The Next Generation of Materials Researchers and the Discipline of Materials Science and Engineering: MRS Membership Identity and Role

In this letter, I consider a topic that has been debated by members of the Materials Research Society frequently over the years: MRS "membership identity" and the broader role of MRS with regard to the education of the next generation of materials researchers. Because MRS is not largely connected to a single academic discipline, like other societies such as the American Physical Society (APS), the American Chemical Society (ACS), or the American Institute of Chemical Engineers (AIChE), the issue of "membership identity" comes up: Are we uncorrelated collections of researchers, not tied together by a common vision or culture? In other words, are we still a "meetings only" society, as some have asked? Upon addressing the question of "membership identity," I will discuss the philosophy that drives meeting programming. This will provide a context for (1) the important role the Society plays in educating future materials researchers, and (2) its connections to the evolution of materials science and engineering as a discipline.

Based on the results of our most recent membership survey, taken in 2005, approximately 45% of our members regard MRS as their primary society, which is a larger proportion than in previous years. The fact remains, then, that 15% of our members identify ACS as their primary society and a slightly larger, yet comparable, number identify APS as their primary society. With regard to age distribution, 75% of our members are younger than 45 years old (this places me in the oldest quartile). Nearly 40% of our members are from non-U.S. countries, primarily Asia and Europe, and most of us (60%) are from academia, with other major components of the membership coming from industry (including manufacturing) and national laboratories. Our membership has grown steadily over the years to an all-time high of nearly 14,000. One conclusion we might draw from these data is that we are a young, vibrant, and *interdisciplinary* society.

MRS technical programming is driven by a central technical theme: Through fundamental understanding, how do we develop methods/strategies for the synthesis/processing and analysis of materials, with the goal of enabling one to "tailor" materials properties for specific applications? Programming strategies compel meeting chairs, who are carefully chosen, to "push the envelope" to bring diverse groups of researchers who work on similar materials-related problems to realize this vision. Our unique strength is the composition of our membership; we are agile and able to capture, and define, cutting-edge areas of materials. Therefore, I would argue that we are a society of materials researchers, bound by a common vision, regardless of whether we self-identify as materials scientists, physicists, chemists, or engineers. In this regard, we accomplish the mission of the Society: to facilitate the creation and dissemination of interdisciplinary materials research.

"MRS has helped define a field and a profession…."

MRS shares a key responsibility in the education of the next generation of materials researchers. To this end, I now pose a question that has been raised by a number of people: With materials research now done in many departments within a given institution, why is it still important to have an MSE department? (This comment applies with minor translation from academia to industry and government laboratories.) This issue is compounded by the observation that successful multi-investigator grants on materials exist in universities even where MSE departments do not exist. While I concede that this is a fair question, there is a danger associated with it. To understand why this is a slippery slope, I would ask you to bear with me on a walk through the historical evolution of the field. Many would argue that the roots of MSE departments are connected to metallurgy. Early in the last century, metallurgy progressed from an art to a science through the adoption of ideas and tools from other disciplines, notably, physics, chemistry, and mathematics. The fundamental ideas of mathematics and crystallography were used to interpret structural information about atomic arrangements of metals, discerned from x-ray diffraction patterns. Detailed knowledge of defects and microstructure was discerned largely due to the development of the electron microscope. Phase diagrams were developed to understand interrelations between microstructure, composition, and temperature. The realization of the connection between processing, structure (microstructure/nanostructure), and properties followed. So, not all steels behave the same way; a phase diagram is essential to understand how best to exploit the properties of steels. The infrastructure in any modern society relied on these developments in the field. Therefore, the notion of the connection between synthesis–processing–structure–properties (which many of us have come to know as the materials tetrahedron) is the heart of the field of MSE. This is not a formal part of other disciplines. Currently, the areas of emphasis in MSE departments are diverse, as they cover a range of "hard" and "soft" materials systems. Regardless of the materials system, the central theme or core (synthesis–processing–structure–properties) is the same. No two MSE departments are identical (this is not that different from physics and chemistry departments, for example), so the challenges that confront them in some ways are unique to the institution.

MSE departments are important for reasons that include the following: (1) Some industries and government laboratories (metals, ceramics, polymers) require students with specific training in MSE; such students bring skills that are not taught in other departments. (2) MSE departments serve as a focal point for materials characterization and materials processing facilities at universities. Institutions that lack them do not compete well. (3) Researchers who work exclusively on materials processing, particularly for use by researchers who study physical properties, do not naturally find homes in physics or chemistry departments, for example. Such researchers make an incredible difference in the quality of materials research on campuses. (4) Students from non-MSE departments who work on materials problems can take MSE courses and learn

https://doi.org/10.1557/mrs2006.196 Published online by Cambridge University Press

sufficient details about the field that they can become more effective researchers. Those who have not had the benefit of this will not know what they missed (I am sure their employers do not miss this point). (5) MSE departments enhance the level of interdisciplinarity on a university campus in that they provide a natural bridge between areas of engineering, medicine, and the natural sciences. Schools with the largest interdisciplinary multi-investigator proposals predominantly have diverse and healthy MSE departments.

The big challenge is in identifying how the curriculum in MSE departments should evolve to reflect the developments in the field. Major technological challenges such as energy and sustainability and problems at the interface of medicine and materials are interdisciplinary ones in which materials research plays a central role. In order to fulfill this role, the MSE department of the future needs to continue developing as the major player in the interdisciplinary research infrastructure of universities.

In light of the rapid changes in the field and associated changes in the curriculum, MRS should play a very active role in accreditation issues. The impact of MRS goes far beyond meetings: MRS has helped define a field and a profession, and as a professional society, MRS helps define the expectations of the next generation of researchers to tackle the difficult interdisciplinary problems.

PETER F. GREEN
2006 MRS President

RESEARCH/RESEARCHERS

Color-Coded Method Visualizes Drug Release in Cancer Cells

Philip Low, the Ralph C. Corley Distinguished Professor of Chemistry at Purdue University, and his colleagues at Purdue and Endocyte Inc., have discovered details of how drugs are released within a cancer cell, improving the ability to deliver drugs to a specific target without affecting surrounding cells. "Most new drugs under development will be targeted directly to the pathologic, disease-causing cells, and we have shed light on the details of one mechanism by which this is achieved," Low said.

As reported in the September 12 issue of the *Proceedings of the National Academy of Sciences* (p. 13872; 10.1073/pnas.0601455103), Low and his team developed a color-coded method to visualize the cellular mechanisms by using a technique called fluorescence resonance energy transfer imaging (see Figure 1). "The drug turns from red to green when it is released inside the cell, clearly illuminating the process," said Jun Yang, a postdoctoral research associate in Low's group.

In targeted drug therapy, drugs are linked to molecules that are used in excess by pathologic cells—for example, a required nutrient—in order to transport drugs directly to the targeted cells while avoiding significant delivery of the toxic drug to normal cells. One commonly used agent, referred to as a ligand, is the vitamin folic acid. Cancer cells need folic acid to grow and divide and therefore have developed abundant receptors to capture it. These receptors are largely absent in normal cells. This means folic acid, and the drug linked to it, are attracted to the pathologic cells and are harmless to healthy cells, Low said.

"It is desirable to have the drug released from the ligand, folic acid, once the folate-linked complex enters the cell," Yang said. "This 'conditional drug release' is usually realized by attaching folate to the drug through a linker that falls apart inside the cell. There were several linkers in common use, but with mixed efficiency. In this study, we undertook to interrogate the full details of this breakdown process."

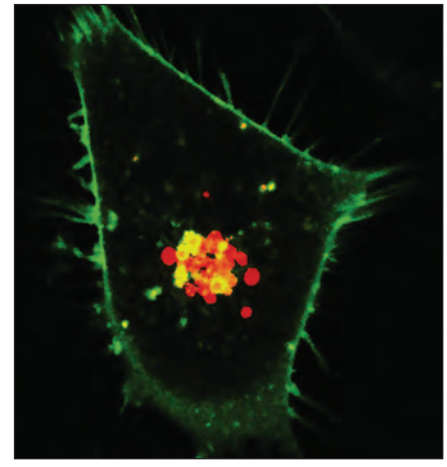

Figure 1. Depiction of drug release within a treated cancer cell. Once inside the cell, the drug turns from red to green as receptor endocytosis releases it from its folate-linker. By linking to the vitamin, toxic drugs are transported directly to the cancer cell and do not harm healthy cells. (Image courtesy of Proceedings of the National Academy of Sciences*).*

https://doi.org/10.1557/mrs2006.196 Published online by Cambridge University Press