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on the evolving curriculum in materials science & engineering

In 1950, materials science and engineering did not exist as a university department. Instead, there were separate departments for metallurgical engineering and ceramic engineering. Polymers were taught in chemistry and chemical engineering departments. Solid-state physics was a well-established branch of physics, but introductory solid-state physics was taught in metallurgy departments. Specific areas of electronic materials were taught in many different departments. Subjects such as corrosion, mechanical properties, and materials processing were also found in a wide range of university departments.

During the following ten to fifteen years, many universities initiated educational programs in materials science and engineering. In 1955, for instance, the metallurgy department at Northwestern University broadened its coverage to include several subfields of materials science and engineering – polymers, metals, electronic materials, and ceramics. The university's board of trustees changed the name of the department to materials science in January of 1959. Some time earlier the concept of a unified materials course based on principles that applied to a broad range of materials, rather than on the cataloging of materials and their properties, began to take form.

It has long been recognized that interdisciplinarity is at the core of materials science. In his *Ten Books on Architecture* more than two thousand years ago, Vitruvius cited wood, steel, bronze, rope, and stone as the *materia* that constitute machines. In recent times, electrical engineers, ceramists, physicists, and chemists worked together at Arthur Von Hippel's laboratory for insulator research at the Massachusetts Institute of Technology, one of the first interdisciplinary materials science laboratories at a university. During World War II at the Metallurgical Laboratory at the University of Chicago, researchers from almost every branch of the physical sciences and engineering collaborated on designing and building nuclear reactors. The development of the transistor at the Bell Telephone Laboratories was achieved through a collaboration of researchers in many materials subfields.

After World War II, the engineering sciences became an increasingly large component of engineering education. The U.S. government and many indus-

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trial companies put pressure on the universities to provide a broader education in materials, fundamental for developing new products and improving existing ones. In 1952, the American Society of Engineering Education appointed the Committee on Evaluation of Engineering Education. The committee's report recommended thirty-six semester hours of engineering sciences in the curriculum. It listed engineering materials as well as physical metallurgy as engineering sciences. In 1956, the first report of the Atomic Energy Commission's Metallurgy and Materials Branch recommended new buildings and facilities for education and research in materials. The Office of Naval Research's Solid States Sciences Advisory Panel issued a report on the opportunities for solid-state sciences research after examining the U.S. Navy's materials problems. A study by the National Academy of Sciences chaired by J. Herbert Hollomon (who had assembled a materials department at the GE Research Laboratory) recommended the creation of a national materials laboratory. These and other considerations such as Sputnik led the Advanced Research Projects Agency of the Department of Defense to issue an invitation to all major universities in the United States to submit pre-proposals for funding to establish interdisciplinary materials research laboratories, with education of doctoral students to be a major component. The program still exists and is sponsored by the National Science Foundation.

The emergence of materials science and engineering as an academic discipline was a logical pedagogical development. The ability to incorporate such a wide range of materials into a single curriculum stems from the focus of materials science: the study of the relationships among processing, structure, and properties of materials. This paradigm provides the intellectual framework for choosing the scientific base and experimental methods that are discussed in the curricula. It is more efficient to teach basic information in solid-state physics, thermodynamics, kinetics, molecular and crystalline structure, mechanical properties, etc. for all materials than to teach these subjects separately for each class of materials.

Biological materials are now being integrated into the materials science and engineering curricula at many universities. Of course, wood and cellulose products have been among man's most important materials from the beginning of civilization, but the current major push has come from the biomedical field. The resurgence of interest in biomaterials since the 1970s is largely a result of the revolution that has taken place in molecular biology. Given the exquisite molecular control afforded by the techniques that have been developed by molecular biologists and biochemists, it is now possible to control the biological response of materials and to use biological routes to create new materials. Incorporating such approaches into materials curricula will require broadening the scope of the basic courses to include molecular biology and biochemistry.

Nerves carry electrical impulses from one region of the body to another, a subject that could be taught in a course on electronic materials. Similarly, the basics of molecular biology can be developed under the rubric of a course on soft or biological materials. By keeping the focus on the processing-structure-properties-performance paradigm of materials science, folding this new area into existing materials science curricula will be straightforward. Subjects such as X-ray diffraction and electron microscopy and diffraction currently include biological materials.

Of course, the discovery of the double helix was based on X-ray diffraction observations, and electron microscopy has long been a tool of the biological scientist. The theories of the bonding between atoms and how atoms are arranged in a material are general to all materials. Self-assembly is a phase transformation and must follow the same thermodynamic and kinetic principles as solidification, crystallization, and precipitation. Bones require a set of mechanical properties not too dissimilar from those required of other structural materials. Functionalized molecular scaffolds are used to promote the growth of a wide range of tissues. The processing-structure-properties-performance paradigm of materials science and engineering is illustrated by the strong relationship between the structure of the molecular scaffolds and the ability of these scaffolds to promote cell growth.

The materials science and engineering curriculum has evolved considerably over the past fifty years. Biological materials will be the next major addition to the curriculum. The result will be a broader and yet more intellectually vibrant field of study.