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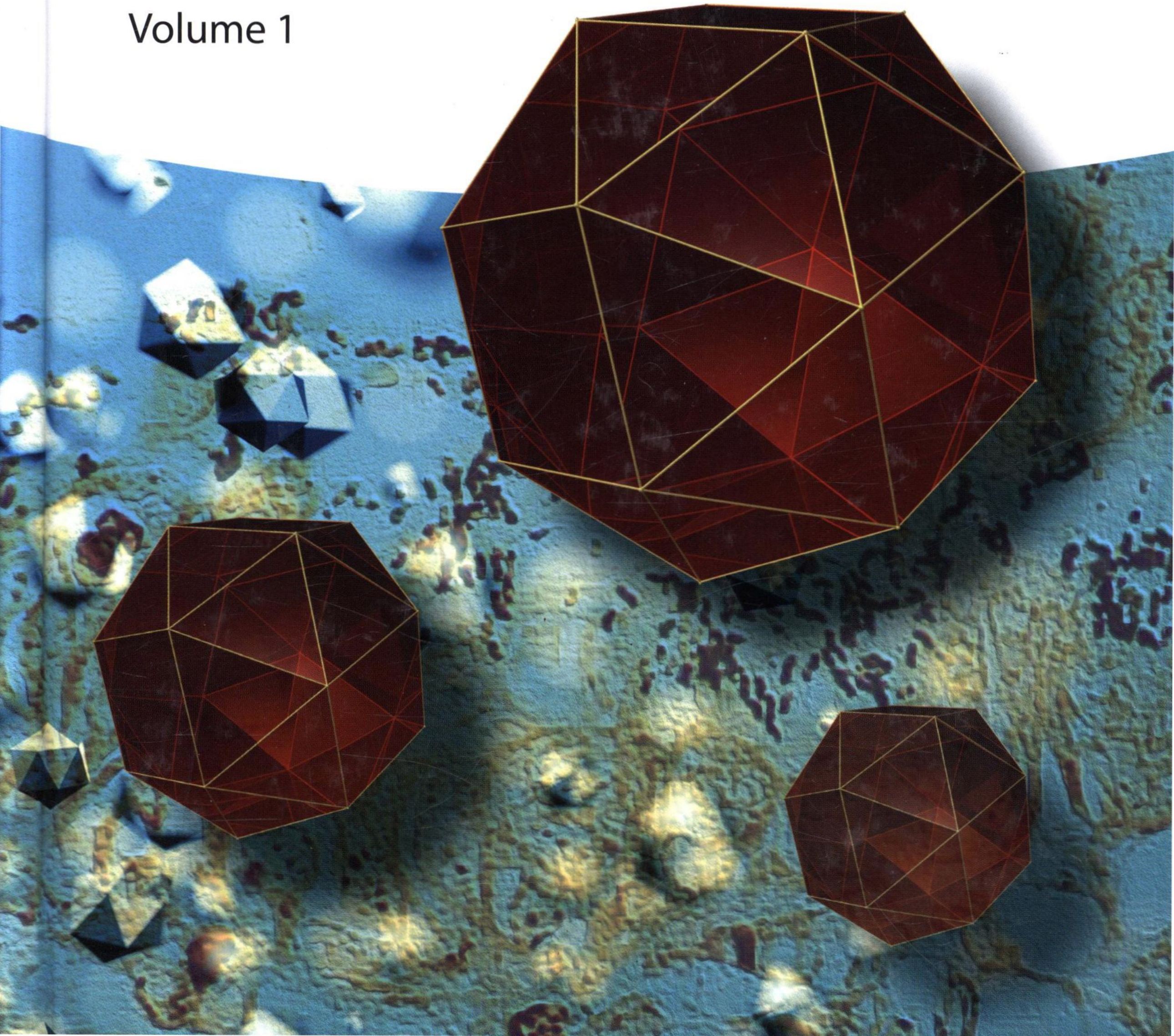
Edited by
Marie-Helene Delville and Andreas Taubert

Hybrid Organic–Inorganic Interfaces

Towards Advanced Functional Materials

Volume 1



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Hybrid organic–inorganic materials and the rational design of their interfaces open up the access to a wide spectrum of functionalities not achievable with traditional concepts of materials science. This innovative class of materials has a major impact in many application domains such as optics, electronics, mechanics, energy storage and conversion, protective coatings, catalysis, sensing and nanomedicine. The properties of these materials do not only depend on the chemical structure, and the mutual interaction between their nano-scale building blocks, but are also strongly influenced by the interfaces they share.

This handbook focuses on the most recent investigations concerning the design, control, and dynamics of hybrid organic-inorganic interfaces, covering: (i) characterization methods of interfaces, (ii) innovative computational approaches and simulation of interaction processes, (iii) in-situ studies of dynamic aspects controlling the formation of these interfaces, and (iv) the role of the interface for process optimization, devices, and applications in such areas as optics, electronics, energy and medicine.

Marie-Helene Delville *is a Senior Researcher at French National Centre for Scientific Research CNRS since 1985 and in the Institute of Condensed Matter of Bordeaux since 1997. Her research interests are focused on the fundamental and practical aspects involved in the synthesis of organic-inorganic colloidal nano-objects as well as the role of interfaces. She has been from 2012 to 2016, the chair of a European COST action (Action No MP1202, section Materials, Physics, and Nanosciences) concerning the "Rational design of hybrid organic-inorganic interfaces: the next step towards advanced functional materials".*

Andreas Taubert *is Professor of Supramolecular Chemistry at the University of Potsdam, Germany. After his PhD at the Max-Planck-Institute for Polymer Research in Mainz he was a postdoc at the University of Pennsylvania, USA, and then a group leader at the University of Basel, Switzerland. His research interests are bioinspired hybrid materials and materials chemistry with ionic liquids. Since 2010 he has been one of the organizers of a series of symposia on hybrid materials at the E-MRS Spring Meetings.*

Volume 1 of 2

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Hybrid Organic–Inorganic Interfaces

Preface

The Interface: A Key Issue in Hybrid Materials

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Hybrid materials are currently among the most intensely researched topics in chemistry, physics, biology, and engineering. This stems from the fact that the proper combination of organic, polymeric, and inorganic functional components often leads to the formation of new materials with interesting and useful physical properties that are superior to those found in other materials. Two main challenges in this context, however, are (i) the proper selection of the components to obtain a specific function and (ii) the a priori (rational) design of a material with predetermined properties for a specific application.

One of the key parameters in these complex advanced materials is the interface. Modern hybrid materials often contain more than one interface, and the physical properties (and hence the performance of a material) strongly depend on how processes at these interfaces take place. For example, the behavior of charge carriers in an electrochemical device such as a solar cell or a battery will directly influence the performance of this device. Control over the structure, the properties, and the dynamics of these interfaces is therefore of utmost importance for proper device operation. Poorly defined interfaces will lead to rapid degradation of a device or even its complete destruction.

As a result, understanding the structure and physical properties of hybrid materials and the ability to rationally design these parameters is one of the key requirements for successful materials development. This particularly applies to interfaces; they are the decisive factor controlling whether a device will function properly and efficiently or not.

Interfaces, however, are very difficult to fabricate, to design in detail, and to characterize. Consequently, the rational design of interface-based materials with preprogrammed interface chemistry and physics is not easily accessible, and often, the design of interfaces for specific applications relies on trial-and-error approaches. In light of the ever-growing need for such materials with ever-improved properties, trial-and-error methods toward hybrid materials with defined interfaces are not ideal. Rather, there is a need for rational approaches based on established fundamental and quantitative principles of solid-state materials formation, interface engineering, and interface design. Moreover, there is a need to understand the correlation between the structure and composition of the interface in relation to the rest of the material to achieve a synthesis-by-design approach toward specifically tailored hybrid materials with specifically tailored interfaces for every application necessary.

As the correlation of structure and properties in hybrid materials and interfaces is a complex and challenging task, there have been multiple attempts of providing platforms for the exchange of information on this topic on a larger scale. For example, the European Union has set up a highly successful COST Action, COST MP1202 coordinated by one of the editors of this book, to enhance and accelerate the development of hybrid materials and interfaces for essentially every application possible – from energy and environment to healthcare and beyond. A series of symposia on advanced hybrid materials at the E-MRS Spring Meetings in operation since 2010, again co-organized by one of the editors of this book, has been another successful outlet for research on hybrid materials and interfaces. There is, however, still a need to better connect individual research findings and groups and to compile the necessary information available on how functional hybrid interfaces can be designed for perfect performance such that researchers from all fields have direct and easy access to all necessary information on the topic.

The current book for the first time assembles contributions from experts in all fields of hybrid materials and interface synthesis, design, characterization, computation, and application to provide a compact yet informative and thorough overview over the field and its future perspectives. A major focus is on interfaces in 2D and 3D hybrid materials, their structure, properties, adaptation to different requirements, their analysis, and their application. Applications cover the most important fields such as energy, catalysis, gas separation, or healthcare.

The second section focuses on special aspects of the material–biology interface, largely with the challenges of modern healthcare in an aging society in mind. These chapters again provide an in-depth overview over recent developments, the state of the art, and future perspectives.

Finally, the third section focuses on computation and analysis of hybrid interfaces. Although the importance of this subject has long been recognized, the details of interface analysis are still challenging and new and interesting developments are to be expected in the future. Again, this section provides a detailed overview over the state of the art, and the entire book will provide an invaluable source of information both for the experts in the field and the newcomer interested in developing his or her own powerful research profile in the general area of hybrid materials and interfaces.

The editors of this book would like to express their gratitude not only to the team at Wiley-VCH for making this book possible but also to the numerous authors for their excellent and diverse contributions. It has been a pleasure working with everyone, and the editors hope that this book will foster further collaborations and projects, old and new, in this fascinating research field at the interface of chemistry, physics, biology, engineering, and everyday life.

Marie-Helene Delville and Andreas Taubert

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