Materials Research—Current Issues and Future Directions

Editorial Essay

By John W. Collette* and Joel S. Miller*

"I am making the first announcement of a brand new chemical textile fiber. This textile fiber is the first man-made organic textile fiber prepared wholly from materials from the mineral kingdom...; Though wholly fabricated from such common materials as coal, water, and air, Nylon can be fashioned into filaments as strong as steel, as fine as a spider's web, yet more elastic than any of the common natural fibers."[1] This announcement by Du Pont's Vice-President, Dr. *Charles Stine*, on October 27, 1938, caught the public attention and can, perhaps more than any other single event, be viewed as the beginning of the *Age of Polymers*. Few if any futurists would have predicted how the subsequent avalanche of synthetic polymers would change the way man thinks about and uses materials. As part of the 50th anniversary celebrations of Nylon the "Advanced Materials Conference on Current Issues and Future Directions in Materials Research" was held in Wilmington, Delaware, USA, on October 23.–24., 1988. It provided an opportunity to focus on the theme of shaping the future in the evolving new world of materials and material systems.

Historically, the commercialization of Nylon culminated several decades of technological advances in Europe and the United States which had seen the growth of a polymer industry based largely on the chemical modification of cellulose. Major research efforts were also under way seeking a substitute for natural rubber. Then within one decade, a completely new series of synthetic materials—Neoprene rubber, styrene/butadiene rubber, polystyrene, polyvinylchloride, polyvinylbutyral, polymethylmethacrylate, Nylon and Teflon were developed which provided properties previously unattainable. Fifty years after its introduction, the worldwide market for nylon polyamides has grown to an annual size of 12 billion pounds. Sales are still expanding at a rate significantly faster than the gross national product. This, however, represents only a fraction of the global business in synthetic polymers.

There have been many technological developments during this period. New scientific advances in synthesis, in physical techniques, and in computational capabilities are increasing our ability to make, characterize, and understand the properties of specifically structured materials. The coalescence of macromolecular, metallurgical, and ceramic technologies around a common need to provide specific structural properties has catalyzed interdisciplinary work and synergized the translation of advances in one field to others. The increasing overlap of science with technology has seen scientific advances moving rapidly into technological development and advances in technology catalyzing scientific investigations into new materials.

Dr. *Ardent Bement*, Vice President for Technology at TRW Inc., in a keynote introduction to the conference, noted that never before have materials engineers been able to offer so many options to the design engineers in assisting them to reconcile conflicting ideals of efficiency, economy, functionality, durability, and aesthetics.[2] *Bement* provided a historical perspective of synthetic polymers in the evolution of materials science. He looked forward to even more exciting developments as microelectronic technology is combined with materials to provide a new generation of smart materials systems.

Prof. *Merton Flemings*, in his presentation entitled "National Perspectives on Materials Science and Engineering," observed that materials technologies are a key element in improved productivity and overall economic growth.[3] All leading nations and industries have targeted materials, and especially advanced polymers, as a theme for research emphasis. *Flemings* succinctly reviewed the preliminary findings from a forthcoming National Research Council Study on "Opportunities and Needs in Materials Science and Engineering" which he co-chaired. This study has identified important opportunities for improved materials in the aerospace, electronics, health care, automotive, chemical, and energy industries. Noteworthy conclusions include an urgent need for increased efforts on the synthesis and processing of materials and on education. Furthermore, improved interdisciplinary interaction between chemists involved in synthesis, physicists and physical chemists involved in structure and property determination, and engineers who process the material and fabricate the product are critical to future progress.

These themes were reiterated in the major technical talks (on which the following articles in this issue are based): Dr. *Michael Salkind* described the revolution taking place in aerospace materials to meet the challenges of lower weight with higher operating temperatures. The future will see increasing effort on so-called smart systems which can respond dynamically to external stresses (exemplified by the flying replica of the extinct reptile *Quetzalcoatl Northropi*). Dr. *David McCall* outlined the materials challenges in electronics applications as the drive towards miniaturization exacer-

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bates the complex interactions between the metals, ceramics, and polymers used in these systems. Prof. *David Williams* emphasized the embryonic character of materials technology in healthcare applications. Current materials used to replace bones or other body parts generally have only a single, simple function, usually a mechanical one. Truly functional replacements which combine mechanical properties with biological characteristics will require major advances in understanding how natural materials function and in the design of smart materials. Prof. *Walter Michaeli* used liquid crystal polymers to exemplify the importance of processing on materials properties. He also showed the value of computer modeling to guide part design based on knowledge of the behavior of the polymer during processing.

The importance of interdisciplinary work and of a systems approach to materials application was vividly apparent in the history of the development of Kevlar aramid fiber by Drs. *David Tanner, James Fitzgerald,* and *Brian Phillips.* With a highly engineered material such as Kevlar, market emphasis shifts from simply selling the product, to providing a system which meets a functional need. A complex composite, for example, may involve both organic and inorganic fiber reinforcement in a matrix of two or more different resins, all chosen to provide specific properties. The materials scientist has to be concerned not only that each individual material has the optimum properties needed but has also to understand the complex interactions between them in the final system.

The interdisciplinary nature inherent in materials research, the globalization of scientific effort and the intense international competition in advanced materials are combining to bring about many changes: partnerships between different companies to share technology, increased industrial/academic collaboration, and an effort by the government to facilitate technology transfer from government laboratories. This has affected the way research and development is carried out and placed new demands on the current science and engineering educational system. The particular issues of education and of collaboration between industry, academia, and government were addressed by the panel of industrial, academic, and government representatives. For a critical summary of this discussion see Prof. *Gerhard Wegner*'s contribution in this issue. The panel highlighted many of the changes already taking place. These include: 1) increased industrial support of academic research; 2) more collaborative programs between industry and individual university scientists; 3) visiting scientist programs to bring academic researchers to industry; 4) government policies aimed at encouraging effective liaisons between the different sectors; and 5) an increase in interdisciplinary training and research in academia. Some major gaps are the virtual absence of industrial scientists taking sabbaticals at universities and the limited number of Americans who study in Japan. A major issue discussed was how to increase interdisciplinary programs at universities without sacrificing the quality of the scientific training.

The materials field has never been so vibrant and full of expanding opportunities as it is today. Materials science is truly a dynamic global science of growing critical importance to mankind. The conceptual focus of materials research is changing from using available materials, to designing systems and materials in the context of a functional application. A major challenge for the future is to assure a climate which is conducive to effective R & D. We must optimize the fruitful partnership between industry, universities, and government. Educational programs at universities must be strengthened, and must recognize that advances will require experts who can communicate and cooperate in interdisciplinary programs. These goals must be met if we are to remain competitive in an increasingly technological world.

[1] D. Hounshell, J. K. Smith: *Science and Corporate Strategy*, Cambridge University Press, New York 1988, p. 270.

[2] A. L. Bement, *Metallurg. Trans. 18 A* (1987) p. 363.

[3] J. P. Clark, M. C. Flemings, *Sci. Am. 255* (1986) No. 4, p. 50.

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