

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS
Board on Physics and Astronomy

TECHNICAL PROGRESS REPORT

to the
Department of Energy
on the

Solid State Sciences Committee (SSSC)

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This progress report covers activities of the Solid State Sciences Committee for the period May 1, 1991 to April 30, 1992.

SUMMARY

The Solid State Sciences Committee (SSSC) of the National Research Council (NRC) is charged with monitoring the health of the field of materials science in the United States. Accordingly, the Committee identifies and examines both broad and specific issues affecting the field. Regular meetings, teleconferences, briefings from agencies and the scientific community, the formation of study panels to prepare reports, and special forums are among the mechanisms used by the SSSC to meet its charge. This progress report presents a review of SSSC activities from May 1, 1991 through April 30, 1992. The details of prior activities are discussed in earlier reports:

During the above period, the SSSC has continued to track and participate, when requested, in the development of a Federal initiative on advanced materials and processing. Specifically, the SSSC is presently planning the 1992 SSSC Forum (to be cosponsored with the National Materials Advisory Board (NMAB)). The thrust will be to highlight the Federal Advanced Materials and Processing Program (AMPP).

In keeping with its charge to identify and highlight specific areas for scientific and technological opportunities, the SSSC completed publication of the report *Diluted Magnetic Semiconductors* and launched a study on biomolecular materials. Preliminary plans also have been developed for studies on neutron scattering science, on ultrasmall devices, and on molecular routes to materials.

THE COMMITTEE

The Solid State Sciences Committee is a standing committee under the auspices of the Board on Physics and Astronomy (BPA), Commission on Physical Sciences, Mathematics, and Applications (CPSMA) of the National Academy of Sciences (NAS)--National Research Council. The SSSC is a multidisciplinary committee with membership drawn from universities, industry, government, and national laboratories. Areas of expertise on the committee include condensed matter physics, solid state chemistry, and basic materials science aspects of ceramics, electronic materials, metallurgy, and polymers. It is broadly representative of the community, providing perspective on various issues that affect the progress and vitality of the materials sciences. A special effort has been made to ensure that the committee takes into account the roles of both the science and engineering communities in the field. (A roster is attached.)

The Committee identifies and makes recommendations on the needs of the materials research, development, and applications community, particularly in connection with research opportunities and support.

MASTER

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and provides guidance to federal agencies regarding their materials sciences research programs. The operating guidelines of the SSSC, organized in 1971, include the following: (1) to respond to requests for technical advice and assistance from federal agencies; (2) to organize and publish studies in the solid state sciences with strong multidisciplinary connections to other fields of science and technology; (3) to act as an educational resource for the community of solid state scientists in the United States by identifying critical scientific issues and opportunities; and (4) to provide a forum for discussion among solid state scientists and Washington policymakers.

The SSSC has conducted a number of studies related to many aspects and concerns of solid state sciences and materials sciences and is well prepared to respond to requests for studies on a broad array of topics and issues. Specific report-generating projects under the aegis of the SSSC are separately proposed and funded as the committee identifies key issues itself or accepts requests from agencies of the government and develops corresponding activities.

HIGHLIGHTS OF COMMITTEE MEETINGS

Regular meetings of the Committee are essential to maintaining continuous contact with representatives of both the federal agencies and the scientific community. The highlights of meetings held during the performance period of this contract are presented below:

June 1 - 2, 1991 (Irvine, CA). The SSSC held an off-site retreat at the Beckman Center of the National Academy of Sciences and Engineering. At the retreat, the Committee assessed its effectiveness over the past several years and established plans for the future. Input and advice were received from Phil Smith, NRC Executive Officer, Norman Metzger, CPSMA Executive Director, and past chairs of the Committee—Praveen Chaudhari, William Brinkman, and Martin Blume. In light of the successful followup to the materials study, the Committee was advised to continue monitoring (and help if requested) the interagency group that was responsible for developing the materials crosscut. The Committee was also advised to begin considering ways to contribute to discussions on several issues, including big science versus small science, critical technologies, international collaboration, and K-12 education. The following actions were identified and assigned to individual members or subcommittees: plan for the next SSSC Forum; develop a detailed outline for a study on ultras-small devices; develop a matrix that explicitly shows the relationship between materials science and engineering and emerging technologies identified in the OSTP, DoD, and DOC reports; approach the agencies to gauge interest for a study on molecular routes to materials; contact the agencies to determine whether the SSSC should contribute to the discussion on technology transfer; and develop plans for a research briefing on opportunities in condensed matter physics.

October 15, 1991 (Washington, DC). At the June 1 - 2, 1991 retreat, the Committee assessed its effectiveness over the past several years and established plans for the future. Therefore, this meeting included a review of action plans that were adopted at that retreat. Also, much of the meeting was devoted to a discussion on the development of the federal program on advanced materials and processing. Karl Erb, Acting Associate Director, Physical Sciences, Office of Science and Technology Policy and Henry Ehrenreich, OSTP Consultant, were the invited guests. Status reports were presented on the recently-completed study on diluted magnetic semiconductors, the newly-beginning study on biomolecular materials, and proposed studies on neutron scattering science, on ultras-small devices, and on molecular routes to materials.

In addition to the above regular meeting, representatives of the SSSC have participated in several teleconferences over the past few months to review the status of the proposed study on neutron scattering science that has been requested by the Department of Energy (DOE), and to plan the 1992 SSSC Forum.

STATUS OF SSSC PROJECTS

Summary

Over the past several years, the SSSC organized a number of special panels on topics of concern to federal agencies, the solid state sciences community, and materials sciences community and initiated the following projects:

- Diluted Magnetic Semiconductors
- Scientific assessment of biomolecular materials
- An assessment of neutron scattering science
- 1992 SSSC Forum
- Study on ultrasmall devices
- Study on molecular routes to materials

The current status of these projects bears directly on the activities of the SSSC during the performance of this contract.

Diluted Magnetic Semiconductors

Under the auspices of the SSSC, the Panel on Diluted Magnetic Semiconductors (see attached roster) completed publication of its report. The results were presented in oral briefings to the full SSSC at the October 1991 meeting and also to sponsors.

Biomolecular Materials

The SSSC has initiated an assessment of the scientific potential and research status of self-assembling and biomolecular materials. A panel, chaired by Philip Pincus of the University of California at Santa Barbara, consisting of 12 people with expertise in such areas as solid state physics, chemical physics, organic chemistry, physical chemistry, polymer chemistry, materials science and engineering, biomolecular engineering, molecular biology, biochemistry, and biophysics has been formed to carry out the study (see attached roster). The panel is conducting an assessment that builds on results of recent developments in the area. These developments include the 1990 NSF workshop and recently-released report *Biomolecular Materials: Report of the University/Industry Workshop* and the ongoing NMAB study on synthetic hierarchical structures.

The charge to the study panel includes the following elements:

- Assess the status of research on biomolecular materials in the United States.
 - Identify the scientific frontiers and opportunities; provide a clear definition of research in the field.
 - Identify the technological opportunities.
 - Assess these opportunities for research using the criteria of intellectual challenge, prospects for illumination of classical research questions within specific fields, importance as a multidisciplinary research effort, and potential for applications.
 - Assess applications using the criteria of potential for contributing to industrial competitiveness, national defense, human health, and other aspects of human welfare.
- Identify and address the issues in the field.
 - Quality, size, and scope of the educational programs necessary to advance the field.
 - Assess the institutional infrastructure in which research in this area is conducted and identify changes that would improve the research and educational effort.
 - Identify small-scale instrumentation needs.
 - Develop a research strategy that is responsive to the issues.

- Compare the U.S. program with those of Japan and western Europe. Identify opportunities for international cooperation.
- Assess the linkage of theory and experiment.
- Assess manpower requirements and the prospects for meeting them.
- Identify the users of scientific advances in this area and their needs.
- Make recommendations to federal agencies and to the community as to optimum research directions for addressing the issues.

To date, two meetings of the panel have been held in Washington, D.C.—October 16 - 17, 1991 and December 15 - 17, 1991. At the first meeting, the panel met with representatives from NSF, DOE, AFOSR, ARO, and NIH to discuss the scope and direction of the study. At the second meeting, themes were identified and writing assignments made. The panel currently is composing a preliminary draft of the report which will be reviewed at a subsequent meeting. As the oversight committee for the panel, the SSSC assists the panel, as necessary, in addressing the charge. David Litster, SSSC Chair, is also an active participant in the study. Following completion of the study, the SSSC will actively promote and disseminate the results of the study.

Neutron Scattering Science

The DOE has identified a need for a new assessment by the scientific community of the research that can be carried out on the proposed Advanced Neutron Source (ANS). The need for this facility and its scientific priority has already been established through the Seitz-Eastman Committee and other activities, the most recent of which is the report *Materials Science and Engineering for the 1990s*. However, because of the increasing length of time between the establishment of the need for a facility and construction decisions, it is felt that a contemporary examination of the neutron scattering science would be useful.

The SSSC has a long-standing history of addressing issues related to materials facilities, in general, and neutron scattering sources and light sources, in particular. SSSC attention to issues in this area has resulted in several NRC reports, including *An Assessment of the National Need for Facilities Dedicated to the Production of Synchrotron Radiation* (1976), *Current Status of Facilities Dedicated to the Production of Synchrotron Radiation* (1983), and *Current Status of Neutron Scattering Facilities in the United States* (1984). Recognizing that the SSSC has addressed related issues in the past, the Director of the Materials Sciences Division, DOE contacted the SSSC about a role for the NRC. The neutron science study is the result of those discussions and a subsequent program initiation meeting organized by the SSSC and held on December 4 - 5, 1990.

The study panel will examine the opportunities and needs for neutron science in the United States. Special attention will be given to the overall size, composition, and needs of the broad and interdisciplinary scientific community expected to use the proposed ANS. The SSSC has identified a number of opportunities and concerns for neutron science in the United States in view of the scientific and technological advances since the comprehensive studies of the early 1980s, the changes in the worldwide array of sources and instrumental capabilities in the field, and the trends in the U.S. competitive position. The charge to the panel will include the following elements:

- Assess the scientific opportunities and technological benefits of neutron science.
- Address user issues such as
 - the adequacy of the proposed ANS to address the scientific goals as defined by the user community;
 - the size and composition of the present user base and trends in these factors;
 - access for research by the industrial community.
- Consider instrumentation needs at an Advanced Neutron Scattering Facility.
- Assess the education impact of an ANS in terms of training new scientists.

The panel will not go beyond scientific assessment in the direction of taking a position for or against construction of the facility. That issue has already been dealt with in a broad context by the NRC through the Seitz-Eastman study.

Recently, the SSSC has been assembling a slate of nominees to conduct the study. The proposed panel would include 7 generalists chosen for their familiarity with broad areas of science and technology (including polymer science, chemistry, and biology as well as condensed matter physics, materials science and engineering) and 6 experts chosen for their specialized knowledge in various aspects of neutron science. These latter areas would include (1) inelastic neutron scattering, (2) diffraction, (3) reflectometry, (4) advanced instrumentation, (5) neutron sources, (6) neutron physics and isotopes. The panel plans to hold two one-day meetings in Washington, D.C. and then a two-day workshop at the Beckman Center. Following the workshop, a third and final one-day meeting would be held in Washington, D.C. to assess the input from the workshop. A panel of 13 members, composed partly of experts in specialized areas of neutron scattering science and partly of generalists with broad experience in science and technology, would prepare a research-briefing-style report on the results of the assessment.

1992 SSSC Forum

As part of its charter to provide continuing focus on issues of concern to the materials science community and Washington policymakers, the SSSC has hosted (or cohosted) annual forums for over a decade. In general, the forum process was designed to bring together the scientific community and policy makers in Washington. At the Forums, policymakers are asked to address a general theme and to respond to discussion and to questions from the audience. There is also usually a scientific or technical theme on which talks are presented. Invitees to the Forums include members of the SSSC Forum, which consists of several hundred leaders of the materials research community; members of the NMAB, past and current members of the BPA and its committees and panels; heads of materials science and engineering departments; and liaisons from materials-related societies.

The 1985 Spring Forum was jointly sponsored by the SSSC and the NMAB. It was at this Forum that a consensus developed that a new assessment of the field of materials science and engineering would be useful and timely. As a result, a Committee on Materials Science and Engineering was formed under the joint auspices of the SSSC and the NMAB. The Committee's report, *Materials Science and Engineering for the 1990s*, was featured at the 1989 Forum. The intervening forums focused on the progress of the study in addition to specific areas of the study which were of particular interest to the community. Topics treated at these forums have included "research opportunities in the field of materials science and engineering;" "materials science and engineering: an agenda for the year 2000;" and "superconductivity." The focus of the 1991 Forum was the federal response to a National Forum on Materials that was the culminating activity of the regional meeting process that was initiated to follow up the MSE study. The 1991 SSSC Forum was held on February 27, 1991 at the National Academy of Sciences in Washington, D.C. Keynote speeches were given by Dr. D. Allan Bromley, Science Advisor to the President and Director of the Office of Science and Technology Policy, and Senator Al Gore (D-Tenn). The second session of the Forum focused on synthesizing the results of the regional meetings that were organized to develop ideas for the implementation of the recommendations of the materials study and from a National Coordinating Meeting that was held on January 25 and brought together the work of the regional meetings. The third session addressed the topic "Consortia in Materials Science and Engineering." Siegfried Hecker, Director of Los Alamos National Laboratory, discussed the superconductivity pilot centers that have been established at DOE national laboratories. Other speakers addressed other examples and issues connected with consortia and government-university-industry collaboration. Independent funding for the Forum was obtained from DOE, NSF, AFOSR, and ONR.

The SSSC is planning to hold the 1992 SSSC Forum in June 1992. The theme of the Forum will be the Advanced Materials and Processing Program (AMPP) developed by the Office of Science and Technology Policy to implement the recommendations of the report *Materials Science and Engineering for the 1990s*. The 1992 Forum would serve to acquaint the MSE community with the Federal Advanced Materials and Processing Program (AMPP) and to involve interested members of the Senate and House of Representatives in discussions regarding its implementation. Preliminary discussions with the President's Science Advisor and with the Director of Energy Research, as well as program managers responsible for materials at the National Science Foundation (NSF) lead the SSSC to conclude that this Forum will be a particularly critical and

important event in the process that began with the 1985 Forum. Representatives of the SSSC and the NMAB have held several teleconferences to begin the planning of the 1992 Forum. (A tentative agenda is attached.)

Ultrasmall Devices

The SSSC has determined that an assessment of the science and technology underpinning the development of ultrasmall devices is timely. In particular, the SSSC proposes to form a panel to prepare a report assessing the status of relevant research and the technological potential of electronic semiconductor devices beyond the "scaling limit" of present integrated circuit technology. The materials science and engineering communities have identified this area of research as an emerging area of technological and scientific opportunity with the potential for high payoff in terms of contributing to national needs, particularly in the areas of information, communication, and control. The Department of Defense and the Department of Commerce have each identified advances in the broader areas of advanced semiconductor devices, optoelectronics, and microelectronic circuits as being of critical importance to the United States. The Office of Science and Technology Policy also has included microelectronics and optoelectronics and micro- and nanofabrication on its list of 22 technologies which are deemed critical to the nation's economic prosperity and security. Therefore, this project also could serve as an example of the kind of science and technology assessment that will be required to justify new initiatives in basic research as the Congress begins more pervasively to consider the value of these initiatives in terms of clearly-identified benefits to the nation.

Although industrial researchers have pursued this area for several years, Federal agencies are just beginning to recognize the potentially great national importance of ultrasmall devices. Over the past few years, advances have been made on two fronts—science and technology. Basic research in this area has indicated that the successful continuation of progress in increasing the scale of integration of electronic devices will depend on reducing feature sizes to the level at which a number physical phenomena arise in their design and processing that do not come into play at larger feature sizes. In addition, applied research on and development of innovative structures, particularly using silicon, show much promise for maintaining competitiveness in the area of advanced semiconductor devices. The objectives of this project are twofold: (1) to identify key developments in the basic science underpinning research on ultrasmall devices, specify the direction for this emerging area of research, and assess the long-term science value of research in this area; and (2) to assess and evaluate technological advances that might result as an outgrowth of the development of novel structures.

Representatives of the SSSC are discussing the scope of this project with the agencies to determine interest.

Molecular Routes To Materials

In the BPA report *Condensed Matter Physics in Physics Through the 1990s*, the SSSC report *Artificially Structured Materials*, and the Board on Chemical Sciences and Technology's report *Opportunities in Chemistry*, the atomic and molecular tailoring of materials and control of reaction processes were discussed. The SSSC has developed preliminary plans to conduct a study of this area and is currently gauging agency interest in this activity. Discussions aimed at focusing the scope of this study and involving members of the SSSC, the BCST, and agency representatives are ongoing.

Attachments

- (1) Roster of the Solid State Sciences Committee
- (2) Roster of the Panel on Diluted Magnetic Semiconductors
- (3) Roster of the Panel on Biomolecular Materials
- (4) Tentative Agenda for the 1992 SSSC Forum