New Broad Materials Study Discussed at NAS

A meeting billed as a "Forum on Materials Science and Engineering" was held March 7-8, 1985 at the National Academy of Science in Washington, DC, to afford the materials community an opportunity to help define the scope and emphasis of a proposed new study of Materials Science and Engineering to be conducted by the National Research Council (NRC). Under the auspices of the Solid State Sciences Committee (SSSC) and the National Materials Advisory Board (NMAB), the meeting included representatives of government, industry, and academia. A series of speakers contributed their perspectives on the need for and definition of such a study.

Day One:
Defining the Needs of Industry, Education and Government

Introductory remarks were made by Edward J. Dulis (Crucible Research Center), on behalf of the NMAB, who pointed to the important role played by materials science in the health of the industrial base in the United States. William F. Brinkman (Sandia National Laboratories), on behalf of the SSSC, indicated that the study needs to be defined in terms of what is surveyed *and* what kind of recommendations it is expected to produce. Brinkman also noted that emphasis on federally funded programs is appropriate because the targets for the recommendations are primarily those who prioritize application of federal support. He also warned the audience to avoid in its discussions the tendency to get bogged down trying to come up with a definition of materials science which does not exist and is largely a question of semantics.

Taking the podium next was Congressman Donald Fuqua (Florida), chairman of the House Committee on Science and Technology. After reviewing recent legislative history in the area and suggesting that the NRC might act as advisor to the (yet to be formed) National Critical Materials Council, the Congressman admonished those who conduct a new study not to allow specific-issue disagreements to interfere with compromise and consensus for the whole community's benefit. He emphasized that the materials community must set the research needs and priorities, while noting that the other nations such as Japan, Europe, and the USSR seem to be well along on their own better defined agendas in materials research.

He listed the nation's defense, economic, and foreign policy goals as those to which materials research ought to speak. Congressman Fuqua cautioned that specialization within disciplinary fields causes "tunnel vision," whereas for materials research, interdisciplinary knowledge is needed. The fact that traditional education splits materials scientists into traditional disciplines, probably handicapping the field, led Fuqua to suggest a more integrated approach at universities. In ending, he noted that the last report in a scientific area that enjoyed great influence was the post-war report ("Science, the Endless Frontier") of Vanevar Bush to President Roosevelt some 40 years ago.

The Office of Science and Technology Policy was represented by OSTP Deputy Director John McTague. McTague shared the view that a broad study could raise awareness of the Congress and the public with regard to the importance of materials science and engineering to the nation. He offered two perceptual warnings. First, the profession ought not allow its practitioners to become "prisoners of language" by believing that materials research, simply because it is one phrase, represents one unified field. It is diverse and has recently become devisive. His corollary and second warning was that "a materials community as such does not exist and we are fooling ourselves if we think that. . . . There exist many communities." For this reason the "dimensionality" of any study would need to be high. As background, he noted that earlier reports with more constrained definitions could be regarded as one-dimensional (citing a Field Report on Astronomy, High-Energy Physics [HEPAF], Nuclear Science Advisory Committee report), two-dimensional (the Seitz-Eastman report on major facilities), or three-dimensional (the Pimental report on opportunities in chemistry). By analogy he estimated the materials science and engineering study to be five or six dimensional and suggested the thrust should be to emphasize a few specific areas where an impressive case can be made for expectations of "amazing progress" and an impact analysis can be provided to relate it to national goals. McTague's overall point concerning the great prospects for materials research can be summed up by his quote from Pogo, ". . . we has met an insurmountable opportunity."

Erich Bloch, director of the National Science Foundation, repeatedly emphasized the interdisciplinary nature of materials research and the need for inter-institutional cooperation. His concerns lay in the areas of the international challenge, pursuit of multidisciplinary research, industry cooperation, and community (i.e., materials community) development. Simply stated, the United States is lagging in many international markets where it must enhance its research efforts *and* improve its ability to apply results. The multidisciplinary approach is needed which implies the breaking of traditional disciplinary boundaries where the NSF's MRL's on university campuses are a good model.

The disciplinary orientation of the university structure is not conducive to the tasks at hand, as is the more problem-oriented structure of the industrial lab. Bloch noted that the NSF would soon be announcing the inception of the MRL philosophy. The cooperation between industry and university and between industries is a useful way to leverage federal funds and needs to be extended beyond the level of the many connections between individuals that now exist. Community development will be a natural consequence of the bridging of disciplines, the increased industry-university collaborations, and cooperations among universities and national laboratories. Bloch felt that community development is one of those perceptual as well as substantive issues where "thinking it so can make it happen."

The director of the Defense Advanced Research Projects Agency (DARPA)., Robert Cooper, brought his audience a view not yet so succinctly phased by previous speakers. His agency and the DoD agencies in general are mission oriented and expect materials science and engineering research work to be directed toward solution of materials problems in defense and other areas of high national priority. Materials science is not distinguished from

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materials engineering in a mission agency, but rather it is viewed as a continuum that translates research results into applications.

Cooper pointed to the COSMAT study as a model to be avoided in that its duration from planning stage to final reports exceeded four years. He noted that COMSAT (circa 1971-1975) overlooked electronic materials and that the country has lost the lead now in areas such as GaAs. A new study should be done expeditiously and be tied to specific national needs.

Cooper then listed a wide range of specific materials areas where defense systems place demands on materials performance beyond that currently available. "The most sought after stuff is 'unobtainium.'" As a general matter, Cooper stressed that the proposed study should deal with student support in interdisciplinary university curricula, development of the research infrastructure including upgrading of facilities, reduction of our nation's dependence on foreign materials, and setting of research priorities in connection with defining long-term national needs in many areas.

Alvin Trivelpiece, director of Basic Energy Sciences in the Department of Energy, pointed to the distinction between "need-driven" and "curiosity-driven" materials research, maintaining that the former ought to be stressed over, but not to the exclusion of, the latter. He also felt that it is the rising level of complexity of materials research studies that now demand more complex and bigger facilities (such as surveyed by the Seitz-Eastman committee.)

After a lunch break, the participants heard the views of AT&T Bell Labs' William Slichter who spoke to future directions in industrial materials R&D. In addition to reciting an extended list of specific materials/topics of current interest in the areas of high-technology materials, high-performance materials, synthesis methodology, and characterization, he emphasized that the schematic view of what materials research is needs to be expanded. Rather than just "structure-property" relationships, a "structure-process-property" troika must be considered. Examples of where "processing per se is at the forefront of materials research are in materials far from equilibrium (rapid solidification, ion implantation, laser surface alloying) and in ultra-small dimension materials (microcircuits, hetero-structure devices, thin films, filimentary and layered composites, and compositionally modulated superlattices).

Materials Science and Engineering Study

Prospectus

DRAFT

Materials research and development have received increasing emphasis within the Federal government in recent years. The decline in our basic industries, the need to enhance productivity and competitiveness, and the movement towards a high-technology economy all combine to focus attention on the importance of improved and new materials as well as advanced techniques for processing and manufacturing. In 1980 the Congress passed the National Materials and Minerals Policy, Research and Development Act (Public Law 96-479) ". . . to provide for a national policy for materials and to strengthen the materials research, development, production capability, and performance of the United States. . ." In response to this Act, the Administration in April of 1982 issued a definitive policy statement on materials. The statement treated land use, natural resources and strategic materials in some detail, but did not address budgetary matters, advanced materials research, or the detailed organizational structure to carry out identified research and development (R&D) policies. In 1984, the Congress passed the National Critical Materials Act (Public Law 98-373: Title II) establishing a National Critical Materials Council in the Executive Office of the President, an action that has yet to be implemented.

In January 1985, the House Science and Technology Committee sponsored a congressional workshop to develop an Advanced Materials R&D National Program Plan at which further discussion of the need for an assessment of materials science and engineering took place. The leadership and staff of this congressional committee together with several executive departments that have large materials research programs, such as the Department of Energy and the National Science Foundation, are responsible, at least in part, for creating the current climate conducive to a comprehensive materials research and engineering study. Since the materials community as well as government interests are very diverse, it was decided to hold a forum to elicit input from the community prior to completing the scope of the work.

The purpose of the March 7-8 Forum on Materials Science and Engineering is to gather ideas for the scope of a major study on that subject. Interested groups including various professional societies, agency representatives, and other committees of the National Research Council have been involved. The purpose of the meeting is to bring together the concerned groups to develop a consensus on the best approach for carrying out a materials science and engineering study.

Generally, it is expected that the committee that will be formed to carry out the study will be charged to address the following general tasks: (1) examine the progress that has taken place over the last decade and explore the opportunities for the next decade; (2) examine the balance of federal programs with regard to facilities, instrumentation, manpower, and other issues as well as the balance among various scientific and engineering disciplines such as materials synthesis and characterization; (3) review the relationship between the federal program and national applications needs; (4) assess the needs of materials research and engineering for the next decade. Federal programs to be reviewed will include those of the agencies with major materials science and engineering programs including the Department of Energy, National Science Foundation, Office of Naval Research, Army Research Office, Air Force Office of Scientific Research, National Aeronautics and Space Administration, National Bureau of Standards, and others. The scientific scope will be broad, reflecting ongoing materials research and engineering work.

The specific issues to be addressed in the study will be the subject of a roundtable discussion at the Forum. On the agenda will be a discussion of the relative emphasis to be given to (1) assessing agency materials science and engineering programs with regard to balance and possible gaps; (2) surveying the materials R&D field to give greater definition and coherence to the field; (3) identifying major scientific and engineering opportunities; and (4) setting national priorities for materials research and engineering including facilities and educational needs. The objective of the roundtable discussion is to identify how much emphasis should be placed on these and other objectives for the study. A detailed plan of action will be prepared subsequent to the March meeting.

One result of the study will be a report that will review the status of materials science and engineering. It is expected that this report will serve the purpose of further unifying the field, assessing current materials research and engineering, and providing a plan for continued oversight of materials research issues.

U.S. Steel Vice President for Research Harry Paxton then offered some industrial perspectives of a more socio-political nature. He contended that materials make "systems" work. Thus materials issues need to be considered in the systems context. These broader issues relate to the cost of the system relative to the cost of the material(s), the cost of failure (including litigation), and the product life cycle relative to time in the research stage. He commented on the influence of competitive market forces, on the "value" of the technology relative to the cost to produce it (often difficult to quantify), federal policy implications (including taxes, antitrust, depreciation, export controls), and the need to improve processing as a science. This last refers not so much to process invention in the lab, but to the impact of the lack of reproducibility, the need for employee retraining, and the costs associated with facility addition or expansion, all of which determine the efficacy of pursuing a new materials opportunity into production.

From the Massachusetts Institute of Technology, Prof. Mildred Dresselhaus then addressed the case for small science in the context of materials research. She contrasted the viewpoints of practitioners of the research with those of the funding agencies, thereby pointing to opportunities for miscommunication. She stated that national goal, vis a vis large versus small facilities, as the maintenance of a balance between them. Her point was that frontier research needs big facilities more now, but frontier research is also done in small science context and that is where the students are trained. She pointed out that with the large facility, the applications are focused, whereas in small science the needs are diverse. She conceded that the practitioners of small science have not adequately articulated the needs of the field. Dresselhaus called for more cooperation within the materials research community, the identification of a group to speak for the community, some agreement for opportunities, needs, and balance with the articulation of the same, and a mechanism for monitoring the health of the community.

Concerned about university instrumentation, Prof. Ted Geballe of Stanford then reminded everyone that "facilities" and "instrumentation" are one and the same problem at the universities. After pointing to examples of seminal work which only could have arisen in the small instrumented lab, he concluded that the study "must treat the relative rate of approach to a new synchrotron versus the rate of approach to 200 scanning transmission microscopes around the U.S." Following Geballe, Dean Eastman (IBM) summarized the report of the Seitz-Eastman committee concerning major materials facilities. (Eastman's summary appears in Vol IX, No. 6 of the **BULLETIN** as his Plenary Session address from the 1984 MRS Fall Meeting.)

Ending the first day's presentations was a series of brief remarks by invited representatives of several professional societies. On the panel were Richard Spriggs of the American Ceramic Society, Rob Thompson for the Materials Physics Topical Group of the American Physical Society, Miles Klein for the Condensed Matter Physics Division of APS, Mel Bernstein of The Metallurgical Society of AIME, Don Blickweed of the American Society for Metals, and representing the Materials Research Society was 1985 President Elton N. Kaufmann. Each speaker described the activities of their respective society or division within the context of its relation to materials research and the particular discipline emphasized by their group. That the presentations were largely disciplinary was also noted by Robert Laudise (AT&T Bell Labs) who noted (somewhat plaintively) from the audience that chemists were not represented on the panel.

On behalf of MRS, Kaufmann pointed out that the Materials Research Society has no disciplinary ax to grind, that its members are also members of at least one if not more of the other societies represented in the forum, and that MRS, as the most diverse and interdisciplinary organization available, would welcome the opportunity to support the NRC study, if requested.

Day Two:
Criteria and Recommendations for Successful Study

On the morning of day two, Prof. Morris Cohen of the Massachusetts Institute of Technology (and the chairman of the original COSMAT study) addressed the group. Cohen reviewed the history behind the COSMAT study and referred to its summary report (1974) and four supplements (1975), all published under the title, "Materials and Man's Needs." He pointed out that COSMAT had been rather comprehensive in that it covered 46 categories in materials research (19 classes of material, 13 properties of materials, and 14 processes.)

Taking the opposite view to McTague's contention of diversity being truth and unity being an illusion (bolstered by language), Cohen contended that "materials science and engineering" is a unified endeavor related to structure, properties, processing, and performance of materials which connects basic science and understanding to societal needs and experience. He recommended a new study look at an update of COSMAT in terms of new trends, an analysis of current research defining new frontiers to the year 2000, the interaction of MS&E with the disciplines and its impact on society, the quality education for materials majors and nonmajors, and the needs of MS&E for funds and facilities in the future.

Paul Maxwell of the staff of the House Committee on Science and Technology followed by emphasizing that Congress wants an external group to set priorities in this area. He challenged any study to come forth with possible new, innovative, and unexpected proposals. Next at the podium was the head of the Materials Science Divisions of the Office of Basic Energy Sciences at the DoE, Louis Ianniello. He first pointed to the breadth of involvement of his division with materials and then suggested that the proposed study be as broad. But, he conceded that it can't do it all and must settle for a well-defined subset of issues (possibly determined by an advance scoping phase of the study). He warned against restricting the framers of the study to an elite group since he contended that the maximum benefit of the work will be derived by the participants rather than by the readers of the final report. Other things to avoid, he suggested, are appealing directly for funding, dragging the study out over an extended period of time, and expending too much money on the study itself. Ianniello hoped that the study would create a more cohesive community and a framework for coordination and growth, provide goals for program development, synthesize many existing reports, establish a history of accomplishment, and create a new institutional mechanism for advice (to the agencies).

Robert Cooper (DARPA) returned to the microphone to say that "anything worth studying can be done in nine months" and pledged that delays in funding the study would not occur to the extent he could influence it. (Louis Nasanow of NSF concurred by noting that a good plan will be easy to fund.) Cooper's scenario for the study is simply that one asks the nation what it thinks the nation needs, then from those goals, list the research efforts which will reach them.

From the audience came a somewhat different suggestion espoused by Geballe and others. Why not run two parallel studies: one on the basic research and educational needs and opportunities which will highlight where the most progress might be expected, and a second on the definition of national needs and goals in many areas. Then at or near completion of these independent studies, they should be compared to set priorities for the research based on potential impact on national needs. Unfortunately discussion of this creative idea was of necessity truncated to allow time for the last presentation in which Dean Eastman provided the attendees with a straw-man outline of a possible organizational framework for the NRC study. Eastman itemized a set of national goals:

- Maintain leadership in basic science
- Provide leadership in applied research for:
  - National security
  - The national economy
  - Adequate energy supplies
  - Adequate essential materials supplies
  - Acceptable standard of living (health, environment, transport, communication, recreation, etc.)
- Industry, university, and government to perform in achieving the above

Eastman said the study itself could be structured categorically along the lines of these goals with additional chapters concerning such issues as manpower.

The Next Step

The study which may be proposed by the NRC and which was discussed for the one and one half days in March will be no mean feat. As any participant in that forum quickly realized, attendees and speakers often found themselves speaking on "different wavelengths," or advocating approaches very specific to a particular discipline, a particular institutional type, or a particular view of the national needs and goals in a mission-oriented context. In short, the very process into which it is so natural for this community to fall as a result of its diversity along many dimensions, is the process that a fair and authoritative study must asiduously avoid if it is to succeed.

More than defining and prioritizing materials science and engineering needs and potentials, this study may well highlight the problem (as often viewed by and pointed to by government funders) and the built-in strength (as often perceived by the practitioner) indemic to the community. Given that a major motivation for a study of this kind at this time is the desire to provide the federal government with coherent guidance absent obvious and vocal intra-community dissent, it may behoove the framers of the study to enlist in advance the explicit participation of a broad spectrum of interest groups through more than consultative forums.

Ultimately, however, the task will become one of education—education of the readers and contributors to the study to the fact that the nature of research engenders disagreement on the best course to follow, that in the interdisciplinary mode this is even more the case, and that it is a very healthy climate in which to pursue excellence in research and productivity in development. Should we construct single, simple answers to truly complex questions it seems unlikely that the nation's needs will actually be met.

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