ULRICH B. WIESNER

CONVERGENCE AND COMPLEXITY

Chemistry, biology merge with materials science in soft matter research, a field with much promise

I STUDIED CHEMISTRY IN GERMANY IN the 1980s. I still remember all the discussions and concerns about specialization driving diverging disciplines and the resulting inability of talking a common language in the natural sciences. In Germany, parents tried to prevent their children from studying biology because there were no jobs. At that time, I started to observe two trends: Analytical techniques were moving down in length scale while chemistry was moving up. In 1986, Gerd K. Binnig and Heinrich Rohrer received the Nobel Prize in Physics for their scanning tunneling microscope. A year later, Donald J. Cram, Jean-Marie Lehn, and Charles J. Pedersen won the Nobel Prize in Chemistry for their development and use of molecules with structure-specific interactions of high selectivity.

In the 1990s, I received my Ph.D., did postdoctoral research, and finished my habilitation (German equivalent of an assistant professor position), all in physical polymer chemistry. Pierre-Gilles de Gennes received the Nobel Prize in Physics in 1991 for his work on "soft matter," which helped to establish this field. Scanning tunneling and atomic force microscopy techniques developed rapidly. The process of directly visualizing molecules, a former dream of chemists, became routine. The terms "supramolecular chemistry" and "self-assembly" became common vocabulary for chemists.

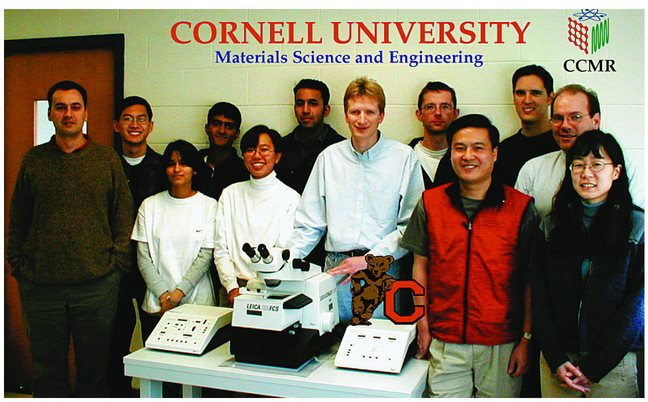
I teach in the materials science and engineering department at Cornell University. For the natural sciences, it is an incredibly fascinating time. In contrast to the 1980s, our languages seem to be converging again. Biology is the new leading science. Nanotechnology seems to be ubiquitous. At Cornell, the powerful concept of integrating artificial and natural systems through engineering materials toward the length scale of biologically relevant molecules has led to the creation of a National Science Foundation science and technology center in nanobiotechnology.

What does a chemist do in materials science? Let's look at two events of late 2000. First, Alan Heeger, Alan MacDiarmid, and Hideki Shirakawa received the Nobel Prize in Chemistry for the discovery and development of conductive polymers. Second, the Von Hippel Award—the highest honor of the Materials Research Society—went to George Whitesides for bringing fundamental concepts of organic chemistry and biology into materials science. These events express the growing appreciation of materials-related issues in chemistry and vice versa. Indeed, the corresponding research perspectives are incredible, and the potential benefits to society of these developments are tremendous, considering the strong correlation between new materials discovery and cultural developments in the past. Today, it is clear that soft matter, based essentially on the chemistry of carbon, already allows or will soon allow the generation of more diverse electronic, magnetic, optical, mechanical, and biological properties.

Where are the challenges? Well, nature generates an enormous variety of functions out of a few building blocks, whereas in the synthetic world, many building blocks are still required to obtain limited functionality. As in natural biomaterials, functionality is often obtained in carbon-based synthetic soft materials, through fine-tuning of ordered and disordered regions organized in hierarchical superstructures. Understanding functionality on the basis of local structure and dynamics involves spanning multiple orders of magnitude in length and time scales, which today remains a challenge.

What is next after nanotechnology? Because development in various areas seems to be cyclic, in the future we probably will use what we learned by going down in length scale to go up again. Although the first process is more analytic, the latter will be more synthetic in nature. One fundamental issue will then be the behavior of complex systems. Synthesizing and understanding a complex system based on multiple subunits that lead to synergistic effects is a considerable task. Nonetheless, it seems a logical pathway for development, because nature has taken it. For example, from the evolutionary pathways of proteins we know that after optimizing a particular structural element, nature often synergistically combines several such optimized elements of comparable complexity to reach an even higher level of performance.

Signs of this move toward complexity are everywhere, and they go well beyond the issues of existing programs in biocomplexity. In my own group, we combine optimized block copolymer structures with inorganic sol/gel chemistry to create novel hybrid materials that exhibit synergistic effects. These materials offer enormous scientific and technological promise in areas ranging from microelectronics to biomolecular detection. Interdisciplinary work and a common language between disciplines are prerequisites for such efforts. In particular, with their insights into molecular structures, the opportunities for significant contributions by chemists will be tremendous.



NEW MACHINE Wiesner (center, blue shirt), surrounded by his colleagues, postdocs, students, and the school mascot, shows off a brand-new machine—a cryoultramicrotome—in a new materials facility.

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