WTEC Panel on

NANOSTRUCTURE SCIENCE AND TECHNOLOGY

R&D Status and Trends in Nanoparticles, Nanostructured Materials, and Nanodevices

FINAL REPORT

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Richard W. Siegel, Panel Chair
Evelyn Hu, Panel Co-Chair
Donald M. Cox
Herb Goronkin
Lynn Jelinski
Carl C. Koch
John Mendel
M. C. Roco
David T. Shaw

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International Technology Research Institute
World Technology (WTEC) Division
Loyola College in Maryland

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WTEC PANEL ON NANOPARTICLES, NANOSTRUCTURED MATERIALS, AND NANODEVICES

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Richard W. Siegel (Panel Chair)
Materials Science and Engineering Dept.
Rensselaer Polytechnic Institute
110 Eighth Street
Troy, New York 12180-3590

Evelyn Hu (Panel Co-Chair)
Center for Quantized Electronic Structures
University of California
Santa Barbara, CA 93106

Donald M. Cox
Exxon Research & Engineering
Clinton Township, Rt. 22E
Annandale, NJ 08801

Herb Goronkin
Motorola EL 508
2100 East Elliott Road
Tempe, AZ 85284

Lynn Jelinski
Center for Advanced Technology
in Biotechnology
130 Biotechnology Bldg.
Cornell University
Ithaca, NY 14853-2703

Carl Koch
Materials Science & Engineering Dept.
North Carolina State University
233 Riddick, Box 7907
Raleigh, NC 27695-7907

John Mendel
Eastman Kodak
1669 Lake Avenue
Rochester, N.Y. 14652-3701

David T. Shaw
Electrical & Computer Eng. Dept.
330b Bonner Hall, North Campus
SUNY Buffalo
Buffalo, NY 14260

NSF Coordinator:
M.C. Roco
National Science Foundation
4201 Wilson Blvd., Suite 525
Arlington, VA 22230

INTERNATIONAL TECHNOLOGY RESEARCH INSTITUTE
World Technology (WTEC) Division

WTEC at Loyola College (previously known as the Japanese Technology Evaluation Center, JTEC) provides assessments of foreign research and development in selected technologies under a cooperative agreement with the National Science Foundation (NSF). Loyola's International Technology Research Institute (ITRI), R.D. Shelton, Director, is the umbrella organization for WTEC. Paul Herer, Senior Advisor for Planning and Technology Evaluation at NSF's Engineering Directorate, is NSF Program Director for WTEC. Several other U.S. government agencies provide support for the program through NSF.

WTEC's mission is to inform U.S. scientists, engineers, and policymakers of global trends in science and technology in a manner that is timely, credible, relevant, efficient, and useful. WTEC's role is central to the government's effort to measure its performance in science and technology. WTEC assessments cover basic research, advanced development, and applications. Panels of typically six technical experts conduct WTEC assessments. Panelists are leading authorities in their field, technically active, and knowledgeable about U.S. and foreign research programs. As part of the assessment process, panels visit and carry out extensive discussions with foreign scientists and engineers in their labs.

The ITRI staff at Loyola College help select topics, recruit expert panelists, arrange study visits to foreign laboratories, organize workshop presentations, and finally, edit and disseminate the final reports.

Dr. R.D. Shelton
ITRI Director
Loyola College
Baltimore, MD 21210

Mr. Geoff Holdridge
WTEC Division Director
Loyola College
Baltimore, MD 21210

Dr. George Gamota
ITRI Associate Director
17 Solomon Pierce Road
Lexington, MA 02173

ABSTRACT

This report reviews the status of research and development in nanoparticles, nanostructured materials, and nanodevices worldwide, with particular focus on comparisons between the United States and other leading industrialized countries. Topics covered include particle synthesis and assembly, dispersions and coatings of nanoparticles, high surface area materials, functional nanoscale devices, bulk behavior of nanostructured materials, and biological methods and applications. The final chapter is a review of related government funding programs around the world. The report also includes site reports for visits conducted by the panel to leading research laboratories in Japan and Europe. The panel held workshops in the United States, Germany, Sweden, and Russia to gather additional information for this report on activities in those countries. The proceedings of the U.S. and Russia workshops are being published separately by WTEC. The panel's conclusions include the following: (1) In the synthesis and assembly area (Chapter 2), the U.S. appears to be ahead with Europe following and then Japan; (2) In the area of biological approaches and applications (Chapter 7), the U.S. and Europe appear to be rather on a par with Japan following; (3) In nanoscale dispersions and coatings (Chapter 3), the U.S. and Europe are again similar with Japan following; (4) For high surface area materials (Chapter 4), the U.S. is clearly ahead of Europe and then Japan; (5) In the nanodevices area (Chapter 5), Japan seems to be leading quite strongly with Europe and the U.S. following; In the area of consolidated materials (Chapter 6), Japan is a clear leader with the U.S. and Europe following. These and other conclusions are reviewed in detail in the panel's executive summary.

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Sincerely,

Geoffrey M. Holdridge
WTEC Division Director and ITRI Series Editor

International Technology Research Institute (ITRI)

R.D. Shelton, Principal Investigator, ITRI Director
George Mackiw, Deputy ITRI Director
George Gamota, Associate ITRI Director
J. Brad Mooney, TTEC Division Director
Robert Margenthaler, BID Division Director

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Foreword

Timely information on scientific and engineering developments occurring in laboratories around the world provides critical input to maintaining the economic and technological strength of the United States. Moreover, sharing this information quickly with other countries can greatly enhance the productivity of scientists and engineers. These are some of the reasons why the National Science Foundation (NSF) has been involved in funding science and technology assessments comparing the United States and foreign countries since the early 1980s. A substantial number of these studies have been conducted by the World Technology Evaluation Center (WTEC) managed by Loyola College through a cooperative agreement with NSF. The National Science and Technology Council (NSTC), Committee on Technology's Interagency Working Group on NanoScience, Engineering and Technology (CT/IWGN) worked with WTEC to develop the scope of this Nanostucture Science and Technology report in an effort to develop a baseline of understanding for how to strategically make Federal nanoscale R&D investments in the coming years.

The purpose of the NSTC/WTEC activity is to assess R&D efforts in other countries in specific areas of technology, to compare these efforts and their results to U.S. research in the same areas, and to identify opportunities for international collaboration in precompetitive research.

Many U.S. organizations support substantial data gathering and analysis efforts focusing on nations such as Japan. But often the results of these studies are not widely available. At the same time, government and privately sponsored studies that are in the public domain tend to be "input" studies. They enumerate inputs to the research and development process, such as monetary expenditures, personnel data, and facilities, but do not provide an

assessment of the quality or quantity of the outputs obtained. Studies of the outputs of the research and development process are more difficult to perform because they require a subjective analysis performed by individuals who are experts in the relevant scientific and technical fields. The NSF staff includes professionals with expertise in a wide range of disciplines. These individuals provide the expertise needed to assemble panels of experts who can perform competent, unbiased reviews of research and development activities. Specific technologies such as telecommunications, biotechnology, and nanotechnology are selected for study by government agencies that have an interest in obtaining the results of an assessment and are able to contribute to its funding. A typical WTEC assessment is sponsored by several agencies.

In the first few years of this activity, most of the studies focused on Japan, reflecting interest in that nation's growing economic prowess. Then, the program was called JTEC (Japanese Technology Evaluation Center). Beginning in 1990, we began to broaden the geographic focus of the studies. As interest in the European Community (now the European Union) grew, we added Europe as an area of study. With the breakup of the former Soviet Union, we began organizing visits to previously restricted research sites opening up there. Most recently, studies have begun to focus also on emerging science and technology capabilities in Asian countries such as the People's Republic of China.

In the past several years, we also have begun to substantially expand our efforts to disseminate information. Attendance at WTEC workshops (in which panels present preliminary findings) has increased, especially industry participation. Representatives of U.S. industry now routinely number 50% or more of the total attendance, with a broad cross-section of government and academic representatives making up the remainder. Publications by WTEC panel members based on our studies have increased, as have the number of presentations by panelists at professional society meetings.

The WTEC program will continue to evolve in response to changing conditions. New global information networks and electronic information management systems provide opportunities to improve both the content and timeliness of WTEC reports. We are now disseminating the results of WTEC studies via the Internet. Over 25 of the most recent WTEC final reports are now available on the World Wide Web (http://itri.loyola.edu) or via anonymous FTP (ftp.wtec.loyola.edu/pub/).

As we seek to refine the WTEC activity, improving the methodology and enhancing the impact, program organizers and participants will continue to operate from the same basic premise that has been behind the program from its inception, i.e., improved awareness of international developments can significantly enhance the scope and effectiveness of international

collaboration and thus benefit the United States and all its international partners in collaborative research and development efforts.

Paul J. Herer
Directorate for Engineering
National Science Foundation
Arlington, VA

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