M. Flemings Reports on MS&E Study at MRS Fall Meeting Forum

Predicts Significantly Increased Support for Research on Materials Synthesis and Processing

Increased support for research on materials synthesis and processing for analysis and modeling, and emphasis on instrumentation and facilities will be among the recommendations in the Materials Science and Engineering Study's final report to the National Academies, according to MIT's Prof. Merton C. Flemings.

Flemings, a co-chair of the MS&E Study Committee along with Praveen Chaudhari of IBM, presented a status report on the soon-to-be-completed study on Tuesday morning, November 29 at the 1988 Fall Meeting of the Materials Research Society in Boston.

[For previous MRS BULLETIN reports on the MS&E Study, see the following issues: Vol. XI, No. 6 (1986) p. 40-44; Vol. XII, No. 1 (1987) p. 75-76; Vol. XII, No. 2 (1987) p. 79-82; and Vol. XII, No. 3, p. 32-34.]

Flemings described the broad mission of the committee as a charge to present "a unified view of recent progress and new directions in Materials Science and Engineering." The committee did this, he said, by "examining a number of issues including societal needs, research opportunities, education, human and other resources, and international cooperation and competition."

Although the committee's report is not final and, at the time of this forum had not been released to the public, Flemings was able to predict one aspect of the conclusions: "We will surely recommend significantly increased support for research on synthesis and processing of materials, with the recommendation that this support should span the spectrum of materials-related activities from science to engineering, and from the creation of new materials to manufacturing...we will recommend increased attention to analysis and modeling...[and] we will no doubt have some recommendations concerning the critical importance of instrumentation and of facilities, including processing facilities."

Flemings opened the forum by reciting a portion of the introductory chapter proposed for the report:

> "Materials have been central to the growth, prosperity, security, and quality of life of human beings since the beginning of history. Only in the last 25 years, and especially in the last decade, has the intellectual foundation of the field which we call Materials Science and Engineering begun to coalesce and to emerge. This has occurred just as the field itself is expanding greatly and contributing strongly to society."

He followed with a litany of examples of how MS&E advances are reflected in large improvements in figures of merit for different materials, relating them to the vastly improved systems and products we have today. For example, the strength-to-density ratio of structural materials has increased throughout the industrial age, with obvious aircraft improvements as a result. Flemings also mentioned how materials strength at high temperatures has improved; how permanent magnets are now over 100 times stronger than those available at the turn of the century; how superconductors have advanced since first discovered in 1911; how optical fibers are 100 orders of magnitude more transparent than in 1966; how new materials have allowed 100-fold faster cutting-tool speeds than at the turn of the century; and how, "in integrated circuits, the number of components per chip has increased at exponential rates since about 1960, making possible the ubiquitous use of the economic 'chip' we know today."

Regarding the new ceramic high temperature superconductors, Flemings specifically pointed out that "what prevents the use of these materials today are precisely those technical issues that comprise materials science and engineering."

The status and importance of materials processing as distinguished from structure/property development was a continuing theme throughout Flemings' summary. Noting that, "new materials processes have had enormous impacts...on the factory floor in all industries, from electronics to the basic materials producers," he referred to the steel industry as a prime example.

Flemings communicated a broad perspective on MS&E in his recognition that "the field has evolved in many parallel and intertwined paths associated with academic disciplines, research and development laboratories and the factory floor. It draws on quantum mechanics at one end and societal needs, including manufacturing, at the other. A proper perspective of the field requires understanding the roles of science, engineering, and their synergies. At the science end of its spectrum, MS&E is rooted in classical disciplinary sciences of physics and chemistry...typically, the most important advances have been made when the research has been placed in a broad context and has been free to follow promising directions which may not have been apparent at the outset."

"The essence of our field," said Flemings, "is the four elements of synthesis and processing, structure, properties, and performance, and their interrelationships." He illustrated this philosophy by showing the symbol proposed for the study report—a tetrahedron with these four components labeling the vertices. Beyond the four elements of the symbol, however, he emphasized that "the field...stretches across all material classes, the full gamut for science and engineering, and involves aspects of social and economic costs, quality, and competitiveness. He gave structure studies their due: "...we can hardly imagine a modern MS&E without intimate knowledge of, and control over, structure at all levels." He went on to say that an important and central finding of the study is that the United States has "a major national weakness in synthesis and processing."

Industrial Surveys

The study surveyed eight industrial sectors with respect to their materials science needs. According to Flemings, "An overriding theme of all [industry] surveys was the primary importance of synthesis and processing with respect to new materials, traditional materials, and fabrication of these materials into useful components and devices...needs in other areas...including new materials...[and]...mathematical modeling." "Another cross-cutting theme," he said, was the "strong belief-...that the federal government should play a leadership role in helping industry develop new strategies for international competitiveness, in helping bring industry and universities together to address these issues, and to lead in reorientation of the missions of the national laboratories to more effectively address industrial needs..."

Research Advances and Opportunities

According to Flemings, the study examined research advances and opportunities in two ways: (1) by materials function to determine the status of structural, electronic, magnetic, photonic, superconducting, and bio-materials; (2) from the

https://doi.org/10.1557/S0883769400063430 Published online by Cambridge University Press

perspective of the "tetrahedron" in terms of synthesis and processing, structure, properties, and performance. Flemings claimed that important and major opportunities spanning the various categorization approaches were identified. He explicitly mentioned a "significant lag...in the development of state-of-the-art instrumentation for structure analysis..." He saw opportunities for materials performance enhancement and "most importantly...in the future for research across the science to engineering spectrum in...synthesis and processing."

Education

Based on surveys by the study's panel on education, Flemings concluded that "the production of trained professionals has remained essentially constant in the face of greatly increased needs and opportunities in the field." He went on to say that the committee "has concluded that undergraduate courses and programs should emphasize the basic elements of the field and their interrelationships...and that new courses and new textbooks, dealing generically with all materials are needed at both the undergraduate and graduate levels." He contended this to be particularly needed in the synthesis and processing area in general and most notably in linking processing with manufacturing.

MS&E Support Resources

Turning to resources (other than human) in support of MS&E, Flemings noted that "at least 15 federal agencies, each with different characteristics and missions, support research and development in materials science and engineering" but that, "a decrease of approximately 11% in materials research and development funding over the 11-year period, 1976 through 1987, for six agencies which play major roles in the materials, had occurred [after correction for inflation]." "More importantly," he continued, "the total nondefense materials research and development expenditures decreased by 23% in constant (1982) dollars." Due to increased support by DOE and NSF in recent times for major facilities, "workers in this field have experienced dramatic reduction in their combined level of effort," he said. That this decline comes at a time of rapid advances in MS&E by other nations, was duly pointed out. Referring to recent high temperature superconductor efforts, Flemings said that of the roughly 100 million dollars in the 1988 federal budget directed toward this area, all but 18 million was reprogrammed from existing efforts and that "the impact on other important areas of research in MS&E must be substantial."

Although based on an 11-year-old survey, the MS&E Committee found that the portion of R&D funds in industry devoted to MS&E (some 19%) far exceeds the corresponding portion of the federal R&D budget (about 5%). If that ratio held today, it would imply 11 billion dollars of industrial materials research, according to Flemings. He went on to note the important roles played in MS&E by some relatively new and some not so new developments, viz., state governments have dramatically expanded local funding of technology thrusts, and several types of centers and laboratories play important roles in MS&E, such as the national laboratories, the materials research laboratories (MRLs) on campuses, and the newer engineering research centers (ERCs), also on the campuses.

International Aspects

The study panel concerned with the international scene had, said Flemings, "a striking observation...[that is] the strong commitment to industrial growth by all major nations [and] to coordinated research and development in which materials science and engineering is a featured element. Materials science and engineering, together with biotechnology and information technology is targeted by all countries as one of the top three key technologies for the future."

In comparing the United States and other nations in terms of identified industrial factors, this panel discovered that the United States was either at parity or had a clear current advantage over five comparison countries with regard to several factors. But the perception of the experts was that, in all but two of 16 subcategories examined, the United States' position is either static or deteriorating. In factors involving capital and financial resources, the United States was found to be at a distinct disadvantage. With regard to "technology factors" defined for such comparisons, basic research in the United States was found to have a clear advantage and to be holding it. In development, manufacturing, and applications, Japan, for example, leads in each of these areas and the relative position of the United States in each is deteriorating. The United States was also found to be at a disadvantage in the context of "government factors" (i.e., policies on industrial development, etc.).

At the end the Boston session, Flemings was joined on stage by Rustum Roy (Pennsylvania State University), Gerald Liedl (Purdue University), and Kathleen Taylor (GM Research Laboratories), all study panel members. Several questions from the audience, which tended to focus on educational issues and on plans to ensure the MS&E Study report's impact on policy making, were fielded and discussed.

Elton N. Kaufmann

https://doi.org/10.1557/S0883769400063430 Published online by Cambridge University Press