ADVANCED MATERIALS

Chemistry of Materials

Editorial Essay

By Leonard V. Interrante*

The association of chemical processes with the preparation and utilization of materials has its roots in the prehistory of materials technology. The fire-hardening of wooden tools and weapons by prehistoric man depended on the same basic chemical process as the current fabrication of carbon fiber by carbonization of an organic polymer fiber. The subsequent bronze and iron ages were similarly dependent on the chemical extraction of copper and iron from their ores, again reflecting the intimate association between chemical processes and materials technology.

Despite the fundamental reliance of materials processing on chemistry, the chemical profession has been slow to take up the challenges of materials technology. Perhaps as a result of this lack of strong input from chemists, the application of chemistry in materials technology has tended to be empirical in nature with an incomplete understanding of the relevant chemical processes involved.

In recent years the increasing demand for advanced materials to meet the needs of current technology has led to a reexamination of this interface between chemisty and materials science as well as an increasing recognition of the need to involve chemistry and chemical engineering more directly in the pursuit of solutions to materials-related problems.[1] The increasing interest in chemistry as a source of new materials, or as a means of processing and using known materials more effectively, is illustrated by the titles of several recent international meetings, e.g., "Better Ceramics Through Chemistry", "Molecular Design of Materials" and "Molecular Chemistry for Solid State Electronics".[2] In the United States this interest has also been reflected in increasing employment opportunities for chemists and chemical engineers in areas which were traditionally the exclusive province of other disciplines, for example, the electronic materials processing and ceramics industries.

Examples of the successful marriage of chemistry and materials science can be found in many areas of current technology. In electronics one can cite the development of chemical and biosensors using surface-modified electrodes[3] and the widespread use of polymers as dielectric materials and as radiation-sensitive resist materials.[4]

Chemistry has also played an important role in the etching and deposition of thin film electronic materials with a rapidly growing interest in plasma- and laser-assisted processing as well as in chemical vapor deposition using designed organometallic precursors.[5] The key role of chemistry in the selective addition and removal of the wide range of materials involved in the construction of a silicon integrated circuit is illustrated by the cross-sectional view of an advanced bipolar device structure in Figure 1.[6] Each of the many steps involved in the construction of this device

[*] Prof. Dr. L. V. Interrante
Department of Chemistry, Rensselaer Polytechnic Institute
Troy, NY 12180-3590 (USA)

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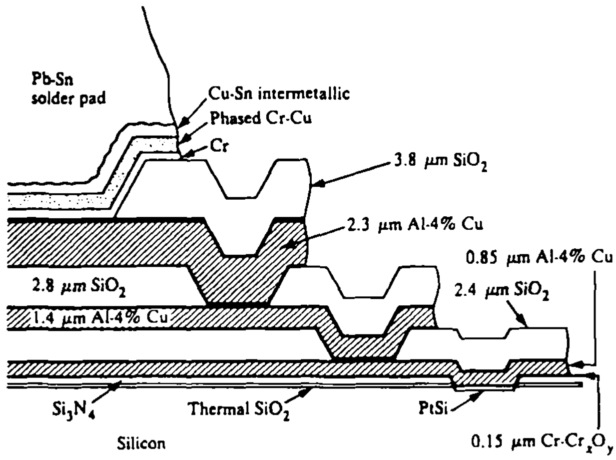

Fig. 1. Cross-section of an integrated circuit chip. [6]

employs one or more chemical processes which bring into play elements of inorganic, organic and polymer chemistry.

In the area of structural and, in particular, composite materials, chemists have been called upon to produce polymeric precursors to materials such as silicon nitride and silicon carbide which can be used to prepare high temperature, high strength ceramic fibers.[7] This work extends to inorganic polymers the growing interest in rod-like organic polymers and carbon fibers as reinforcements for light weight, high strength structural composites.[8]

The current focus on chemistry as a solution to materials-related problems encompasses all of the major chemistry and chemical engineering disciplines and involves both the development of new materials and the processing of known materials. In the context of materials processing there is an increasing demand for improved methods of obtaining known materials in unusual forms such as epitaxial thin films, stable colloidal suspensions, and microporous membranes. The increasing use of sol–gel methods for the processing of ceramic powders, monoliths and films provides an illustration of the opportunities for chemistry in this area.[1,9]

A common theme in materials-related research is the interaction between materials and their environment, for example, in connection with heterogeneous catalysis, corrosion, adhesion, abrasion resistance, the design of biomaterials, chemical sensors and thin film deposition. The full understanding and control of these processes depends to a large extent on the skills of chemists and chemical engineers who are trained in areas such as surface science, analytical chemistry, chemical kinetics and thermodynamics, as well as in the theory and modeling of chemical processes on solid surfaces. On the other hand, it is clear that chemists or chemical engineers working in isolation are not likely to provide the solutions to these and the many other chemistry-related problems in materials science and technology. It is well known in industry that the greatest likelihood of success comes from an interdisciplinary approach to problems, where chemists and chemical engineers combine their knowledge with that of other scientists and engineers.

A prerequisite for effective interaction is effective communication. The scientific and technological questions posed by materials science, and their chemical implications, must be presented and discussed in a manner which is clearly understandable to all of the participants. This will require a better mechanism for communicating the results of forefront research in the area of materials science to chemists and chemical engineers. Similarly, materials scientists and technologists would benefit from increased exposure to the opportunities and advances in materials chemistry. These goals can be attained most effectively through the scientific literature, by the publication of articles which highlight and bring to the attention of the chemical and materials science communities some of the key areas of current interest in materials chemistry as well as examples of forefront research in this area.

The new Advanced Materials section of Angewandte Chemie provides an illustration of how this can be accomplished using a chemistry-related journal. The emphasis on commentary, review papers and meeting highlights in areas of current interest within materials science gives the reader an opportunity to view current work in this area from a chemical perspective.

The American Chemical Society began to explore the prospect of establishing a new primary research journal in materials chemistry in 1985. A major concern throughout this process was whether a new journal was needed, considering the proliferation of journals and the limited resources of our libraries. It was eventually decided that the need for better visibility for materials research within the chemistry community and the lack of an adequate common forum for the broad spectrum of materials chemistry

Prof. Dr. Leonard Interrante received his Ph. D. in inorganic chemistry in 1964 at the University of Illinois, Champaign-Urbana. After postdoctoral study at University College London, and several years as an assistant professor at the University of California at Berkeley, in 1968 he joined the research staff of the General Electric Research and Development Center in Schenectady, N. Y. where he conducted research in inorganic and materials chemistry. He assumed his present position as a Professor of Inorganic Chemisty at Rensselaer Polytechnic Institute in 1985. He has authored and co-authored over 75 publications in coordination chemistry, organometallic and solid state chemistry. His current research interests cover a wide range of materials-related subjects, including the synthesis and investigation of organometallic precursors to ceramic materials, chemical vapor deposition processes, and the preparation of molecular solids with novel electrical and magnetic properties. Dr. Interrante was selected as editor of the new ACS journal, Chemistry of Materials, in January 1988.

research currently in progress throughout the world required a new journal. Such a journal would highlight the role of chemistry as a source of new materials and processes for materials technology and bring together work now widely scattered throughout the literature. The recommendation that a new journal be established was subsequently approved by the ACS and the first issue is scheduled for publication in January, 1989.

From the beginning *Chemistry of Materials* was envisioned as a primary research journal which would emphasize the more chemical and fundamental aspects of materials science which underlie current and future materials technology. This journal seeks to publish the results of forefront research efforts with a molecular-level perspective at the interface of chemistry, chemical engineering and materials science. Preliminary communications and full papers, in addition to selected short reviews highlighting particular topics in materials chemistry, will be featured in its bimonthly issues.

[1] As evidence of this increasing interest in establishing better connections between chemistry, chemical engineering and materials science in the USA, several granting agencies have recently established special initiatives such as the National Science Foundation's "Materials Chemistry" initiative which are specifically directed at encouraging research at the interface between these disciplines.
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[9] J. D. Mackenzie, D. Ulrich (Eds.): *Ultrastructure Processing of Advanced Ceramics*, Wiley, New York 1988 (1010 pages).

Microgels—Polymers with a Special Molecular Architecture

Polymer Networks
Cross-linking
High-impact Polymers

By Markus Antonietti*

1. Introduction

The development of new polymeric systems and the improvement of their physical properties for technological applications can be brought about by two main directions of research. On the one hand, polymer properties can be adjusted by developing new monomer units: the resulting changes in local molecular properties such as rotation barriers, polarity or anisotropy are reflected in bulk polymer properties such as stiffness or flexibility, solubility, or properties associated with crystallinity. However, for obvious reasons, the scope for inventing useful "new" monomers is limited. Consequently this strategy increasingly leads to "low quantity" polymers with very special properties.

[*] Dr. M. Antonietti
Institut für Physikalische Chemie der Universität
Welder Weg 15, D-6500 Mainz (FRG)

On the other hand, the properties of polymeric materials are also determined by the geometrical parameters of their macromolecules. For instance, short and long chain linear polymers have completely different properties; branched and cross-linked systems again show different behavior. Here the microscopic topology of the polymer chains and the resulting geometrical interactions, such as entanglements or even knots, are reflected in the product properties. An understanding of the relationships between these microscopic parameters and macroscopic properties helps to improve existing materials by controlling the topological structure without necessarily changing the chemical composition of the macromolecular system. These types of approaches have just started to yield quantitative relationships in polymer science. Thus, the possibilities for obtaining "new" materials (or better still, old materials with new properties) are most promising. Often small changes in reaction conditions result in different topologies and create or improve the desired property.