging from established applications in packaging, electronics and textiles to highly sophisticated applications currently being developed in biomedicine and aerospace. On the other hand substantial progress was achieved in fundamental research, enabling stimuli other than heat to induce the shape-memory effect (e.g. alternating magnetic field or light) and the capability to perform more complex shape changes (e.g. two subsequent shape changes). Finally, the shape-memory effect could be successfully combined with other functions, such as biodegradability or electrical conductivity, resulting in multifunctional polymers. The fundamental knowledge about structure–function relationships offers the possibility of a targeted development of tailored SMP for specific applications. All this together makes this rapidly progressing research field very exciting.

In this volume the basic principles of shape-memory polymers and shape-memory polymer composites, as well as the related characterization methods are described. Furthermore, an overview of the application spectrum for SMP is presented, whereby special emphasis is given to biomedical applications.

In the first chapter actively moving materials are classified according to the mechanisms enabling the shape change. General molecular design principles are explained, supported by specific examples. The second chapter comprises shape-memory polymer composites. The improvement of mechanical properties and the implementation of novel functions such as electrical conductivity, magnetism, and biofunctionality originating from incorporation of layered silicate, polyhedral oligomeric silsesquioxanes, magnetic particles, carbon fillers, and hydroxylapatite are described. The shape–memory effect of an appropriate polymer results from a combination of its molecular structure and a tailored programming procedure. Specific characterization methods are required to explore the
structure–function relationships of SMP, which are discussed in chapter three. Besides characterization methods for molecular and morphological levels such as nuclear magnetic resonance (NMR) methods, differential scanning calorimetry (DSC), dynamic mechanical analysis at varied temperature (DMTA), polarized light microscopy (POM), scanning/transmission and atomic force microscopy, as well as wide and small X-ray scattering (WAXS, SAXS), characterization methods for the macroscopic level are described, including cyclic, thermomechanical tensile tests and bending tests. Finally, modelling approaches for simulating the thermomechanical behaviour of shape–memory polymers are presented.

In the fourth chapter, biomedical applications of shape–memory polymers are presented. Vascular, orthopaedic, and neuronal applications are elaborated to illustrate how SMP can improve the standard of treatment. Additionally, the practical challenges of the development of SMP for biomedical devices are described. The fifth chapter deals with multifunctional SMP. The combination of the shape–memory effect with hydrolytic degradability and the capability to release a drug in a controlled way are described as an example of multifunctionality. Drug loading and release, as well as the effects of the drugs on the shape–memory properties are discussed and potential applications in minimally-invasive surgery are outlined.

I thank all the authors who have contributed to this volume of Advances in Polymer Science. Ingrid Samide (Springer) and Karolin Schmälzlin (GKSS) are gratefully acknowledged for administrative support, and K.S. for her contribution to the preface. I hope that readers will appreciate the choice of the topics included in the book and will be stimulated by this fascinating field of polymer science.

January, 2010

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Shape-Memory Polymers
Lendlein, A. (Ed.)
2010, XII, 210 p. 101 illus., Hardcover
ISBN: 978-3-642-12358-0