

# Hybrid porous solids: past, present, future

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This critical review will be of interest to the experts in porous solids (including catalysis), but also solid state chemists and physicists. It presents the state-of-the-art on hybrid porous solids, their advantages, their new routes of synthesis, the structural concepts useful for their 'design', aiming at reaching very large pores. Their dynamic properties and the possibility of predicting their structure are described. The large tunability of the pore size leads to unprecedented properties and applications. They concern adsorption of species, storage and delivery and the physical properties of the dense phases. (323 references)

This new class of porous solids<sup>1</sup> emerged as a new domain of research ca. fifteen years ago. More or less considered at the beginning as a curiosity, it has transformed into a fully qualified field of research with an explosion of papers (Fig. 1). As usual for a new domain, most of the papers currently refer to new phases with their crystal structure and sometimes some indications about the porosity. It was a necessary step for justifying the richness of the field, as it was previously for the mesoporous compounds.<sup>2,3</sup> The latter impressed the community of zeolites and microporous phases by the huge gap in the dimensions of the pores. The interest towards hybrid porous solids concerns more the important increase in chemical versatility compared to 'classical' porous solids. The present contribution on hybrid solids will therefore be placed in the continuum of the story of porous solids, with their similarities with the other families, their advantages, their potentialities and the unprecedented properties they sometimes exhibit. It represents a global introduction to the domain of hybrid porous solids, not a complete review. Some of them have

already been recently published: for a detailed inventory of what exists see ref. 4–12.

## 1. Some definitions

Hybrid porous solids result from the reaction between organic and inorganic species in order to build up three-dimensional frameworks whose skeleton contains both organic and inorganic moieties only linked by strong bonds, at variance to supramolecular chemistry. Conceptually, there is no difference between classical inorganic porous solids and hybrid ones (Fig. 2). Indeed, the three-dimensional skeleton can be described for both of them by the association of secondary building units (SBU).<sup>13</sup> However, whereas the inorganic SBU contains only inorganic parts (tetrahedral species like SiO<sub>4</sub>, PO<sub>4</sub>, AsO<sub>4</sub>, SO<sub>4</sub>, associated with metallic cations in four-, five- or six-coordination), in the hybrid SBU, the anionic species are replaced by organic linkers, creating a contrast between the bonds within the framework: mainly covalent for the organic parts, ionocovalent for the inorganic. Moreover, as far as the porous character is concerned, organic ligands with multiple bonds must be preferred in order to ensure rigid topologies as for inorganic solids with an open framework.

The tremendous development of this family generated a new vocabulary. In the first hybrid open frameworks<sup>14–19</sup> the inorganic part contained either isolated polyhedra or small

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*structural chemistry of inorganic and hybrid porous solids, their mechanisms of formation and their applications in gas storage, drug delivery and nanosciences.*

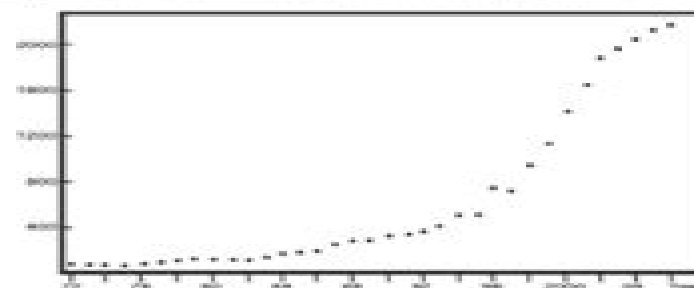


Fig. 1

# Reactivity In Solids Past Present And Future

**Victor M. Corman**



## **Reactivity In Solids Past Present And Future:**

**Reactivity of Solids** International Union of Pure and Applied Chemistry, 1996 1E 1976 Discus **Organic Molecular Solids** William Jones, 2019-09-17 Interest in organic molecular solids extends to a range of fields including chemistry physics electrical engineering and materials science In chemistry it applies to such topics as solid state reactivity crystal engineering theoretical approaches to crystal structure determination and morphology control In physics electrical engineering and materials science the possibility of producing organic based materials such as crystals polymers thin films or liquid crystals with potential electronic opto electronic and magnetic uses is a major area of current research interest throughout the world Organic Molecular Solids examines the uses of organic based materials over a wide range of applications and interests Each chapter surveys a relevant topic providing appropriate introductory background information and modern developments

**Functional Supramolecular Materials** Rahul Banerjee, 2017-05-09 This book provides a comprehensive review of the structure and function of organic and metal organic supramolecular materials which will be of interest to students and researchers in this field Thermal Decomposition of Ionic Solids A.K. Galwey, M.E. Brown, 1999-02-25 The principal objective of this book is to stimulate interest in research that will extend available theory towards a greater understanding of the steps involved in solid state decompositions and the properties of solids that control reactivities Much of the activity in this field has been directed towards increasing the range of reactants for which decomposition kinetic data is available rather than extending insights into the fundamental chemistry of the reactions being studied The first part of the book Chapters 1 6 is concerned with theoretical aspects of the subject The second part Chapters 7 17 surveys groups of reactions classified by similarities of chemical composition The final Chapter 18 reviews the subject by unifying features identified as significant and proposes possible directions for future progress Studies of thermal reactions of ionic compounds have contributed considerably to the theory of solid state chemistry Furthermore many of these rate processes have substantial technological importance for example in the manufacture of cement the exploitation of ores and in the stability testing of drugs explosives and oxidizing agents Despite the prolonged and continuing research effort concerned with these reactions there is no recent overall review This book is intended to contribute towards correcting this omission The essential unity of the subject is recognized by the systematic treatment of reactions carefully selected to be instructive and representative of the subject as a whole The authors have contributed more than 200 original research articles to the literature many during their 25 years of collaboration Features of this book Gives a comprehensive in depth survey of a rarely reviewed subject Reviews methods used in studies of thermal decompositions of solids Discusses patterns of subject development perceived from an extensive literature survey This book is expected to be of greatest value and interest to scientists concerned with the chemical properties and reactions of solids including chemists physicists pharmacists material scientists crystallographers metallurgists and others This wide coverage of the literature dealing with thermal reactions of solids will be of value to both

academic and industrial researchers by reviewing the current status of the theory of the subject It could also provide a useful starting point for the exploitation of crystalline materials in practical and industrial applications The contents will also be relevant to a wide variety of researchers including for example those concerned with the stabilities of polymers and composite materials the processing of minerals the shelf lives of pharmaceuticals etc

**Reactivity of Solids : Past, Present and Future , A Chemistry for the 21st Century monograph** ,1996 **Integrated Chemical Processes** Kai Sundmacher,Achim Kienle,Andreas Seidel-Morgenstern,2006-03-06 This is the first book dedicated to the entire field of integrated chemical processes covering process design analysis operation and control of these processes Both the editors and authors are internationally recognized experts from different fields in industry and academia and their contributions describe all aspects of intelligent integrations of chemical reactions and physical unit operations such as heat exchange separational operations and mechanical unit operations As a unique feature the book also introduces new concepts for treating different integration concepts on a generalized basis Of great value to a broad audience of researchers and engineers from industry and academia

*Handbook of Thermal Analysis and Calorimetry* Michael E. Brown,Patrick K. Gallagher,2003-12-08 This is the second volume of a four volume set intended to describe the techniques and applications of thermoanalytical and calorimetric methods The general techniques and methodology are covered extensively in Volume 1 along with the fundamental physicochemical background needed Consequently the subsequent volumes dwell on the applications of these powerful and versatile methods while assuming a familiarity with the techniques Volume 2 covers major areas of inorganic materials and some related general topics e g catalysis geochemistry and the preservation of art The chapters are written by established practitioners in the field with the intent of presenting a sampling of the how thermoanalytical and calorimetric methods have contributed to progress in their respective areas The chapters are not intended as exhaustive reviews of the topics but rather to illustrate to the readers what has been achieved and to encourage them to consider extending these applications further into their domains of interest Provides an appreciation for how thermal methods can be applied to inorganic materials and processes Provides an insight into the versatility of thermal methods Shares the experiences of experts in a variety of different fields A valuable reference source covering a huge area of materials coverage

**Reactivity of Molecular Solids** Elena Boldyreva,Vladimir Boldyrev,1999-10-18 Reporting on advances in the field of molecular solid state chemistry each volume focuses on selected areas and highlights methods and results in syntheses properties and applications The volumes in this series provide a forum for the discussion of chemical physical biological and crystallographic aspects of the molecular solid state Eight chapters focus on the theoretical aspects of the reactivity of solids and the applications that are of practical importance In a collection of reviews that highlight hot topics in the field of molecular solids the authors of this volume emphasise the problems facing them Contents Interplay between Intra and Intermolecular Interactions in Solid State Reactions Cooperative Effects in Solid State Reactions Some Aspects of

Bimolecular Photoreactions in Crystals Kinetics and Spatial Propagation of Intramolecular Reactions in Solids Kinetic Descriptions of the Simplest Bimolecular Reactions in Organic Solids Radical Solid State Reactions at High Pressure Polymorphs and Solvates of Molecular Solids in the Pharmaceutical Industry Mechanochemical Synthesis and Mechanical Activation of Drugs Reactivity of Molecular Solids will be of interest to all chemists working in the pharmaceutical fine chemicals and food industries and also in molecular electronics and materials science *Mechanochemistry in Nanoscience and Minerals Engineering* Peter Balaz, 2008-10-20 Mechanochemistry as a branch of solid state chemistry enquires into processes which proceed in solids due to the application of mechanical energy This provides a thorough up to date overview of mechanochemistry of solids and minerals Applications of mechanochemistry in nanoscience with special impact on nanogeoscience are described Selected advanced identification methods most frequently applied in nanoscience are described as well as the advantage of mechanochemical approach in minerals engineering Examples of industrial applications are given Mechanochemical technology is being applied in many industrial fields powder metallurgy synthesis of nanometals alloys and nanocompounds building industry activation of cements chemical industry solid waste treatment catalyst synthesis coal ashes utilization minerals engineering ore enrichment enhancement of processes of extractive metallurgy agriculture industry solubility increase of fertilizers and pharmaceutical industry improvement of solubility and bioavailability of drugs This reference serves as an introduction to newcomers to mechanochemistry and encourages more experienced researchers to broaden their knowledge and discover novel applications in the field **Modern Inorganic Synthetic Chemistry** Ruren Xu, Wenqin Pang, Qisheng Huo, 2011-01-13 The contributors to this book discuss inorganic synthesis reactions dealing with inorganic synthesis and preparative chemistry under specific conditions They go on to describe the synthesis preparation and assembly of six important categories of compounds with wide coverage of distinct synthetic chemistry systems **Introduction to Thermal Analysis** M.E. Brown, 2006-01-10 to Thermal Analysis Techniques and Applications Edited by Michael E Brown Chemistry Department Rhodes University Grahamstown South Africa KLUWER ACADEMIC PUBLISHERS NEW YORK BOSTON DORDRECHT LONDON MOSCOW eBook ISBN 0 306 48404 8 Print ISBN 1 4020 0472 9 2004 Kluwer Academic Publishers New York Boston Dordrecht London Moscow Print 2001 Kluwer Academic Publishers Dordrecht All rights reserved No part of this eBook may be reproduced or transmitted in any form or by any means electronic mechanical recording or otherwise without written consent from the Publisher Created in the United States of America Visit Kluwer Online at <http://kluweronline.com> and Kluwer's eBookstore at <http://ebooks.kluweronline.com> CONTENTS Preface to the First Edition Chapman Hall London 1988 ix About the First Edition of this Book x Preface to the Second Edition xi 1 INTRODUCTION 1 1 Definition and History 1 1 2 Thermal Analysis Instruments 4 References 11 2 THERMAL EVENTS 2 1 Introduction 13 2 2 The Solid State 13 2 3 Reactions of Solids 14 2 4 Decomposition of Solids 15 2 5 Reaction with the Surrounding Atmosphere 16 2 6 Solid Solid Interactions 16 References 17 3

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 Dibyendu Sarkar,Rupali Datta,Robyn Hannigan,2011-09-14 This volume is for environmental researchers and government  
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 initiated organic reactions This book considers transformations of organic substances upon      *High-Pressure*  
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crystallographers potentially interested in high pressure as a variable as well as an introductory guide to new researchers in the field     High-Pressure Crystallography Elena Boldyreva,Przemyslaw Dera,2010-09-03 This unique book is devoted to the theme of crystallographic studies at high pressure It places emphasis on the phenomena characteristic to the compressed state of matter as well as experimental and theoretical techniques used to study these phenomena     **High-Energy Ball Milling** Małgorzata Sopicka-Lizer,2010-05-24 Mechanochemical processing is a novel and cost effective method of producing a wide range of nanopowders It involves the use of a high energy ball mill to initiate chemical reactions and structural changes High energy ball milling Mechanochemical processing of nanopowders reviews the latest techniques in mechanochemistry and how they can be applied to the synthesis and processing of various high tech materials Part one discusses the basic science of mechanochemistry with chapters on such topics as the mechanism and kinetics of mechanochemical processes kinetic behaviour in mechanochemically induced structural and chemical transformations and materials design through mechanochemical processing Part two reviews mechanochemical treatment of different materials including synthesis of complex ceramic oxides production of intermetallic compound powders synthesis of organic compounds synthesis of metallic ceramic composite powders and activation of covalent bond based materials Part three covers mechanochemical processes in metal powder systems and other applications with coverage of topics such as plating and surface modification using ultrasonic vibrations activated powders as precursors for spark plasma sintering titanium dioxide photocatalyst synthesis by mechanochemical doping and synthesis of materials for lithium ion batteries With its distinguished editor and international team of contributors High energy ball milling Mechanochemical processing of nanopowders is a standard reference for all those involved in the production of ceramic and metallic components using sintering and other powder metallurgy techniques to produce net shape components Examines the latest techniques in mechanochemistry and how they can be applied to the synthesis and processing of various high tech materials Discusses the basic science of mechanochemistry including kinetic behaviour processes and mechanisms and materials design through mechanochemical processing Reviews mechanochemical treatment of different materials including synthesis of ceramic oxides organic compounds and metallic ceramic composite powders     *Proceedings of the Symposium on High Temperature Corrosion and Materials Chemistry* Electrochemical Society. High Temperature Materials Division,Electrochemical Society. Corrosion Division,Electrochemical Society. Meeting,1998     Chemical Abstracts Service Source Index American Chemical Society. Chemical Abstracts Service,1907 A key source to journal and conference abbreviations in the sciences Although it focuses on chemistry other scientific and engineering disciplines are also well represented In addition to the abbreviation and full title each entry also contains publishing info title changes language and frequency of publication and libraries owning that title Over 130 000 entries representing more than 70 000 publications dating back to 1907 are included

**Particle Breakage** Agba D. Salman,Mojtaba Ghadiri,Michael Hounslow,2007-11-01 Particle breakage is an important

process within a wide range of solids processing industries including pharmaceuticals food agricultural and mining Breakage of particles can be defined as intentional and unintentional depending on whether it is desired or not Through understanding of the science and underlying mechanisms behind this phenomenon particle breakage can be either minimised or encouraged within an efficient and effective process Particle Breakage examines particle breakage at three different length scales ranging from single particle studies through groups of particles and looking at solid processing steps as a whole This book is the widest ranging book in the field and includes the most up to date techniques such as Distinct Element Method DEM Monte Carlo simulations and Population Balance Equations PBE This handbook provides an overview of the current state of the art and particle breakage From the small scale of a single particle to the study of whole processes for breakage both by experimental study and mathematical modelling Covering a wide range of subjects and industrial applications Allows the reader an understanding of the science behind engineered breakage processes Giving an unrestrictive and interdisciplinary approach



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