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Panel Discussion

Improving Effectiveness in Materials Research

By Gerhard Wegner *

High temperature materials, electronic materials, composites and superconductors are featured as regularly in the business press as in scientific journals. Materials science receives heavy management attention as well as public and political interest worldwide. The Materials Research Society (MRS), founded only a few years ago in the US, is rapidly growing into one of the largest professional societies, with offshoots on other continents. Despite the obvious successes of materials science as a field of industrial relevance and academic concern, the people involved do not seem to be very satisfied. One of the key issues is finding the proper balance between industrial or market driven research and development and the necessity to conduct in depth research of a basic nature to find and understand new materials. This issue is intimately related to the role of industry in defining and supporting research areas in academic institutions. Conversely, the transfer of basic knowledge, new insights and novel methods from the ivory tower of the university to the harsh and competitive ground of the industrial world does not seem to work well and finds many obstacles.

This, in a nutshell, was the content of a panel discussion organized and directed by Du Pont's *Rudolf Pariser*, Director for Advanced Materials Science in the Central Research and Development Center at Wilmington, Delaware, USA. The panel discussion was part of an Advanced Materials Conference celebrating the 50th anniversary of Nylon and the invention of Teflon, both products being cornerstones of the commercialization of polymeric materials.

[*] Prof. G. Wegner
Max-Planck-Institut für Polymerforschung
Jakob-Welder-Weg 11, D-6500 Mainz (FRG)

A Climate of Worldwide Competition and Collaboration

"The climate in Du Pont research is characterized by increasing worldwide competition and collaboration, the globalization of business and the need to respond quickly and specifically to market needs, energy and raw materials resources and environmental issues...", Dr. *Pariser* told the audience of more than 150 invited scientists from US and foreign universities, research institutes and agencies involved in materials science studies.

Du Pont's approach to research and development reflects the change of attitude towards materials science worldwide. As little as ten years ago, the laboratories were organized to emphasize specific polymeric materials, such as elastomers or textile fibers with relatively little interaction between them. Today, research has expanded beyond polymers and includes ceramics and metals as well. The emphasis is on materials systems and systems functionality. New fields are under development based on polymer composites and structural ceramics, inorganic fibers and molecular composites. Thus, an advanced materials laboratory has been created where many materials disciplines are combined into one organization with broad functional research themes. The trend is toward multidisciplinarity among the research staff as well. In addition, Du Pont has a rapidly increasing involvement with US universities. The more than US $ 25 million which were spent by Du Pont in 1988 alone to support university research programs was a substantial part of the total US $ 630 million by which US industry supported R & D at American universities.

Support of academic programs cannot be seen independently from the hiring policy. "We at Du Pont," Dr. *Pariser* said, "have always tried to hire the very best students. We are also emphasizing the ability to collaborate and interact with others, to communicate, and to show a high degree of initiative and self-management." As a policy, Du Pont tries to hire the best students from the classical disciplines, frequently from the top rated universities, despite the fact that these graduates need substantial reeducation and another two or more years further training to adapt to the R & D subjects of industry. Secondly, graduates are hired with specific expertise which is urgently required, for the exploration of polymer composites, thin film techniques or ceramic processing. The contribution of these graduates can be of immediate value but there exists the problem that they may be too specialized and lack the flexibility needed to respond to future challenges.

The rapid development of materials science and its impact on chemical industry obviously requires changes of emphasis in the education of scientists and engineers alike. An interdisciplinary education is absolutely necessary, otherwise the students and graduates will not learn to adapt to the unexpected developments which, for good reasons, are the basis for the further success of industry.

Graduate Education in Materials

What should an active and successful Department of Materials Science look like? How should it be organized? What about the balance between "core" subjects and specialized training programs?

These questions were raised by Dr. *Anthony Evans*, Chairman of the Department of Materials at the University of California, Santa Barbara. As a general philosophy he suggested a multidisciplinary curriculum with three fields of specialization. These, for example, could be:

- Structural materials
  (advanced composites, light weight alloys, tough ceramics)
- Electronic materials
  (compound semiconductors, optoelectronic devices, quantum wells)
- Macromolecular materials
  (high-strength fibers, interfaces, conducting polymers)

Furthermore, training and research projects should be favored, which have the integrated concept of devising a model, testing the properties and establishing the role of processing in the quality control of the materials and devices. This requires substantial investment in capital equipment and continuous support to maintain sophisticated equipment. Among others, the following facilities should be made available for training and research: machinery to process ceramics, metals, and polymer fibers and to prepare surface structures (molecular beam epitaxy); all methods for structure investigation, notably electron microscopy (SEM, TEM etc.) and, last but not least, sufficient computing hardware. Dr. *Evans* also emphasized the role of unconventional industry–university relationships which help to motivate the research students and faculty. Among other suggestions he mentioned "research condominiums," a term which describes a joint university–industry research program in which space, facilities, students and faculty are shared for a certain time to solve a specific but interdisciplinary problem which is of interest to one or more industrial partners. The active participation of researchers from industry in such "research condominiums" is the necessary ingredient which differentiates this from conventional industry supported programs.

The Impact of Government Policies

"The problem of revitalization of civilian R & D effort in the US is compounded by the heavy emphasis on military programs in our federal R & D budget. We spend almost twice as much on the military programs as on civilian efforts, with relatively little payoff in economic terms. This puts us at a significant disadvantage compared to our trading partners." This was one of a number of rather blunt statements by Dr. *John H. Moore*, Deputy Director of the National Science Foundation, describing current trends in the US-federal policy towards science and technology. He greatly deplored the fact that when only civilian R & D is considered, the US rate of investment, at 1.9% of the gross national product (GNP), is only about two-thirds the level of Japan and below that of West Germany and France. On the other hand, Dr. *Moore* reported, there was a major shift of the administration away from supporting applied research and development programs and toward basic research. As a result, basic research now gets about 40% of the non-defensive federal R & D dollar today as opposed to about 23% in 1977. Although the administration and its institutions recognize the importance of basic research as fundamental for further economic development, they also emphasize increased interaction between industry and academia. "We need explicit mechanisms," Dr. *Moore* said, "to make sure that results of our (academic) laboratories flow smoothly into industry." One such mechanism is the establishment of Engineering Research Centers (ERC's). Center topics include combustion processes, biotechnology, process engineering, robotics in microelectronics processing, composite materials and intelligent systems engineering. NSF presently supports 18 ERC's and plans to increase that number.

A Change of Culture is Needed

"University researchers will have to lose any lingering disdain for concern about marketability and profit of their discoveries. They will have to learn that directed research does not automatically represent a threat to free academic inquiry" said Dr. *Alan Schriesheim,* Director of Argonne National Laboratory and Professor of Chemistry at the University of Chicago, to a somewhat startled audience. He reported on his attempts to increase the sensitivity of the research staff of the Argonne National Laboratory to the commercial potential of their work. One feature was to make patents and R & D awards a legitimate factor in promotion applications along with the traditional scientific publication list. Another feature was the creation of a Technology Transfer Center which became pro-active rather than re-active to commercial opportunity.

The Need of Goal Oriented Basic Research

Effective communication in the materials area is a challenge which requires the interdisciplinary approach illustrated in this issue of Advanced Materials. The Materials Research Society (MRS) has also taken on the challenge by sponsoring multidisciplinary meetings, *Kathleen C. Taylor,* past president of the MRS, told the audience. In addition, the MRS attempts to fill the gap between basic research and application by emphasizing goal oriented basic research. Improved effectiveness in research is reached by fast communication of recent results; however, it is not recommended to abandon peer review which would lead to a rapid decline in the quality of the published reports.

Dr. *Kathleen Taylor* is head of the Physical Chemistry Department at the General Motors Research Laboratory and is thus an expert at considering the needs in materials in the automobile industry. Summarizing the current trends and needs in that industry, she pointed to the increasing importance of plastics and composite materials. Plastics now comprise more than 200 lb of the weight of each vehicle, and when all polymer-based materials are considered including elastomers, paints, adhesives and sealants, this number is 400 lb. Reduction of the production costs in the manufacturing process and the decrease in number of individual parts by integral design is the advantage offered by polymers over conventional materials. The major deficiencies of ceramics as substitutes for metals are still the low reliability caused by brittle failure and the high cost of fabrication.

Another issue is the development of long life batteries, a prerequisite if the electric vehicle is to become a common feature. Fuel cell technology will require that efficient low cost membranes and electrocatalysts become available. Last but not least, it becomes more and more important to predict performance based upon a knowledge of chemical-physical characteristics and operating parameters—a wide open field for theoretical work.

Specialists or Generalists—the Role of Education

Coming back to the initial remarks of Dr. *Pariser* on the role of education and the impact of industry–university relationships in materials science, Harvard's Professor *George M. Whitesides* commented on the function of the universities. The key problem is that it takes a very long time to learn how to educate a good expert in a decent time and that professors are faced with the problem of teaching the right subject. Although being a chaired professor himself, he did not hesitate to remark that professors in general are not amenable to new ideas. He suggested therefore that industry should give preference to assistant professors who are eager to open up their own field of expertise. Professor *Whitesides* emphasized furthermore that if one wants to establish a meaningful interaction between industry and university the motivation must be clear. Finally, technology transfer will never work unless accompanied by the transfer of personnel. He thus called for an increased exchange of personnel over shorter or longer periods between university laboratories and industrial sites.

What is the Message?

Did the panel discussion convey a message to the audience, to the public, to the scientific community? This foreign observer, invited as a guest to participate in the celebration of the 50th anniversary of Nylon and Teflon, was left with mixed feelings. Du Pont deserves applause for the attempt to focus on the intellectual background of commercial enterprises in chemical industry and on the role of basic and academic research for past and present developments of product lines in materials. Many of the statements made by panelists from industry will be taken as encouragement by those who fight for better recognition of materials science as an academic subject in universities and academic circles. On the other hand, no solutions were given—and probably can never properly be given—how to bridge the gap between the needs of industry for more specific research on actual products and processing, and the aspiration of academia to work on very general aspects and laws controlling materials structure and dynamics.

Not too surprising to the foreign guest, the panel discussion was almost entirely centered on the US despite the initial remarks of Dr. *Pariser* on the global issues. Non-US developments were only mentioned in the context of how US industry and the US educational system could maintain leadership in technology and business or regain ground lost in the recent years to Japan or to Europe. The competition by Japan was seen as the major issue by many of the panelists although there are similar problems in this country when it comes to the central point of how materials science and materials science centers can be properly supported, and oriented toward goals worth the money invested.

Overall the panel discussion gave a snapshot of the current state of mind of US materials scientists in industry, universities and academic research centers, and that is certainly helpful for further orientation.