

## Review

# Highly Reactive Thermite Energetic Materials: Preparation, Characterization, and Applications: A Review

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**Abstract:** As a promising kind of functional material, highly reactive thermite energetic materials (tEMs) with outstanding reactive activation can release heat quickly at a high reaction rate after low-energy stimulation, which is widely used in sensors, triggers, mining, propellants, demolition, ordnance or weapons, and space technology. Thus, this review aims to provide a holistic view of the recent progress in the development of multifunctional highly reactive tEMs with controllable micro/nano-structures for various engineering applications via different fabricated techniques, including the mechanical mixing method, vapor deposition method, assembly method, sol-gel method, electrospinning method, and so on. The systematic classification of novel structured tEMs in terms of nano-structural superiority and exothermic performance are clarified, based on which, suggestions regarding possible future research directions are proposed. Their potential applications within these rapidly expanding areas are further highlighted. Notably, the prospects or challenges of current works, as well as possible innovative research ideas, are discussed in detail, providing further valuable guidelines for future study.

**Keywords:** energetic materials; nanostructures; thermites; systematic classification; exothermic performance; broad prospects

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## 1. Introduction

Energetic materials (EMs), regarded as a kind of promising functional material, can generate enormous amounts of thermal energy at a high rate of heat release within a surprisingly short time (< 1 s) after a small energy stimulation, and are widely used in the fields of sensors, trigger, mining, propellants, demolition, ordnance or weapons, civilian and military [1–4]. With the rapid development of nanotechnology, designing nano-energetic materials (nEMs) with nanostructured-fuel and oxidizer has attracted increasing attention, especially in the last two decades [5,6]. Compared with traditional micro-EMs, nEMs have a faster burning rate and a more intense loading process due to a larger contact area and shorter mass transfer distance among reactants during the exothermic reaction process [7,8], and their superior structure and performance advantages allow them to exhibit wider application potentials in micro-electro-mechanical systems (MEMS), lab-on-a-chip devices, miniaturized or sophisticated weapons and equipment [9–14].

As the promising subclass of nEMs, highly reactive thermite EMs (tEMs) with an outstanding heat release ability due to high reaction enthalpy have drawn increasing interest and have wide application prospects in the fields of sensors, microelectronics, propeller machinery, miniaturized detonating primers and advanced military industry

# Preparation And Characterization Of Materials

**Jurgen M. Honig, Chintamani Nagesa  
Ramachandra Rao**



## **Preparation And Characterization Of Materials:**

**Preparation and Characterization of Materials** Jurgen M. Honig, Chintamani Nagesa Ramachandra Rao, 1981 Crystal growth and other preparation techniques Selected characterization techniques Ferroics Layered materials and surface treatment Metal oxides and other electronic materials Amorphous materials including glasses High temperature ceramics

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*Molecular Materials* Sanjay Malhotra, B. L. V. Prasad, Jordi Fraxedas, 2017-05-12 The field of molecular materials research looks at the preparation and characterization of potentially useful materials with enhanced physical chemical and biomedical properties Molecular Materials Preparation Characterization and Applications discusses the cutting edge interdisciplinary research in the area of advanced molecular based materials This book explores multiple aspects of molecular materials including their synthesis and characterization and gives information on their application in various fields **Materials**

**Preparation and Characterization** PENNSYLVANIA STATE UNIV UNIVERSITY PARK MATERIALS RESEARCH LAB., 1971 The report brings together reports on the research of faculty affiliated with the Materials Research Laboratory at the Pennsylvania State University It includes but is not limited to the research supported by the Advanced Research Projects Agency The report brings together under new headings the interrelated work conducted by faculty members with backgrounds in a variety of disciplines In addition it singles out certain classes of materials receiving special attention as follows Preparation of materials Characterization of materials Properties of materials Noncrystalline solids including glasses Solid state geoscience and biosciences The report also includes a description of the extensive efforts of the laboratory under the heading of Science and Technology Transfer and finally appends a bibliography of papers published during the last twelve months reprints of which are available upon request Author Preparation and Homogeneity Characterization of an

Austenitic Iron-chromium-nickel Alloy Harvey Yakowitz, Arthur W. Ruff, Robert Ernest Michaelis, 1972 **Structural Design and Controllable Preparation of the Function-Directed Crystalline Materials** Maochun Hong, 2023-11-21 This book presents the findings of a major research program investigating structural design and controllable preparation of function directed crystalline materials The program was launched by the National Natural Science Foundation of China during the 11th Five Year Plan period which was started in October 2008 and concluded at the end of 2016 This book first summarizes the overall scientific objectives and the current state of the art of crystalline materials research in China and the international frontier It also focuses on exploring the relationships between structures compositions and properties of crystalline materials and proposes new mechanisms and models for new materials exploration In addition it introduces a new functional motif theory that can guide the development of crystalline materials with optical electrical and other composite

functions and presents new research methods for the controlled synthesis and assembly of crystalline materials and detection and characterization of functional motifs Furthermore practical applications for materials such as photoelectric conversion materials nonlinear optical materials laser and fluorescent crystal materials and ferroelectric and microwave dielectric materials have been described Given its scope this book is of interest to researchers who work in crystalline materials It also promotes the multidisciplinary collaboration among chemistry materials science and physics *Molecular Materials* Sanjay Malhotra, Jordi Fraxedas, Amitava Patra, B. L. V. Prasad, 2016-03-15 The field of molecular research looks at the preparation and characterization of potentially useful molecular materials with enhanced electronic and biomedical properties The book discusses the cutting edge interdisciplinary research in the area of chemistry surface science and materials The book gives information on the application of materials in various fields such as solid state electronics energy environment communication agriculture bio materials fine chemicals and pharmaceuticals The book focuses on the latest developments in the application of materials science in daily life NBS Special Publication, 1966 *Annual Report of the National Bureau of Standards* United States. National Bureau of Standards, 1961 **Technical Highlights of the National Bureau of Standards** United States. National Bureau of Standards, 1965 *Sample Preparation Techniques for Chemical Analysis* Massoud Kaykhaii, 2021-12-22 Despite having powerful software microchips and solid state detectors that enable analytical chemists to achieve fast stable and accurate signals from their instruments sample preparation is the most important step in chemical analysis Issues can arise at this step for various reasons including a low concentration of analytes incompatibility of the sample with the analytical instrument and matrix interferences This volume discusses the basics of sample preparation and examines modern techniques that can be used by both novice and expert analytical chemists Chapters review microextraction surface spectroscopy analysis and techniques for particle tissue and cellular separation Preparation and Use of Superconductive Fixed Point Devices, SRM 767 James F. Schooley, R. J. Soulen, George Albert Evans, 1972 Hearings, Reports and Prints of the House Committee on Appropriations United States. Congress. House. Committee on Appropriations, 1968 *Preparation of NBS Copper-base Spectrochemical Standards* Robert Ernest Michaelis, Leroy Linwood Wyman, Richard Flitsch, 1964 *Preparation of NBS White Case Iron Spectrochemical Standards* Robert Ernest Michaelis, Leroy Linwood Wyman, 1964 **Flame Retardant Polymeric Materials** Yuan Hu, Xin Wang, 2019-08-22 Flame Retardant Polymeric Materials provides a comprehensive and up to date overview of the field from basic properties and mechanisms of action for flame retardants to emerging methods materials and industrial applications With over 120 black and white images Hu and Wang cover the latest in the development of novel polymer nanocomposites such as graphene CNTs LDHs POSS and techniques such as layer by layer assembly These expert authors also include discussions on the important flame retardant systems based on phosphorus silicon and boron In doing so they highlight the use of flame retardants in varying industries for example construction textiles and aviation This comprehensive handbook is an essential

read for students and academics of physics with a particular interest in flame retardant materials It would also be recommended for professionals within the materials science and engineering fields

**Advanced and Emerging Polybenzoxazine Science and Technology** Hatsuo Ishida,Pablo Froimowicz,2017-01-18 Advanced and Emerging Polybenzoxazine Science and Technology introduces advanced topics of benzoxazine resins and polybenzoxazines as presented through the collaboration of leading experts in the benzoxazine community representing the authoritative introduction to the subjects Broad topics covered include the recent development and improved understanding of the subjects including low temperature cure aerogels and carbon aerogels smart chemistry in fire retarding materials and coatings metal containing benzoxazines rational design of advanced properties and materials from natural renew In the past twenty years the number of papers on polybenzoxazine has continuously increased at an exponential rate During the past three years the number of papers published is more than the previous 17 years combined The material is now part of only a few successfully commercialized polymers in the past 35 years Therefore interest in this material in both academia and industry is very strong Includes the latest advancements in benzoxazine chemistry Describes advanced materials such as aerogels carbons smart coatings nanofibers and shape memory materials Includes additional characterization data and techniques such as FT IR Raman NMR DSC and TGA analyses

**Sustainable Materials and Systems for Water Desalination** Inamuddin,Anish Khan,2021-09-30 This edited book explores the most promising and reliable technological developments expected to impact on the next generation of desalination systems The book includes research studies which takes the reader on a fascinating walk through the multidisciplinary world of membrane science applied to water treatment Concerning the ultimate technological advancement the book seeks to investigate how to bridge the gap between the laboratory scale and the applicability to industry

**Aerospace Materials Handbook** Sam Zhang,Dongliang Zhao,2016-04-19 Whether an airplane or a space shuttle a flying machine requires advanced materials to provide a strong lightweight body and a powerful engine that functions at high temperature The Aerospace Materials Handbook examines these materials covering traditional superalloys as well as more recently developed light alloys Capturing state of the art developments in materials research for aeronautical and aerospace applications this book provides a timely reference for both newcomers and veteran researchers in the field The chapters address developments in bulk materials coatings traditional materials and new materials Beginning with an overview of superalloys including nickel nickel iron and cobalt based superalloys the text covers machining laser cladding and alloying corrosion performance high temperature oxidation thermal spraying and nanostructured coatings It also includes four categories of composites used in aerospace metal matrix polymer carbon nanotube reinforced polymer and self healing composites The text describes preparation processing and fatigue of lightweight magnesium alloys as well as an exciting new class of materials aerogels This book brings readers to the cutting edge of research in materials for aerospace and aeronautics It provides an entry point into this field and presents

details to stimulate future research This unique up to date resource offers knowledge to enable practitioners to develop faster more efficient and more reliable air and spacecraft

Thin Films: Preparation, Characterization, Applications Manuel P. Soriaga, John Stickney, Lawrence A. Bottomley, Youn-Geun Kim, 2012-12-06 This book is about thin films what they are how they are prepared how they are characterized and what they are used for The contents of this book not only showcase the diversity of thin films but also reveals the commonality among the work performed in a variety of areas The chapters in this volume are based on invited papers presented by prominent researchers in the field at a Symposium on Thin Films Preparation Characterization Applications at the 221st National Meeting of the American Chemical Society held in San Diego California The coverage of the symposium was extensive topics ranged from highly ordered metal adlayers on well defined electrode surfaces to bio organic films on non metallic nanoparticles An objective of this book is for the readers to be able to draw from the experience and results of others in order to improve and expand the understanding of the science and technology of their own thin films systems

Preparation And Characterization Of Materials: Bestsellers in 2023 The year 2023 has witnessed a remarkable surge in literary brilliance, with numerous captivating novels captivating the hearts of readers worldwide. Lets delve into the realm of top-selling books, exploring the engaging narratives that have enthralled audiences this year. The Must-Read : Colleen Hoover's "It Ends with Us" This heartfelt tale of love, loss, and resilience has captivated readers with its raw and emotional exploration of domestic abuse. Hoover skillfully weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can succeed. Uncover the Best : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This spellbinding historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids compelling storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Preparation And Characterization Of Materials : Delia Owens "Where the Crawdads Sing" This captivating coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens weaves a tale of resilience, survival, and the transformative power of nature, entrancing readers with its evocative prose and mesmerizing setting. These popular novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of engaging stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a brilliant and suspenseful novel that will keep you guessing until the very end. The novel is a cautionary tale about the dangers of obsession and the power of evil.

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