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COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS

Board on Physics and Astronomy

Solid State Sciences Committee

TECHNICAL PROGRESS REPORT & CONTINUATION PROPOSAL

to the

Department of Energy

on the

Solid State Sciences Committee (SSSC)

Contract No. DE-FG05-91ER45442

This progress report covers activities of the Solid State Sciences Committee for the period May 1, 1992 to April 30, 1993.

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, 1992 through April 30, 1993. 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 1993 SSSC Forum (to be cosponsored with the National Materials Advisory Board (NMAB) and the Washington Materials Forum (WMF)). 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 continued to oversee the conduct of a study on biomolecular materials. Preliminary plans also were developed for a study on neutron science, however, further activity is pending. A proposed study on ultrasmall devices has been expanded and absorbed into a broader context; the BPA, with SSSC participation, is preparing to hold a program initiation meeting to evaluate the need for a study on information technology and hardware.

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. [See attached roster.]

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, and provides

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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 initiate and oversee the conduct and publication of studies in the solid state sciences and its strong multidisciplinary connections to other fields of science and technology; (3) to act as an educational resource for the community of solid state scientists and materials scientists in the United States by identifying critical scientific issues and opportunities; and (4) to provide a forum for discussion among solid state and materials scientists and Washington policymakers. These objectives continue to serve as the guidelines for the committee and, in response, several mechanisms have been developed to achieve these objectives. In particular, the SSSC organizes and conducts special technical studies, surveys, workshops, and other meetings. The SSSC also functions as an oversight committee for *ad hoc* panels charged with the task of preparing reports on specific issues or topics. Symposia held at the National Academy of Sciences or at research centers have been used to focus attention on particular issues connected with facilities, programs, or other matters of concern to the community. The SSSC continues to use these mechanisms to develop and undertake new projects.

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 and special meetings with the federal agency representatives and the scientific community are essential to maintaining continuous contact with both groups. The highlights of meetings held during the period May 1, 1992 to April 30, 1993 are presented below:

October 15, 1991 (Washington, DC). [Although this meeting occurred before the current performance period began, it impacted the Committee's activities during the performance period.] This meeting included a review of action plans that were adopted at an earlier retreat where the Committee had assessed its effectiveness over the past several years and established plans for the future. 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 ultrasmall devices, and on molecular routes to materials. [Summary minutes are available upon request.]

October 26, 1992 (Washington, DC). The fall 1992 meeting of the SSSC focused on several areas. Charles Shank, new SSSC member, talked about the changing role of the National Labs. John Rush, Paul Fleury, and Julia Weertman reviewed the preliminary recommendations of the Basic Energy Sciences Advisory Committee (BESAC) Panel on Neutron Science and the Townes Committee response to this interim report. The impact of this activity on the planned SSSC study on neutron science was discussed. Pierre Hohenberg led an open discussion on the changing role of the National Science Foundation. There was a lengthy discussion involving committee members and the John Hopps, new Director of the NSF Materials Science Division. Jerry Smith reviewed the DOE Materials Research Program. Finally, the Committee received status reports on its activities and considered future plans. [Summary minutes are available upon request.]

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 1993 SSSC Forum.

SSSC Briefings and Representation at Other Meetings

Committee members are often requested to brief agency representatives, the scientific community, or other groups on matters of importance to the solid state and materials sciences community-at-large. The highlights of these activities during the period May 1, 1992 to April 30, 1993 are presented below:

April 25-26, 1992 (Washington, DC). The SSSC Chair attended the April 1992 meeting of the BPA. The Chair reviewed the activities of SSSC and its panels.

STATUS OF SSSC PROJECTS

Summary

Over the past several years, the SSSC initiated or completed several projects. Under the auspices of the SSSC the Panel on Biomolecular Materials began an assessment of the field. In addition, the Committee has undertaken several other projects, including the following:

- Scientific Assessment of Biomolecular Materials
- An Assessment of Neutron Science
- 1993 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.

Assessment of Biomolecular Materials

The SSSC has initiated an assessment of the scientific potential and research status of self-assembling and biomolecular materials. The project received funding from the NRC, NSF, DOE, ARO, and ONR and is now underway. The study is being conducted by the Panel on Biomolecular Materials (PBMM), chaired by Philip Pincus (University of California at Santa Barbara), which consists 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 (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 PBMM has met several times and developed an action plan to address the formal charge which includes the following elements:

- Assess the status of research on biomolecular materials in the United States.
 - Identify the scientific forefronts 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 US. 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.

Three meetings of the Panel have been held in Washington, DC—October 16 - 17, 1991, December 15 - 17, 1991, and December 16-17, 1992. 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. At the third meeting, the Panel reviewed and revised the working draft of the report and made plans to hold a workshop early in 1993. As the oversight committee for the PBMM, the SSSC continues to assist the Panel in addressing the charge. David Litster, SSSC Chair, has been an active participant in the study. Following completion of the study, the SSSC will actively promote and disseminate the results of the study.

Assessment of Neutron Scattering Science

Early in FY92, the Director of the Materials Sciences Division at DOE requested that the SSSC conduct an assessment of the research that could be carried out on a proposed Advanced Neutron Source (ANS) to be built at Oak Ridge National Laboratory. The request specified that the SSSC 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 and other activities, the most recent of which is the report *Materials Science and Engineering for the 1990s*. Because of the increasing length of time between the establishment of the need for a facility and construction decisions, it was felt that a contemporary examination of the neutron 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). 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.

As proposed, the study panel would examine the opportunities and needs for neutron science in the United States. Special attention would 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 US competitive position. The charge to the panel would 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.

Following the request, the SSSC assembled 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 proposed plan was to hold two one-day meetings in Washington, DC 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, DC to assess the input from the workshop. A panel of 13 members, composed partly of experts in specialized areas of neutron 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.

Recently, the Director of the Office of Energy Research at DOE asked the Basic Energy Advisory Committee to form a panel to reestablish the need for the ANS in the context of the OER budget restrictions and report directly to the Townes Committee advising the Director. As a result of that activity, the SSSC has been requested to postpone any further assessment of the status of neutron science until DOE has established its final plan regarding neutron facilities. The SSSC will continue to pursue discussions on the best course of action.

1993 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 policymakers 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 SSSC is planning to hold the 1993 SSSC Forum in May 1993. The Forum will highlight the multiagency Advanced Materials and Processing Program (AMPP) that was developed by the Office of Science and Technology Policy. The OSTP report outlining the program, which was prepared by the Federal Coordinating Council on Science, Engineering, and Technology's Committee on Industrial Technology, supplemented the President's Fiscal Year 1993 Budget Request. It cited an NRC report prepared under the Solid State Sciences Committee and the National Materials Advisory Board: "The AMPP draws heavily on a series of comprehensive and broad-based studies, particularly a 1989 report by the National Research Council (NRC), *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials*. The impact of this MS&E report has been extensive."

The Forum will be held on May 4-5, 1993 at the National Academy of Sciences in Washington DC. The 1993 SSSC Forum will be jointly sponsored with the National Materials Advisory Board and the Washington Materials Forum. The Washington Materials Forum (WMF), organized in 1991, is a consortium of professional societies with an interest in materials science and technology. The WMF consists of the Materials Research Society, American Physical Society, American Chemical Society, American Ceramics Society, American Vacuum Society, ASM International, The Metals, Mining, and Materials Society, Society of Photo-Optical Instrumentation Engineers, Society for Hybrid Microelectronics, Mineralogical Society of America, American Institute of Chemical Engineers, American Society of Mechanical Engineers, Electro-Chemical Society, Inc., and the Federation of Materials Societies.

The overall theme of next year's forum is "the restructuring of materials science and technology in the US: from research to manufacturing." On May 4, the Forum will begin with a keynote address by Senator Jeff Bingaman (D, New Mexico), introduced by Robert M. White, President of the National Academy of Engineering. Robert M. White (Department of Commerce; Chair, Committee on Industry and Technology, OSTP) will follow with an overview of the Advanced Materials Processing Program. The federal agencies' perspective on AMPP will

be presented. The first day will conclude with talks focusing on the integration of science, engineering, and societal needs in materials.

On May 5, the emphasis will be on challenges for materials in the 21st century. Tom George (Motorola), Jim McGroddy (IBM), William Brinkman (AT&T), Robert Davis (Boeing), Jim Williams (GE), and Roland Haitz (Hewlett-Packard) will talk about these challenges from several perspectives, including microelectronic materials, optoelectronic materials, structural materials, and light-weight materials. Finally, technology transfer, precompetitive R&D collaboration, the role of university research, and engineering education will be the subject of talks by Cherri Langenfeld (DOE), John McTague (Ford), Venkatesh Narayanamurti (UCSB) and others.

Representatives of the SSSC, the NMAB, and the WMF have held teleconferences throughout the summer and fall of 1992 to plan the 1993 Forum. [An agenda is available upon request.] As the oversight committee for this activity, the SSSC will continue to develop and implement plans for the Forum.

Ultrasmall Devices (Program Initiation of a Study on Information Technology/Hardware)

The SSSC has been considering the problems of developing ultrasmall devices. The next generation of ultra-large-scale integrated circuits will begin to face new physical phenomena that take place at the extremely small length scales involved, such as quantum interference and non-equilibrium transport. At the present pace of development, (IC) technology as it is now conceived is expected to reach the "scaling limit" in the neighborhood of the year 2000. At that time, it will be necessary to be prepared with alternatives. The materials science and engineering community has identified the area of semiconductor electronic and optoelectronic devices beyond the scaling limit of present IC technology to be an important emerging area of scientific and technological opportunity. Progress in this area has the potential for high payoff in terms of contributing to national needs, particularly in information, communication, computing, and control.

The area of ultrasmall devices is extraordinary by virtue of the confluence of two factors: progress in understanding fundamental problems of quantum physics and electronics/photonics of nanoscale semiconductors, and the urgent need for new approaches to bridge the gap between present technology and future needs for integrated circuits. Ultrasmall devices extend the miniaturization of electronics and photonics into the realm where the active elements are so small and so dense that quantum-mechanical tunneling and particle-wave interference effects not important at larger scales dominate their behavior. The possibilities for applications are many, but the rules governing the operation of such devices are different from those governing present-day devices and must be determined through research.

To assess the potential of future trends in a broad context, it is not sufficient to think about developments at the component level alone—options for new information and communication architectures must be considered. For example, there is a growing emphasis on massively parallel architectures for processors. There are special requirements for the devices and interconnects in such a system. The concept of integrated services data networks made possible by fiber optic communication opens up the possibility of a significant restructuring of the ways that we access and move information. Again, the hardware requirements and the system architecture interact.

SSSC representatives have worked together with members of the BPA, the NMAB, and the CSTB to develop plans to hold a program initiation meeting to determine the desirability and need of a broad study on information hardware/technology. A detailed description is given in the attached prospectus.

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. Although initial agency interest has been limited, the SSSC will continue to hold discussions aimed at focusing the scope of this study and involving members of the BCST and agency representatives.

Attachments

- (1) Roster of the Solid State Sciences Committee
- (2) Roster of the Panel on Biomolecular Materials
- (3) Prospectus for a Program Initiation Meeting to Consider as Assessment of Information Technology/Hardware