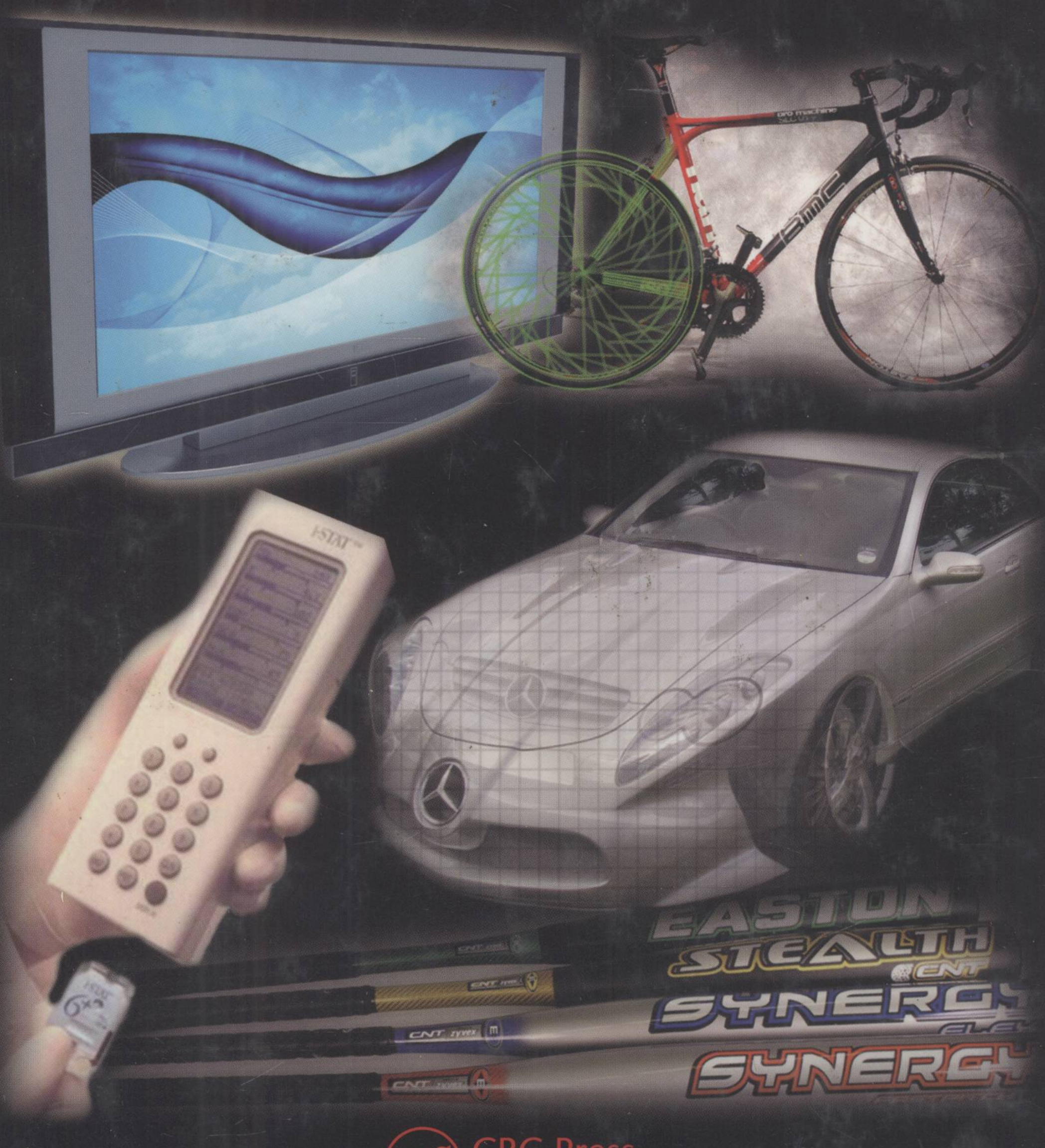
Commercializing Micro-Nanotechnology Products

Edited by David Tolfree and Mark J. Jackson



CRC Press
Taylor & Francis Group

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-13: 978-0-8493-8315-1 (Hardcover)

Library of Congress Cataloging-in-Publication Data

Tolfree, David, 1938-
Commercializing micro-nanotechnology products / David Tolfree and Mark J. Jackson.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-8493-8315-1 (alk. paper)
1. Nanotechnology. 2. Microtechnology. 3. Nanotechnology--Economic aspects. 4. Microtechnology--Economic aspects. I. Jackson, Mark J. II. Title.

T174.7.T65 2007
620'.50688--dc22 2007025686

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FIGURE 6.7 Airbag module (Bosch) source.

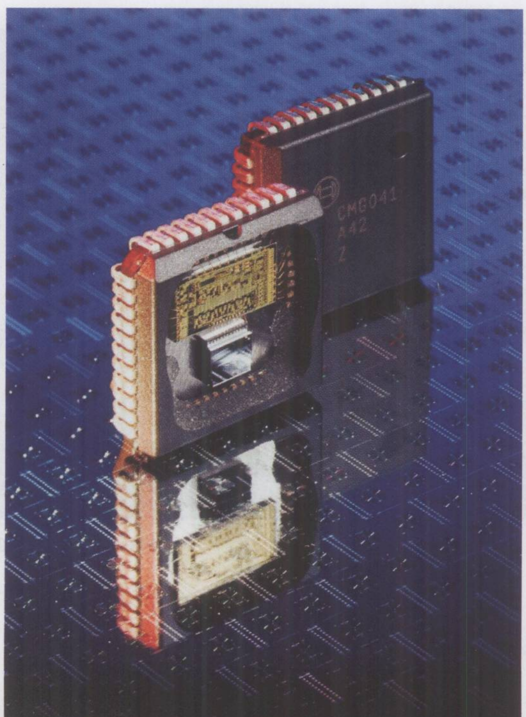

FIGURE 6.8 Gyro sensor (Bosch source).

FIGURE 1.6 I-stat blood analyzer and cartridge.

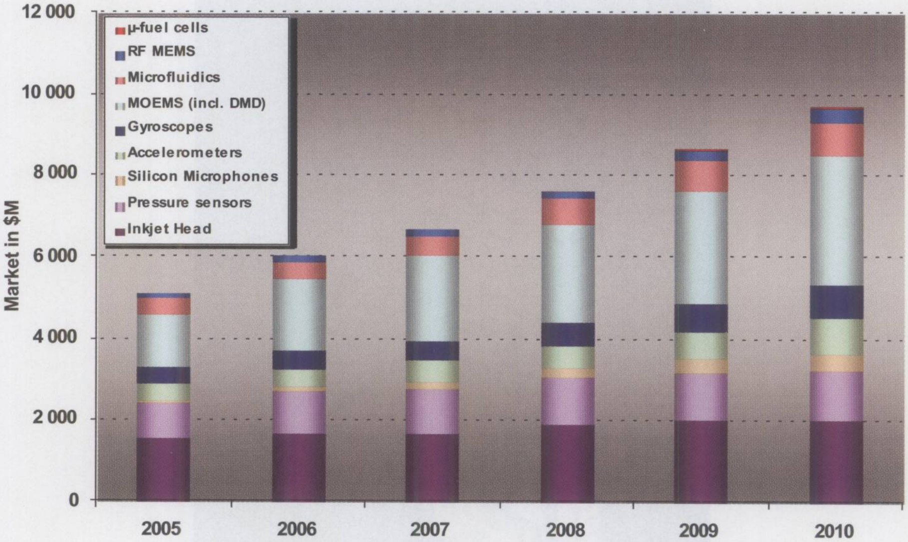

FIGURE 6.3 Value of the MEMS markets.

FIGURE 8.7 Four NanoEffector® Probes in a Zyvex nanomanipulator.

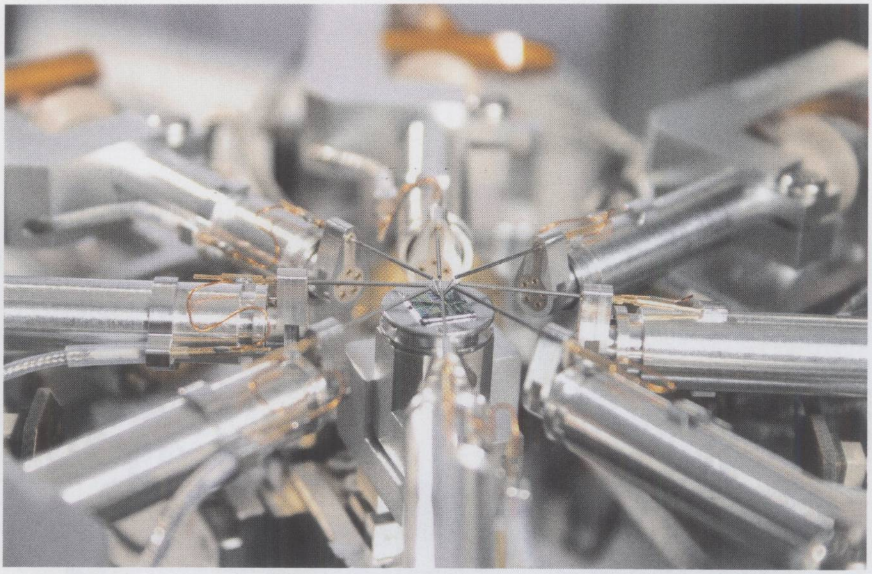

FIGURE 8.5 Zyvex nProber with positioners aligned 250 microns apart from each other, just a few millimeters above the center stage.

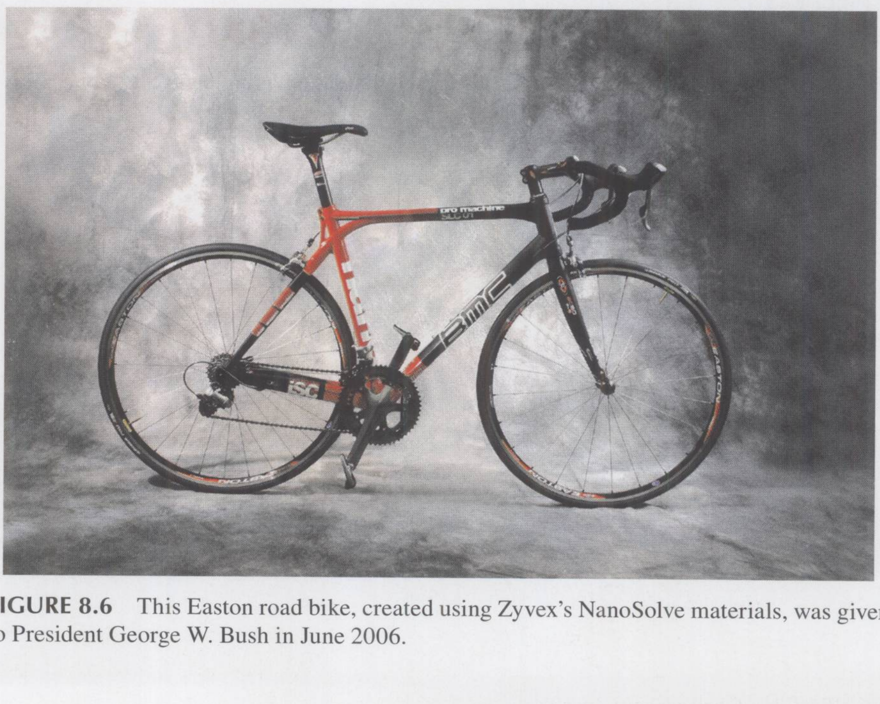

FIGURE 8.6 This Easton road bike, created using Zyvex's NanoSolve materials, was given to President George W. Bush in June 2006.

FIGURE 9.14 **(d)** Robotic system for mounting and assembling Respimat.

FIGURE 9.24 Respimat production line.

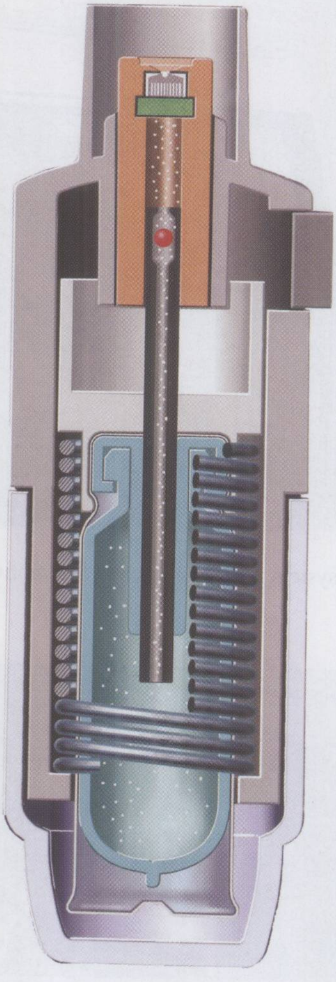

FIGURE 9.12 Schematic diagram Respimat brochure.

Preface

Now, in the first decade of the twenty-first century, we are witnessing a quiet manufacturing revolution resulting from the rapid advances made in science and technology in the twentieth century. We are now in the information age and the third industrial revolution based on a knowledge-driven economy. Small technologies, led by micro-nanotechnology, the products of physics, chemistry and engineering and more recently biology, are key drivers of this economy. They are already impacting industries and are having a profound effect on the way people live and work.

The ubiquitous use of computers and mobile telephones in industry and commerce, satellite links for communication, improved protective sunscreens, cosmetics, stain-resistant fabrics, composite materials for vehicles and sports equipment, portable diagnostic medical devices, targeted drug delivery systems, fire and water resistant coatings and materials for fuel cells are among some of the products currently on the market or are near-market. There is the promise of many more products in the foreseeable future. The further application of these technologies to manufacture new products and systems is well underway in the US, Asia and Europe but their potential disruptive nature, coupled with public concerns about some aspects of nanotechnology, have raised possible health issues that need to be examined.

The emergence of the global market is producing unparalleled opportunities but is also forcing up the pace of international competition. Nations that have a strategy for economic development based on innovation and the exploitation of science and technology, since they are the key to wealth creation and prosperity, will become leaders in this market. We can expect a high demand for new products, systems and services to meet the growing needs of the new economies of Europe and Asia. It is predicted that the global market for micro-nanoproducts and systems will exceed $1 trillion in the next decade.

Companies create wealth from the commercial exploitation of their intellectual property. Taking the results of research to full commercialization requires experience in design, manufacturing and marketing and a suitable infrastructure that encourages innovation and the training of technologists and engineers with an understanding of business. Competitive advantage is gained by deploying such a workforce for the development and realization of low cost, high quality products and services that offer at the right time unique advantages to the buyer. Failure to do this will put delays in the full commercialization cycle.

Most Governments in the industrialized world are funding micro-nanotechnology research and development because of the economic benefits they will bring to their countries. At present the number of companies that have been successful in markets for micro-nanoproducts is relatively small but this is expected to grow significantly in the coming years. There is an urgent need to: raise awareness, encourage private investment, establish reliable manufacturing processes and agree on standards for design.

The manufacturing of micro-nanotechnology products raises particular challenges and important fundamental issues related to costs, yields and reproducible quality and acceptability. It is clear that new manufacturing methodologies and processes will have to be developed together with metrology systems, particularly for nanomanufacturing. These will need to extend across multi-disciplinary domains (mechanical, electrical, optical, chemical and biological etc.) if a wide range of new products and systems are to be realized. The challenge facing nations, regions and companies who embrace micro-nanotechnologies is to understand how to manage the economic and social changes they will bring about.

The chapters in this book have been written by some of the world's leading academics and practitioners. Chapter 1 sets the scene by taking the reader along the path to product commercialization, detailing the steps that are needed to convert an idea into a marketable product. Examples are given of products that have successfully entered the market. The authors relate their own experiences in developing and bringing micro-nanoproducts to the market. Chapter 2 is about the importance of entrepreneurship, what is needed to build a successful start-up business and the steps that need to be taken to finance and develop a marketing strategy.

Roadmaps are essential tools for planning a future business or helping decision-makers to develop future strategies. Roadmapping nanotechnology is relatively new, so in Chapter 3 the authors discuss the various definitions of nanotechnology and how the issues they raise relate to the production of roadmaps. The various types of roadmaps and the methods used to collect information and produce them are described. In Chapter 4, the role of government agencies, private investors and corporations in expediting technology transfer from universities is covered with particular reference to the US National Nanotechnology Initiative.

Public research organizations carry out much of the research and development in micro-nanotechnology. This can raise problems when reaching out into the commercial market place. In Chapter 5, the authors describe their experiences on how the Dutch Institute of Nanotechnology known as Mesa +, located within the University of Twente, developed a commercialization strategy based on a partnership with government and industry by applying the Triple Helix concept which is described in the text. The roles of the partners and the collaboration process at three levels, the conceptual level, the procedural level and the operational or practical level are described.

Commercialization is about making products that sell in the market place. First, there has to be a market and then a knowledge of how to access it. In Chapter 6, Jean-Christophe Eloy, the Director of Yole Dévelopement, a market research and strategy consulting company and world leader in the analysis and evaluation of the MEMS markets, explains how such markets are developed and analyzed. Examples are given with illustrations of a number of products such as ink-jets and pressure sensors and the markets they supply.

In the remaining Chapters, 7, 8 and 9, three leading micro-nanotechnology development and manufacturing companies in the UK, US and Germany describe how their businesses started and progressed to become market leaders. They provide a valuable insight into how they overcame the difficulties of raising finance and finding the right product to develop for the growing market for micro-nanoproducts.

Their experiences will be a valuable aid to anybody or any company wishing to follow a similar path to commercialization.

In the concluding Chapter 10, the author takes an optimistic but realistic view of how the new technologies will shape the future. Based on current developments, he makes some guarded predictions up to 2030. Beyond that although predictions are tainted with speculation they can help readers visualize the shape of things to come.

The book gives an appraisal of the current status of small technologies and their ability to produce and commercialize new products and systems. An outlook and future perspective of how micro-nanotechnologies will change the future is given to help those concerned about economic and social change. It will be of specific interest to people, companies, and governments wishing to invest in these new technologies and find out about more about the path to commercialization.

The editors wish to thank all the chapter authors for their valued contributions to this book and to the many other professionals from whom we sought knowledge and assistance. We particularly acknowledge the proofreading skills of Valerie Tolfree, the wife of the lead editor, whose patience and encouragement helped in the writing of this book.

David Tolfree and Mark J. Jackson
Editors

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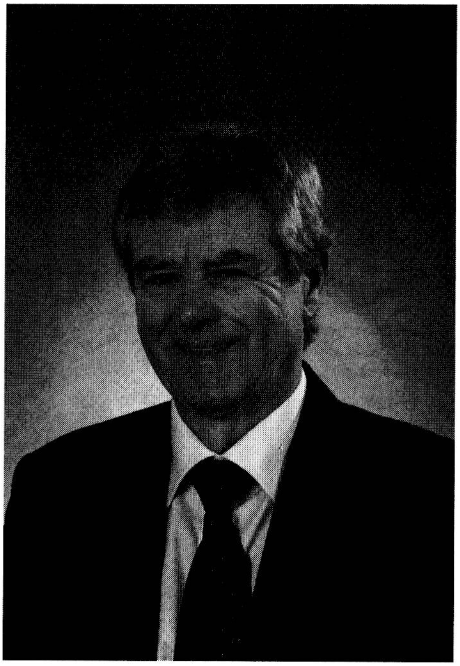

David Tolfree, MSc., F.Inst.P., CPhys., F.IoN. is the co-founder and Executive Director of Technopreneur Ltd, a consultancy company for the exploitation of micro-nanotechnology, established at Daresbury in Cheshire, England. He is one of the founders of MANCEF (Micro and Nanotechnology Commercialization Educational Foundation), an international body dedicated to commercialization and education, and is currently its European Vice-President. David is also one of the founders of the UK Institute of Nanotechnology and is a member of its Advisory Board. He is a Chartered Physicist, a Fellow of the Institute of Physics and the Institute of Nanotechnology and has published over 130 papers, including news articles, chapters for books and conference papers, and has given interviews on television and radio. He is internationally recognized as an authority on the exploitation of micro-nanotechnology and co-authored chapters in the MANCEF International Microsystems and Top-Down Nanotechnology Roadmap. He is currently the guest editor and contributor to the International Journal of Nanomanufacturing; and is also on the advisory boards of a number of international conferences.

David gained over 40 years' experience in research, project management and the marketing of research facilities while employed by the Council for the Central Laboratory of the Research Councils (CCLRC) at Daresbury in the UK. His earlier career was spent doing basic research in nuclear particle and accelerator physics, reactor instrumentation, and nuclear weapons development. In 1994, whilst working at the Daresbury Laboratory, he was the first to establish non-silicon microfabrication technology in the UK, transferring much of it from Germany. At that time he was appointed to be the UK coordinator of the first European R&D Network in Microtechnology involving nine countries. He established the first industry-led UK network in LIGA technology, known as the LIGA Club, and acquired over £300K of industry funding for prototype microstructure development using deep X-ray lithography. Afterwards, he created the SMIDGEN (Small Microengineering Intelligence Design Generation Exploitation Network), a consortium of companies and universities, to drive the commercial exploitation of microsystems technologies.

Acknowledged by the UK Government's Foresight Directorate as an example of best practice, it laid the early foundations to the UK MNT Network, part of Government's £92 million Micro and Nanotechnology Manufacturing Initiative established in 2003.

In 2004 David originated a successful proposal to the UK Northwest Development Agency to create a National Microsystems Packaging Centre in the North West of England. Since that time he has been proactive in the exploitation of micro-nanotechnology, working with Government Departments, Regional Development Agencies, companies, research institutes and universities worldwide. In 2005 he was the co-director of the COMS2005 international conference at Baden-Baden in Germany and a session chair at the COMS2006 conference in St Petersburg, Florida. He was on the Joint Organizing Committee of the COMS2007 conference held in Melbourne, Australia and is currently co-chair of the International HARMST-LIGA Commercialization Group.

Mark J. Jackson, Ph.D., M.A., C.Eng., M.Eng. is Professor of Mechanical Engineering at The College of Technology, Purdue University. He began his engineering career in 1983 when he studied for his O.N.C. part I examinations and his first-year apprenticeship-training course in mechanical engineering. After gaining his Ordinary National Diploma in Engineering with distinctions and I.C.I. prize for achievement, he read for a degree in mechanical and manufacturing engineering at Liverpool Polytechnic and spent periods in industry working for I.C.I. Pharmaceuticals, Unilever Industries, and Anglo Blackwells. After graduating with a Master of Engineering (M.Eng.) degree with Distinction under the supervision of Professor Jack Schofield, M.B.E., Dr Jackson subsequently read for a Doctor of Philosophy (Ph.D.) degree at Liverpool in the field of materials engineering focusing primarily on microstructure-property relationships in vitreous-bonded abrasive materials under the supervision of Professor Benjamin Mills. He was subsequently employed by Unicorn Abrasives' Central Research & Development Laboratory (Saint-Gobain Abrasives' Group) as materials technologist, then technical manager, responsible for product and new business development in Europe, and university liaison projects concerned with abrasive process development. Mark Jackson then became a research fellow.

In 2004 he moved to Purdue University as Associate Professor of Mechanical Engineering in the Department of Mechanical Engineering Technology. Mark is active in research work concerned with understanding the properties of materials in the field of micro scale metal cutting, micro and nano abrasive machining, and laser micro machining. He is also involved in developing next generation manufacturing processes and biomedical engineering.

Mark Jackson has directed, co-directed, and managed research grants funded by the Engineering and Physical Sciences Research Council, The Royal Society of London, The Royal Academy of Engineering (London), European Union, Ministry of Defense (London), Atomic Weapons Research Establishment, National Science Foundation, N.A.S.A., U. S. Department of Energy (through Oak Ridge National Laboratory), Y12 National Security Complex at Oak Ridge, Tennessee, and Industrial Companies, which has generated research income in excess of $15 million. Mark has organized many conferences and served as the General Chair of the International Surface Engineering Congress. He has authored and co-authored over 150 publications in archived journals and refereed conference proceedings, has edited a book on 'microfabrication and nanomanufacturing,' is guest editor to a number of refereed journals, and has edited a book on 'surgical tools and medical devices'. He is the editor of the 'International Journal of Nanomanufacturing,' 'International Journal of Molecular Engineering,' International 'Journal of Nanoparticles,' 'International Journal of Nano and Biomaterials,' and is on the editorial board of the 'International Journal of Machining and Machinability of Materials' and 'International Journal of Computational Materials Science and Surface Engineering.'

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