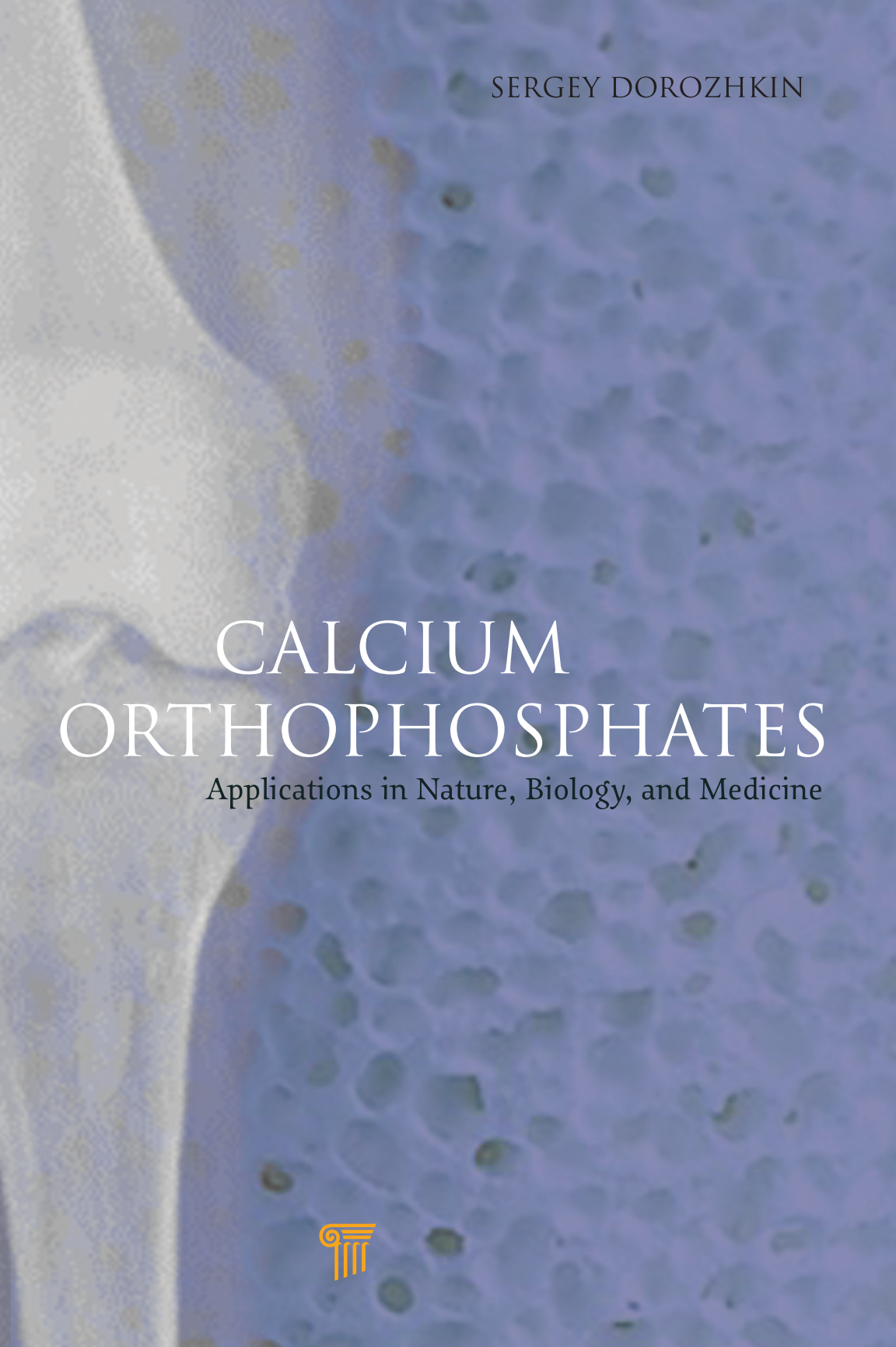
SERGEY DOROZHKIN
CALCIUM ORTHOPHOSPHATES
Applications in Nature, Biology, and Medicine

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Contents

Preface

Calcium apatites and other calcium orthophosphates have been of considerable interest to mineralogists, chemists, material researchers, biologists, and clinicians for many decades. The reasons for this are clear: Calcium apatites form the mineral component of bones and teeth, while some other calcium orthophosphates are involved in biomineralization process in mammals. Furthermore, calcium orthophosphates are found in pathological calcifications. Therefore, calcium apatites and other calcium orthophosphates appear to be biologically friendly inorganics and, thus, they are increasingly used as implantable biomaterials for various types of bone fillers and bone substitutes. As a final point, calcium apatites and other calcium orthophosphates are widely distributed minerals in Nature, providing the worlds supply of phosphorus, particularly phosphates for the production of fertilizers.

Due to the aforementioned, the scientific databases reveal that the research on calcium orthophosphates has a very long history. However, it exploded in the 1960s, and since then the number of publications permanently increased. Simultaneously, the variety of both investigations and biomedical applications of calcium orthophosphates are greatly expanding. Namely, calcium orthophosphate-based bioceramics specific to the *in vivo* applications have been designed, synthesized, investigated, and applied. Furthermore, new synthetic processes for the fabrication of calcium orthophosphates with the desired properties (such as, the Ca/P ratio, crystallinity, phase composition, particle shape and dimensions, ion-substitutions, etc.) have been also developed. Methods of the structural and surface analysis have also greatly progressed. For example, in early studies, the biological responses of living tissues to implanted materials were evaluated by optical microscopy. Nowadays, the biological analysis is performed at the molecular level in combination with the high-end physical techniques. In addition, long-term clinical data are now available. All these findings give the important suggestions for designing new types of calcium orthophosphate-based formulations for biomedical applications.

Therefore, the aim in writing this monograph has been to provide an integrated account of the present knowledge on preparation, chemical composition, structure, properties, and applications of all available calcium orthophosphates, particularly in the biomedical context. Since the entire subject appears to be very broad (over 30,000 publications on calcium apatites and other calcium orthophosphates have been already published), a great number of references to the related publications detailing various specific aspects of the matter have been collected.

The monograph consists of eight chapters. The division arrangement of the chapters is generally based on the subject, with subdivisions on the major aspects, such as introduction, basic definitions and knowledge, structure, preparation, properties, biomedical application, and future directions, ended up by conclusions. This overall scheme is used to emphasize the mutual interrelationships among various calcium orthophosphates. The main purpose has been to group the material in the most natural way and, if appropriate, to provide cross-references from other sections. This is sometimes done explicitly and sometimes by giving section references, where other aspects of the specific subject are discussed. Namely, Chapter 1 contains the general information on all available calcium orthophosphates, including their geological and biological occurrence, chemical composition, structure, solubility, and a brief information on their location in calcified tissues of mammals (bones, teeth, and antlers), including the unwanted (pathological) calcifications. Furthermore, Chapter 1 also encloses an important section on biomimetic crystallization, including artificial simulating solutions. Chapter 2 is devoted to the structure, chemical composition, properties, and biomedical application of amorphous calcium orthophosphates (ACPs), which erroneously are considered as individual compound, whereas in reality, they are just an amorphous (or a very poorly crystalline) state of other calcium orthophosphates. Chapter 3 focuses on the similar topics of nanodimensional and nanocrystalline calcium orthophosphates. The following three chapters are mainly devoted to various aspects of the biomedical applications of calcium orthophosphates. Namely, Chapter 4 describes the available knowledge on bioceramics, Chapter 5 concentrates on the self-setting formulations, and Chapter 6 is devoted to biocomposites and hybrid biomaterials. Chapter 7 appears to be more specific because it is devoted to a narrower subject of the

dissolution mechanism of both hydroxyapatite (HA) and fluorapatite (FA) in acids. This subject provides the chemical fundamentals for both dental caries and osteoporosis. Finally, Chapter 8 gives a brief historical overview on the calcium orthophosphate matter, which is just interesting to read.

To conclude, this monograph represents the author's vision on the topic, which by no means is ideal. Furthermore, since not each and every possible aspect of calcium apatites and other calcium orthophosphates has been described, various imperfections are possible. Thus, any criticism, opinions, or suggestions are always welcome. However, it is worth mentioning that the main goal is not only further development of the subject itself but also making a possible contribution to the welfare of human beings, in particular those with diseases potentially treatable by calcium orthophosphates.

Finally, I would like to acknowledge the continuous encouragement of my mother, Tamara, my wife, Elena, and my son, Denis. Hopefully, publication of this book will help the author find a suitable position in science or industry to provide a better financial support to the beloved members of his family.

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