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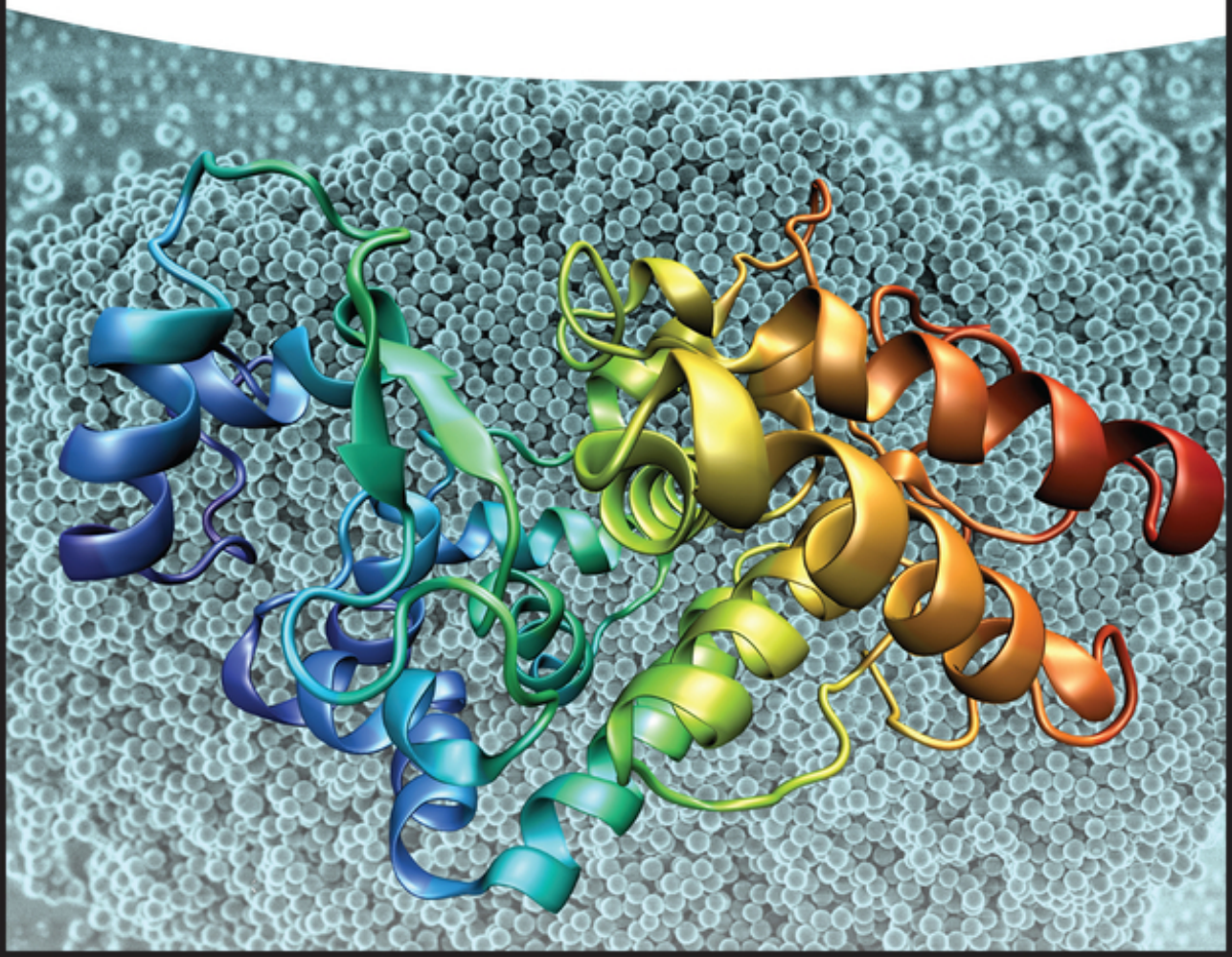
Surface-Functionalized Ceramics

For Biotechnological and Environmental Applications



Surface-Functionalized Ceramics

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Editors

Dr. Laura Treccani
CSMT Gestione S.c.a.r.l.
Polo Tecnologico – Innovative Contamination HUB
Via Branze 45
25123 Brescia
Italy

Dr. Fabian Meder
Istituto Italiano di Tecnologia (IIT)
Bioinspired Soft Robotics
Viale Rinaldo Piaggio 34
56025 Pontedera
Italy

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Dedications and Acknowledgments

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Personal Dedications

Laura Treccani *…to my grandmother Emma, my first scientific mentor*

I should thank countless people who in different ways have contributed to this work. A particular thanks to my former team at the University of Bremen. Thanks to Prof. Kurosch Rezwan and Prof. Georg Grathwohl for giving me the chance to join their Department as PostDoc. Thanks to Kurosch for believing in me and encouraging me. Thank you to my PhD students, students, colleagues, and in particular Tina Kuehn that contributed to amazing ideas and taught me new. I also thank Fabian Meder for joining me in this project.

A deep thanks to my family for supporting me through trying times, always believing in me, and for giving me strength.

Fabian Meder *…to my children, my wife, and family*

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Preface

The surface determines the reactions of materials and essentially qualifies them for specific applications, in particular in biological environments. Ceramic materials – here the high-tech advanced ceramics – can be fabricated in numerous shapes with tailored composition. Since a long time, ceramics are crucial in most scientific and industrial applications. Still, in the past two decades, surface functionalization technologies of ceramics have been revolutionized, allowing a combination of inorganic, organic, and biomolecular matter. This not only creates novel functionalities but also qualifies the final "advanced ceramics" for many new and advanced applications.

This book starts with an overview of the properties and manufacturing of ceramic materials and their surface functionalization – with a focus on biotechnological and environmental applications. Chapters 1 and 2 give an extended summary of compositions and structures of ceramics as well as the fabrication and processing techniques. This provides the necessary background in terms of materials science and processing in combination with selected application examples.

Techniques to vary physicochemical properties such as surface charges, chemical functions, and nanostructures are presented in Chapter 3. Chapter 3 focuses on the most important chemical surface functionalization techniques ranging from surface activation strategies to small molecule and large biomolecule attachment to create functionalities that do not exist in bare ceramics. The result is a new class of functional materials that combines the intrinsic versatility of ceramics with novel and moreover very useful functionalities.

It is, in the context of this book, absolutely necessary to discuss methods to access information on the quality and success of a surface functionalization process by characterization techniques spanning from topographical investigations, such as atomic force microscopy and surface chemical analysis, to the electrokinetic surface characteristics, and Chapters 4–6, respectively, are dedicated to surface analytics, including exiting relevant applications and theory.

Controlling and knowing the surface functionality is essential to understand and predict potential interactions of the functionalized ceramics in a biological environment such as the surface adhesion of biomolecules (Chapter 7) and bacterial interactions (Chapter 8). Such interactions essentially influence the success of the envisioned application, in a positive or negative manner, and the two chapters will introduce the essential processes of these biology–material interactions on the nano- and molecular scales.

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The overview of potential applications in a book about materials so versatile as functionalized ceramics can only be incomplete. Nevertheless, we aimed to give a focus on important – if not some of the most important – examples for the biotechnological and environmental fields such as novel carbon-based antibacterial surfaces (Chapter 9), biosensing and water quality monitoring (Chapter 10), and ceramic adsorbents for bioproduct recovery and purification (Chapter 11) among others.

Overall, with this book, we intend to supply the reader with sufficient fundamentals and examples on the opportunities of surface-functionalized ceramics to provide a general understanding and to provoke creative thinking and novel ideas for designing surface-engineered materials.

This book is for researchers (experimental or theoretical), undergraduate and graduate students of disciplines like materials science, biotechnology, and environmental sciences and related fields that want to get introduced in the pacing developing, interdisciplinary field of functionalized material surfaces, particularly ceramics. A secondary market are biotechnological industries and environmental sectors and their Research and Development (R&D) sections.

October, 2022

Fabian Meder
Istituto Italiano di Technologia, Genova, Italy

Laura Treccani
CSMT Gestione S.c.a.r.l., Brescia, Italy

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Foreword

Against the background of increasing population, we see the immense impact on the environmental pollution and associated climate changes. In this combination, we face today probably the biggest challenge to humankind in its history. In addition, everyone is or will be affected, without exceptions.

As a scientist and scholar, I do teach and educate young adults every day with my team at a university. Through our role at the university, we do shape the minds of these young people. Hence, we do shape tomorrow's society. However, what if there is no tomorrow? Having said this, we should all feel naturally obliged to make our own contribution to the best of our ability.

This is where I see the major and indispensable contribution of this book, showing an important area, where materials scientists can make a great impact toward tomorrow: By having a closer look at the materials interface to the biotechnological and environmental applications world, it gives a review of what is known today and pins down open challenging questions to be tackled at the same time.

Focusing on ceramic materials, it elucidates the strengths of this class of material toward biotechnological and environmental materials. By its inertness and hardness foremost, it is an ideal class of material to interact in a controlled manner with biological entities. At the same time, the inertness can be overcome by surface chemistry tailoring directed to a specific bifunctionality. This step, however, requires a great knowledge about details of ceramic surfaces and the targeted biological environment. By a sophisticated materials design, it can be achieved that biotechnological and environmental applications can reduce significantly energy consumption and environmental pollution. With a focus on antibacterial modifications and ceramic-based adsorbents for bioproduct recovery/purification, this book arches, in an excellent manner, fundamentals to applications, giving the reader a complete picture.

I personally believe that by arching the materials gap to the bioworld, this book helps materials scientists to contribute not only to a better tomorrow but more importantly to make sure that there will be a tomorrow.

With these words, I wish you many new insights and much pleasure in reading this book.

January 2022
Bremen

Prof. Dr.-Ing. Kurosch Rezwan
University of Bremen, Germany

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