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NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

Commission on Physical Sciences, Mathematics, and Applications  
Board on Physics and Astronomy  
Plasma Science Committee

**Final Progress Report**  
for the period  
**7/15/94 through 12/31/97**  
to the  
**Department of Energy**  
on the

## PLASMA SCIENCE COMMITTEE

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This final technical progress report reviews the work of the Plasma Science Committee (PLSC) for the period July 15, 1994, through December 31, 1997.

### The Plasma Science Committee

Organized in 1988 as a standing activity of the National Research Council (NRC), the PLSC is charged with monitoring the continuing health and development of plasma science in the United States. Its goals are to identify the needs of the plasma science community, make recommendations about those needs, and provide guidance about existing research programs in plasma science. Its operating guidelines include the following tasks:

- (1) to provide a continuing forum for the discussion of problems in the field of plasma science;
- (2) to initiate, develop, and oversee special studies focused on high-priority topics;
- (3) to maintain a broad and unified definition of plasma science as a field;
- (4) to maintain a clear and comprehensive formulation of current plasma science policy issues and give guidance to decisionmakers in universities, nonprofit research centers, and government agencies;
- (5) to promote coordination among institutions involved in plasma science;
- (6) to make recommendations aimed at plasma science education;
- (7) to monitor the plasma-related industrial technological base; and
- (8) to sponsor workshops and symposia as a means of communication among different branches of the field.

Several mechanisms have been developed to help the PLSC achieve these objectives. Among these are periodic meetings, teleconferences, briefings from agency representatives and the scientific community, special symposia, and the initiation of studies to prepare reports. The PLSC organizes and oversees special technical studies, surveys, workshops, and symposia. 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. Specific report-generating projects are proposed and funded separately, as the committee identifies key issues itself or

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accepts requests for studies from government agencies. Funds of the Plasma Science Committee may be used to supplement the funds of specific report-generating activities conducted under its auspices.

The PLSC is a multidisciplinary activity with experts drawn from academia, industry, and the national laboratories. The members' expertise covers the full breadth of the field of plasma science, including nonneutral plasmas, space plasma physics, plasma astrophysics, computational plasma physics and applied mathematics, fusion plasmas, fundamental plasma experiments and theory, plasma processing of materials, lighting plasmas, and other topics. It is broadly representative of the community, providing perspective on the many issues that affect the progress and vitality of plasma science.

The PLSC functions as a steering committee for the field of plasma science as a whole. There are other bodies that address issues that affect plasma science, such as the Department of Energy's Fusion Energy Sciences Advisory Committee (FESAC) for fusion plasmas and the National Aeronautics and Space Administration's Sun-Earth Connections Advisory Subcommittee (SECAS) for space plasmas, but the PLSC has a much wider mandate and as a consequence provides a unique and essential voice for the broad plasma science community. To prevent unnecessary duplication of effort the PLSC is careful to maintain contact with these federal advisory groups and with the plasma-related professional societies.

### **PLSC Activities During this Reporting Period**

During this reporting period, the PLSC was involved with two major projects: a decadal assessment of the field as a whole, conducted by the Panel on Opportunities in Plasma Science and Technology (OPST), and a study of data needs in the modeling and simulation of plasma processing of materials, conducted by the Panel on Database Needs in Plasma Processing.

#### **Assessment of Plasma Science**

In 1992 the committee initiated an in-depth study of the field of plasma science, as part of the ongoing strategy of its parent Board on Physics and Astronomy to periodically reassess the fields addressed by the 1986 Brinkman report.<sup>1</sup> The intent was both to assess the state of knowledge in the field and to lay out the priorities of the community in pursuing its research agenda over the next several years. The study was conducted by the Panel on Opportunities in Plasma Science and Technology (OPST) under the PLSC's auspices. Of the 13 OPST members about half of them were chosen for their expertise in specific areas of plasma science; the remainder were selected for their broad knowledge of scientific activities and science policy issues.

The report includes chapters that address seven topical areas and three broad crosscutting issues. The topical areas are low-temperature plasmas; nonneutral plasmas; inertial confinement fusion; magnetic confinement fusion; beams, accelerators, and radiation sources; space plasmas; and plasma astrophysics. In each area the report reviews recent research accomplishments, assesses opportunities in the field, and makes recommendations for future research directions and research support. The report then addresses three broad issues: the status of basic plasma experimentation, the status of theoretical and computational plasma science, and plasma science education. The theme of the report is that although plasma science contributes to a vast array of important applications, the available support for plasma research has focused too narrowly on those applications and has neglected the basic research that provides their ultimate scientific foundation. The report lays out a number of recommendations for remedying this situation.

The OPST panel's report was published in July 1995 under the title *Plasma Science: From Fundamental Research to Technological Applications*. Copies were distributed to decisionmakers at

<sup>1</sup> National Research Council, *Physics Through the 1990s*, National Academy Press, Washington, D.C., 1986, which included the volume *Plasmas and Fluids*.

federal agencies and in the Congress and to department heads at universities with plasma-related research programs. Seven hundred copies were also provided to the American Physical Society at cost for distribution to members of the APS Division of Plasma Physics.

This report was influential in increasing the U.S. research program's focus on basic plasma science, which it identified as the part of the field most in need of attention. Since the release of *Plasma Science* the PLSC has been active in disseminating its conclusions and recommendations through meetings with policymakers, public discussions at professional society conferences, and other mechanisms. It has also been monitoring actions taken in response to the report and considering other ways to follow up and maximize the report's impact and success.

#### Database Needs for Plasma Processing

As one of its first projects, the PLSC initiated a study on the plasma processing of materials. That study's report was published in 1991 under the title *Plasma Processing of Materials: Scientific Opportunities and Technological Challenges*. One of its conclusions was that if we are to develop useful models for simulating the plasma processing of microelectronic devices we will need to improve our knowledge of fundamental plasma properties, and in particular, to obtain a broader range of basic experimental plasma data than now exists. Accordingly, the Panel of Database Needs in Plasma Processing was formed to assess the existing database and make recommendations as to research needs in five areas: electron impact processes, ion impact processes and neutral chemistry, heterogeneous processes, radiative processes and diagnostics, and thermochemistry of reactive species. The panel held a two-day workshop in Washington in April 1995, to develop information for inclusion in its report and to ensure that the full range of perspectives is considered. Approximately 90 people took part in the workshop, including experimental plasma researchers, plasma modelers, and model users from the microelectronics and microelectronics-manufacturing-equipment industries.

Together with the NRC's Committee on Atomic, Molecular, and Optical Science, the PLSC developed the early plans for this study and was active in its initial development. A PLSC representative with expertise in plasma processing participated in the workshop. The PLSC took an active role in reviewing and putting the finishing touches on the study report, and in disseminating the report, which was published in August 1996.

#### **Highlights of PLSC Meetings During this Reporting Period**

Regular meetings of the PLSC and special meetings with agency representatives and the scientific community are essential to the committee's function. Below are some highlights of meetings that have taken place during this reporting period.

*November 8, 1994* (Minneapolis). The committee met during the annual conference of the Division of Plasma Physics of the American Physical Society. Most of the meeting was devoted to an in-depth discussion of the draft report of the OPST study. The committee heard from the cochairs of the study panel and considered the report section by section, with particular focus on the findings and recommendations and how to present them most effectively. Many of its suggestions were incorporated into the final report, including an almost completely rewritten executive summary. The committee also began to develop plans for follow-up briefings with policymakers.

*April 1-2, 1995* (Washington). PLSC vice chair Rick Gottscho participated in the workshop of the Panel on Database Needs in Plasma Processing.

*April 22, 1995* (Washington). PLSC chair Ravi Sudan attended the meeting of Board on Physics and Astronomy to represent the plasma science community and to participate in discussions of the OPST study.

*June, 1995* (Washington). Members of the PLSC and the OPST panel held several meetings with agency officials to discuss the findings and recommendations of the OPST report. On June 5, John Ahearne and PLSC member Steve Cowley met with the director of the DOE Office of Energy Research and other DOE representatives. On June 8, Ravi Sudan, John Ahearne, and Cliff Surko met with the director of NSF and other NSF representatives. On June 15, Ravi Sudan and PLSC members Chuan Liu and Richard Hazeltine met with the Under Secretary of Energy and other DOE representatives.

*November 7, 1995* (Louisville, KY). Ravi Sudan organized a town meeting at the annual meeting of the APS Division of Plasma Physics, including a discussion of the OPST report, the PCAST report on the fusion program, and other matters.

*November 17, 1995* (Washington). David Graves, chair of the Panel on Database Needs in Plasma Processing, gave a progress report on his panel's activities. Norman Bardsley (LLNL) reported on efforts to form a new topical group on low-temperature plasma science within the American Physical Society. The committee discussed the status of federal support for plasma science with representatives of DOE and ONR. (NSF and NASA representatives were unable to attend because of the federal shutdown.) A possible committee activity in the area of plasma science education was discussed. Plans were made for additional activities to disseminate and follow up the recommendations of the OPST report.

*December 7, 1995* (Washington). Cliff Surko and Ravi Sudan gave presentations on the recommendations of the OPST report at a FEAC meeting.

*March 7, 1996* (Washington). Cliff Surko was invited to testify at a congressional hearing conducted by the Energy and Environment Subcommittee of the House Science Committee. His testimony summarized the findings of the OPST report and related them to FEAC's recent report and the ongoing restructuring of the fusion program. Following the hearing, Surko and Ravi Sudan discussed the OPST report's recommendations with a program manager in the NSF Atomic, Molecular, Optical, and Plasma Physics program and the director of the DOE Office of Basic Energy Sciences.

*April 19, 1996* (Washington). Ravi Sudan and Chuan Liu visited NSF to discuss the OPST report with the directors of the Physics Division and the Electrical and Communications Systems Division and the chair of the NSF's plasma science working group.

*October 26, 1997* (Washington). The committee held discussions with agency representatives from the Department of Energy, the National Science Foundation, and the Office of Naval Research. The committee also discussed possible future tasks including the following:

- an update to the *Plasma Science* report,
- a study of high energy-density plasma physics,
- an examination of what constitutes "basic plasma science,"
- a study of societal and economic impact of plasma science,
- a symposium on industry needs in plasma research and education, and
- addressing issues that face plasma science at universities.

### **Continuing Activities of the PLSC**

In order to monitor continuing developments in the field of plasma science and to respond effectively to inquiries from federal agencies, the PLSC will continue to meet approximately twice a year. These meetings will generally be held in Washington in order to facilitate attendance by representatives of the federal agencies, liaison representatives from the plasma-related professional societies, and other interested members of the science policy community. Occasionally the committee will instead meet at the site of a major plasma-related conference to save on travel time and expenses.

The PLSC will continue to follow up the recommendations of the OPST study and to oversee the final stages of the study of data needs in plasma processing. The committee will also continue to make its expertise available to federal agencies in the event that its scientific input is needed to resolve issues that may arise. New projects will be initiated either at the request of a government agency or when the committee itself identifies an issue of importance to the plasma science community that needs to be addressed.