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Nanoparticle Technology Handbook

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second edition

NANOPARTICLE TECHNOLOGY HANDBOOK

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Preface

The Nanoparticle Technology Handbook was the first handbook to be published in the field of nanoparticle technology around five years ago. Since then, nanoparticle technology has further advanced and been applied in many new applications. In response to the demand, it was decided to publish a second edition of the Handbook. The editors are very pleased to see the advancement of this technology and to be engaged in the publication of the second edition.

However, we regret to inform our readers of the sad news that the chief editor of the Handbook's first edition, Mr. Masuo Hosokawa, passed away on March 31, 2010 after a short stay in the hospital, at the age of 85. In fact, he initiated the idea of publishing a handbook for nanoparticle technology. He had been greatly interested in particles and fine powders for many years and had developed various advanced machines such as a unique fine grinding mill and an air classifier in the 1950s, which led to many awards for him, including two decorations from the Japanese government.

His enthusiasm and desire to seek extremely small particles and their innovative properties resulted in the invention of the concepts of MechanoFusion and MechanoChemical Bonding (MCB) technologies, which are in principle based on the mechanical activation of fine particles for particle bonding and surface modification to create new functional materials. Since the 1980s he also introduced some useful technologies to generate nanoparticles by the bottom-up method and proposed nanoparticle technology long before former President Bill Clinton's National Nanotechnology Initiative in 2000. Starting with the evaporation method to make metal nanoparticles and then moving to use CVD methods to create composite nanoparticles, he succeeded in bringing new systems for nanoparticle generation to the commercial market. In addition, in 1991 he founded the Hosokawa Powder Technology Foundation and in 1983 published the first issue of the English technical journal, "KONA Powder and Particle Journal".

In the meantime, publication of the first edition of the Handbook, Nanoparticle Technology had advanced and been employed in various applications. In the second edition, 16 new articles have been added in the application section for subjects related to polymer/filler composites; electronic devices such as displays, sensors and memories; batteries/fuel cells; cosmetics; DDS and biomaterials for medical devices; color materials; environmental protections; etc. During this period of time, there were some epoch-making incidents in the commercialization of some technologies. Fuel cells have been introduced for power generation and heat supply in residential and commercial uses and lithium ion batteries have begun to be adopted by electric and hybrid vehicles for transportation use. Additionally, the nuclear power plant accident caused by the big earthquake and tsunami in the Tohoku area of Japan in March 2011 had an enormous impact on power supply and environmental protection issues related to the life style and way of thinking of the country's population. From these viewpoints, nanoparticles have great potential to contribute to the establishment of a sustainable living environment for human beings by making use of their high functionality and excellent performance.

The editors are grateful to the Hosokawa Powder Technology Foundation for its support and to all the contributors for their cooperation and wish that the second edition of the Handbook would be helpful to readers in understanding the basics of nanoparticles and to provide hints to their application.

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Preface to the first edition

During the last few years the term "Nanotechnology" is increasingly employed to describe the process technologies and analytical techniques for material in the ultrafine range of the order of a millionth of a millimeter. Because they are sure to take an important part in shaping the 21st century, great attention is being paid to these technologies, with many countries actively involved in R&D. As the link between these new technologies and the established particle and powder technology, "Nanoparticle technology" includes the concepts and know-how to create, process and apply the ultrafine particles in the nanometer range, and is one of the key technologies for new material developments.

The technologies that are used to treat powders arrived with mankind, and countless inventions and improvements have been made during history. These particles and powders have very different properties from the bulk materials from which they are derived. There are applications to be seen in all industrial areas.

The history of the academic study of particle and powder technology is not so old. The first related society, Chubu Association of Powder Technology, was founded in Japan in 1956. It later became the Society of Powder Technology, Japan, and celebrated its 50th anniversary in 2006. Correspondingly, the Hosokawa Micromeritics Laboratory was established in 1956 and published its 50th anniversary issue of the annual technical journal *Funsai* (*The Micromeritics*) also in 2006.

Throughout this period a key issue has been to reduce the size of particles to maximise their functional properties and thus find new applications and create new products with superior performance. Great interest has been shown in submicron and even finer particles. Research and development has advanced at a rapid rate due to the cooperation of academia and industry in many areas, starting with particle creation and particle size analysis, and expanding to encompass particle design and processing in the micron- and nanometer-size ranges. Japan has been at the forefront in the conception and development of these technologies.

Due to this interest, the second World Congress in Particle Technology (WCPT) was held in Kyoto in 1990. Eight years later at the 3rd WCPT in Brighton, the author highlighted the importance of these ultrafine particles to an audience of about 700 researchers and engineers during the opening speech. Hosokawa Micron Corp., which celebrated its 90th anniversary in 2006, has been engaged in R&D on particle creation by the build-up (*bottom up*) method in both gaseous and liquid phases for more than 20 years. The result of this research, as combined with that on conventional grinding (*top-down*) processes, has led to the establishment of a mass production system for nanoparticles and to the foundation of a business based on application of these nanoparticles to functional materials.

Founded 15 years ago, the Hosokawa Powder Technology Foundation holds an annual symposium on powder technology for the exchange of information on particle engineering and powder technology. Since 2001, the main topics of the symposium have, in response to the requirements of industry, been related to nanoparticles and nanostructure control. The number of grant proposals received by our Foundation for research into nanoparticles continues to increase, and currently 40% of some 120 proposals relate to nanoparticles.

As a result of this trend, we published 3 years ago, the book *Nanoparticle Technology* to promote nanoparticle-related engineering by documentating the technologies constituting in this field. That book was very well received, and to continue contributing to the common welfare through the promotion of powder technology, we decided to systematically update *Nanoparticle Technology*, adding further developments and many examples of applications. The results of that effort were published in the form of a handbook, first in Japanese in the memorable year 2006, and with the present volume, in English this year. Although R&D in nanoparticle technology advances rapidly, and the contents of the future editions are sure to change, we hope the present collation of state-of-the-art knowledge and information will be of assistance to the researchers, engineers and others interested in this vitally important field.

In closing, I express my sincere sense of gratitude to the authors, the editing committee and the publishing staff for their great efforts in spite of their busy schedules.

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From the Editors

As the size of a solid particle decreases in the order of one millionth of a millimeter, the number of atoms constructing the particle becomes small and in the order of several hundreds or thousands. At this state, the fundamental physical property such as the melting point can change drastically and ceramic materials may be sintered at a lower temperature. Also, as particles get smaller than the wavelength of visible light, they not only become transparent but also emit special light by plasma absorption. They show completely different electromagnetic or physicochemical properties from their bulk counterparts, although they are made of the same materials.

The authors published a book *Nanoparticle Technology* in Japanese in November 2003, which focused on the technology of handling nanoparticles that have unique properties and enormous potential usefulness. This book has drawn great attention from the readers and a growing demand to publish a handbook has developed, which systematically collects the basic information on nanoparticle technology with recent industrial applications.

Nanoparticle Technology to prepare, process, and apply nanoparticles plays a very important role in the development of nanotechnology. It also pays attention to various applications like life sciences, energy, environment, information technology, new materials, etc. However, there has been no handbook or manual on this technology so far. This is the first handbook written in English for handling nanoparticles and surveying their related processing technologies. It has been long awaited by researchers and engineers interested in nanoparticles or their use in the R&D of advanced materials.

This handbook systematically summarizes the fundamentals and state-of-the-art information in various industrial applications related to nanoparticles. However, since the advancement in the fields of concern is so rapid, not only the application developments but also the new physical properties and measuring methods from fundamental research become available as time goes by. Therefore, we plan to revise the contents of the handbook according to new technology developments in the future.

This handbook consists of fundamental and application sections including processing, evaluation, and application in a way different from other similar conventional handbooks. In the fundamental section, the basic properties, structural control of nanoparticles, nanostructural control, and property characterization with the measuring methods in the dispersed particle system are elucidated in detail mainly from the aspects of material processing and property evaluation. At the end of Fundamental Section, a chapter discussing the environmental and safety impact of nanoparticles is also included.

In the Application Section, various nanoparticle applications in the fields of life sciences, environment, energy, information technology, new materials, and production methods are listed according to their future market potential with focus on the new functionalities of nanoparticles.

To publish this handbook, we invited manuscripts from leading researchers and engineers specialized in a broad range of applications of concern as shown in the list of contributors. We would like to thank all the authors who contributed manuscripts despite their busy schedules and our colleagues in Hosokawa overseas operations as well as the staffs of the publisher for their generous supports. We are also deeply indebted to Dr. Y. Tsuji, Managing Director of Hosokawa Powder Technology Foundation and Dr. C. C. Huang of Hosokawa Micron Powder Systems, who gave us many useful comments on the English manuscripts, and to Ms. S. Nakai for her assistance in the preparation of the manuscript and proof.

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