Preface

On passing back through history and prehistory, one finds the Stone Age, the Bronze Age, and the Iron Age. Clearly, Man has in the past related the achievements of former generations to things solid and material – most likely because these materials have been rediscovered as artifacts, long after their day-to-day use. But today, we live in an era dominated by vast progress in the possibilities of information exchange, to a point where this period indeed may be referred to as the "Silicon Age". So, what might be the materials of the future?

Many well-established materials such as metals, ceramics, or plastics can no longer fulfill all of the needs of a technologically advanced society, and today a clear trend can be seen towards more complex functions that may be realized only with the use of materials of more complex composition and structure. At an early stage, engineers and scientists realized that, compared with their pure counterparts, mixtures of materials tend to show superior properties. Excellent examples of this are composite and hybrid structures, and especially those which contain an elastic, malleable organic component together with a hard, inorganic substance. For example, the addition of silica particles to the rubber used to make rubber tires enhances the tire's lifetime, while the properties of even a material as mundane as concrete can be "spiced up" with polymers.

Although, in terms of materials sciences, biominerals belong to this class of composites and hybrids, they also feature well-defined structures on several length scales, from the atomic scale to centimeter-sized functional arrangements of crystals in an organic matrix. In this way they demonstrate properties – or combinations of properties – which have not yet been achieved with synthetic hybrid materials. Thus, when using natural biominerals as a model, it is possible to prepare materials with both improved properties and applications.

Several different terms have been used to describe this approach, notably those appearing in the title of this Handbook, namely "biomimetic" and "bio-inspired". The process of mimicry involves constructing something that resembles the original as closely as possible, although this of course requires a detailed knowledge of the archetype. Inspiration, on the other hand, provides novel ideas which often appear as a "flash", even when observing the "original" only superficially. In fact, inspiration may even be hampered by too good a knowledge of the original, and by trying to follow it too closely. In this sense, we use the

Handbook of Biomineralization. Edited by P. Behrens and E. Bäuerlein

ISBN: 978-3-527-31805-6

term "biomimetic" when the scientific approach follows biomineralization so closely that it also allows conclusions to be drawn about the natural process. Bio-inspired materials are, correspondingly, much more loosely attached to archetype biominerals.

Part I of this volume begins with two chapters, by Behrens, Jahns, and Menzel, and by Brunner and Lutz, which focus on the biomimetic chemistry of silica deposition. On moving away from this amorphous material to crystalline substances, Cölfen's chapter on mesocrystals provides information on a novel model for crystallization processes and their products. Calcium carbonate is not only the most prominent natural biomineral, but also is highly suited to laboratory investigations, and this point is highlighted in chapters on the crystallization of calcium carbonate under monolayers (Volkmer), in layered organic systems resembling mollusk nacre (Imai and Oaki), or in eggshells (Arias, Arias, and Fernandez). de Masi and her co-workers then report on the biomimetic mineralization of protein aggregates. The next chapters, by Orme and Giocondi and by Faivre, describe the calcium phosphate and iron oxide systems, respectively.

Part II of the volume presents bio-inspired approaches to model certain structural features of biominerals, based either on a three-dimensional approach using ice crystals as a template (Deville, Saiz, and Tomsia), or by applying two-dimensional analogues (Helmecke, Behrens, and Menzel; and Tremel and co-workers). In Part III, we have collected "bio-supported" approaches, which do not aim to follow the self-aggregation and self-ordering processes of natural biomineralization, but rather use natural materials in shape-preserving reactions to imprint certain structural features on the resulting product. "Bioclastic" approaches using inorganic preforms are described by Sandhage et al. The use of organic plant tissues to generate inorganic macrostructures is summarized by Schwieger and Greil and their co-workers. In "bio-casting", the pores of biomineral skeletons are used as templates for the generation of macroporous structures (Meldrum).

Moving to smaller biological entities such as templates, Part IV contains details of studies conducted on the mineralization of protein cages (by Douglas and co-workers) and viruses (by Bittner). In Part V, the chapter of Boissière, Allouche, and Coradin on the medical applications of silica capsules formed with biopolymers, builds the first stages of a bridge to Volume 3 of this Handbook. The imaging methods described in the final part of this volume by Zolotoyabko and Stock, respectively, are of course important not only to the study of products of biomimetic, bio-inspired, bioclastic, biocast and synthetic products, but also to the investigation of biominerals themselves.

As editors, we hope that our collection of articles timely reflects the current importance of the field, and also highlights future trends – perhaps at the advent of the "Age of Complex Materials"? We thank all of the contributing authors for their commitment to this book, and especially Dr. Gudrun Walter from Wiley-VCH, without whose enthusiasm this Handbook of Biomineralization may not have materialized. We also thank Cornelia Meinertz-Bäuerlein and Birgit Förster for their ongoing secretarial support.

February 2007

Peter Behrens
Hannover
Germany

Edmund Bäuerlein
Munich/Martinsried
Germany