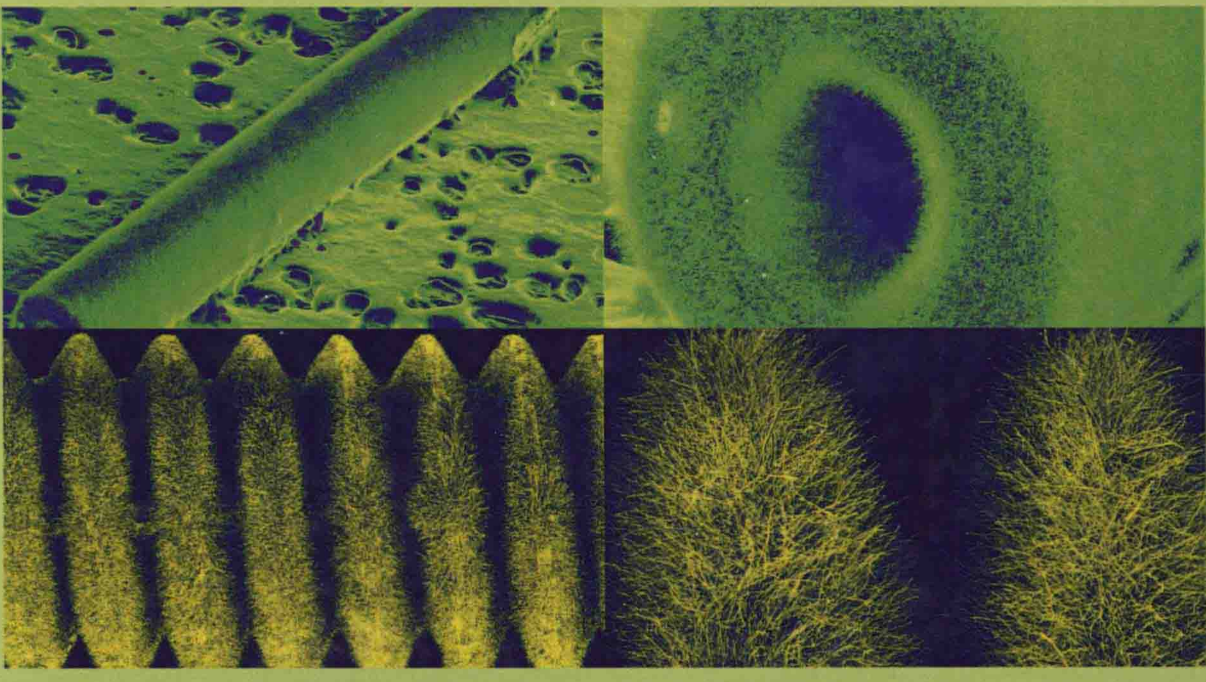
# NANOTUBES AND NANOSHEETS

## Functionalization and Applications of Boron Nitride and Other Nanomaterials



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# NANOTUBES AND NANOSHEETS

# Preface

There are many books about carbon nanotubes and graphene, but this is the first book dedicated to nanotubes and nanosheets made of boron nitride (BN). BN is isostructural to carbon (C) and exists in various crystalline forms. The hexagonal form (h-BN) is analogous to graphite, and the cubic form (c-BN) is similar to diamond. BN nanotubes have exactly the same structure as C nanotubes. Because B and N are neighbors to C on the periodic table, BN nanotubes have a similar density and the same excellent mechanical strength as C nanotubes. Other one-dimensional BN nanomaterials such as nanowires, nanoribbons, nanofibers, and nanorods have also been developed. Recently, inspired by graphene, BN nanosheets (sometimes called white graphene) have been intensively investigated. Although these BN nanomaterials have the same structures and many similar properties to their C counterparts, they cannot replace but only complement each other in many applications.

As this book shows, BN nanotubes and nanosheets are almost electrically insulating, chemically inert, resistant to oxidation at high temperatures, radiation shielding, and biologically safe. These properties have led to many exciting applications where C materials cannot be used, including high-temperature, metal- and ceramic-based composites, substrates for graphene and other semiconducting layers in electronic devices, reusable absorbents for oil and other contaminants, dry solid lubricants, and biomedical applications.

Although BN is akin to a sibling of C in the nanomaterial family, it has received much less attention. One main reason is that the synthesis of BN nanotubes and nanosheets is so complicated that many popular processes used for C nanomaterial production do not work efficiently for BN. Many authors of this book attended the 13th International Conference on the Science and Application of Nanotubes held in Brisbane, Australia, June 25–29, 2012. A symposium dedicated to BN nanotubes and nanosheets was an integral part of the conference for the first time. All participants realized the need to promote research in BN nanomaterials, and this book is one of the outcomes. As exciting new research results in BN nanomaterials continue to appear, many more books will follow.

This book is a reference work that reveals the innovative research work on BN nanotubes and nanosheets. The contributors include many active researchers working in different areas of BN nanomaterials—from synthesis and characterization to computer simulation and applications. An important focus of the book is the applications of BN nanotubes and nanosheets, which are also the focus of current nanotechnology research. Without practical applications, new materials will not have a long-term future. The book describes various applications, including BN nanotube–reinforced, metal- and ceramic-based composites, field emission, desalination, cleanup of oil spillages, biosensing and bioimaging, drug delivery, and biomedical applications, as well as energy storage using BCN and $TiO_2$ nanorods and nanosheets as electrode materials. The book also includes chapters on C and other nanotubes and nanosheets to give readers a broad view of current nanomaterials research.

Finally, I thank my family for their support; my staff, students, collaborators, and colleagues for their important contributions; and the staff at Taylor & Francis Group for their assistance in publishing this book.

# Editor

**Professor Ying (Ian) Chen** is chair of nanotechnology at the newly established Institute for Frontier Materials at Deakin University and node head of the ARC Centre of Excellence for Functional Nanomaterials. Professor Chen invented the ball-milling and annealing method, making his team a world leader in nanomaterials synthesis and commercialization. His research at Deakin University focuses on fundamental research in nanomaterials for energy storage (batteries and capacitors), environmental protection, and medical applications.

Professor Chen earned his BS from Tsinghua University in Beijing, People's Republic of China, and his PhD from the University of Paris-Sud, France. He is listed by the Web of Knowledge as the top author on the two subjects of nanotubes and ball milling. He has contributed to three best-selling books on nanotechnology published by CRC Press. His publications have been cited more than 3000 times over the past 10 years. Professor Chen is a fellow of the Institute of Physics and member of the American Physics Institute, the Materials Research Society, the Australian Materials Union, and the International Mechanochemical Association. He has been honored with several prestigious awards, including Australian Research fellowships from the Australian Research Council and the "1000 Talents" professorship in 2011.

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