

The Beginning of a *Small* Revolution

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Over the past five years, the scientific and engineering communities have witnessed an explosion of interest and investment in the field of nanoscience and nanotechnology. Governments around the world are investing billions of dollars to establish institutes and the infrastructure to carry out state-of-the-art research in this extraordinarily broad and exciting field. The United States government alone recently announced a \$3.7 billion nanotechnology research initiative. China, Japan, Korea, Israel, and many countries in Europe have launched national programs to build centers and expertise in this area. Over 100 startup companies have been launched worldwide, and many corporate giants are investing millions of dollars to carry out research and development programs in nanotechnology. It is not an overstatement to say that the nanoscience revolution, in terms of sheer interest and investment, is one of the biggest things to happen to the scientific and engineering communities since the beginning of modern science.

What is the nanoscience and technology opportunity?

To discuss a field in a meaningful way, a definition and description of that field is needed. One can argue the details of an appropriate definition, but the following three-part definition captures the opportunity and distinguishes the field from other initiatives. Nanoscience and technology is a field that focuses on: 1) the development of synthetic methods and surface analytical tools for building structures and materials, typically on the sub-100 nanometer scale, 2) the identification of the chemical and physical consequences of miniaturization, and 3) the use of such properties in the development of novel and functional materials and devices.

Why the sub-100 nm length scale?

Making and manipulating matter on this length scale is a grand challenge for both scientists and engineers. From an engineering standpoint, the sub-100 nm scale is extraordinarily small, and many of the tools that are used routinely to do microfabrication cannot be used for nanofabrication. However, from the chemist's point of view, this length scale,

especially above 10 nm, is extraordinarily large. Chemists are really "Angstrom-technologists", not nanotechnologists. Even when they work with large molecules, chemists are often manipulating a bond or a localized set of bonds within a larger structure. Although great strides have been made in the area of supramolecular chemistry, the synthetic toolkit required to routinely build structures with control over shape, size, chirality, and function on this length scale does not yet exist. This statement also holds for biochemists and molecular biologists who routinely work with molecules on this length scale. In fact, the investigation of the nanostructure of cells and viruses and the development of an understanding of biomolecular interactions on the nanometer scale is a frontier that demands further exploration.

What are the consequences of miniaturization?

Every substance regardless of composition, when miniaturized to the sub-100 nm length scale, will have new properties. This is where much of the scientific opportunity lies. Noble metal and semiconductor nanoparticles are beautiful examples of this principle. The optical, electrical, mechanical, magnetic, and chemical properties can be systematically manipulated by adjusting the size, composition, and shape of this class of materials on the sub-100 nanometer length scale (Figure 1). Electron transport, manifested in phenomena like Coulomb blockade, as well as the catalytic and thermodynamic properties of structures can be tailored when one can rationally design materials on this length scale. Therefore, analytical tools and synthetic methods that allow one to control composition and architecture on this

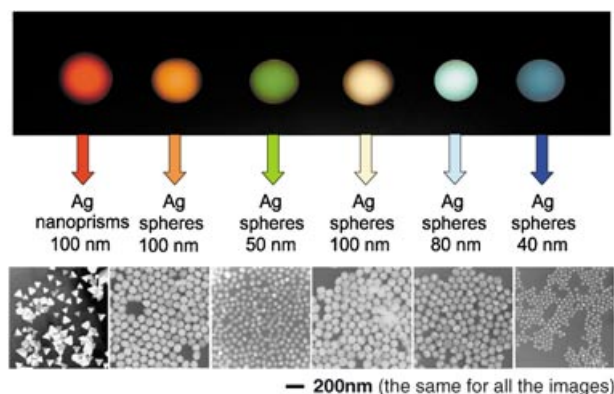


Figure 1. Size, shape, and composition matters. This statement is illustrated here by considering the Rayleigh light-scattering properties of various nanoparticles (quoted nanoparticle sizes are all approximate).

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length scale will yield important advances in almost all fields of science.

Capitalizing on the consequences of miniaturization?

This is the technology component of the definition, and the community is just beginning to learn how designer nanomaterials can be used for important applications including ultrasensitive and selective biosensors, catalysts, ultraminiaurized electronics and photonics, and as additives for cosmetics and many other articles of daily life. Combining nanomaterials with biomolecules will open new avenues in medical diagnostics and drug targeting by allowing one to consider biomarkers that can not be analyzed with conventional diagnostic technologies. This will open the opportunity to study and ultimately treat life-threatening and debilitating diseases such as Alzheimer's disease, HIV-AIDS, and many forms of cancer. More applications undoubtedly will be discovered as the field matures.

How does the field of nanoscience and nanotechnology fit into the existing scientific and engineering disciplines?

If one thinks of the established disciplines in terms of a Venn diagram, where each scientific and engineering discipline is described by a circle within the diagram, nanotechnology is not an independent, isolated circle but rather one that overlaps all of the existing circles and will continue to grow as the field is developed (Figure 2). This is what distinguishes the field from scientific fads that have focused on a particular class of materials (e.g., high-temperature superconductors). It is a field fueled by novel tool development that will impact and change almost every conventional scientific and engineering subdiscipline by providing new ways of fabricating or synthesizing structures with well-defined and tailorable properties through control over nanoscale architecture.

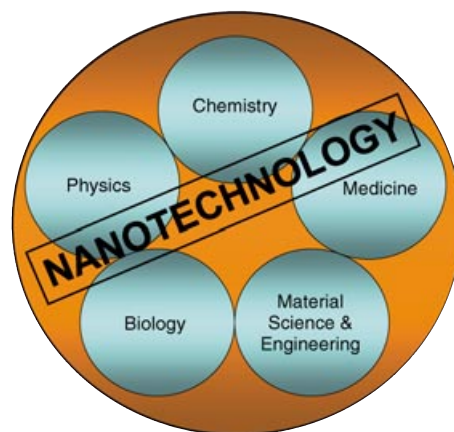


Figure 2. Nanotechnology encompasses all fields: Traditional sub-disciplines each play their hand in modern nano and micro science and technology; *Small* looks to all of these areas to provide its readers with a truly interdisciplinary journal.

With this explosion of scientific and engineering research interest and investment, what are the outlets for publishing ones work?

Because the field is so new, many of the conventional publishing outlets are still the primary choice for those interested in disseminating their work. Some of the highest impact work can be found in *Science* and *Nature*, yet these journals tend to have a very strong biology focus and very little focus on the physical sciences and engineering. There are two journals, *Nano Letters* and *Nanotechnology*, explicitly focusing on advances in this field. *Nano Letters*, a journal of the American Chemical Society, has a strong bent towards chemistry, while *Nanotechnology* (Institute of Physics) emphasizes engineering advances. Nanotechnology papers can be found in many other journals, including *Advanced Materials*, *Angewandte Chemie*, *Applied Physics Letters*, *Chemistry of Materials*, the *Journal of the American Chemical Society*, *Langmuir*, and *Nature Materials*. Even the medical journal *Lancet* has solicited contributions in the field. All of these journals have a strong tie to a particular sub-discipline. In some respects, this is not a negative consequence and demonstrates the extraordinarily broad interest in developments in this field. Researchers will and should continue to publish much of their nanoscience and nanotechnology discoveries in these journals. However, it seems odd that given the breadth of this field and the tremendous level of interest in it, that a journal does not exist to attract some of the best pieces of work in it, regardless of discipline; for example a journal that could compete with the likes of *Nature* and *Science* but with a focus not only on nanotechnology, but also on studies at the microscale where miniaturization has a fundamental impact on our understanding or provides real technological advancement.

It is, therefore, with a real sense of excitement that the Inaugural Issue of *Small* is launched at this time. *Small* aims to attract and highlight the best nanoscience and technology work from all of science, engineering, and medicine to keep aficionados abreast of and provide a forum for the publica-



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tion of the many important advances in this field over the years to come. Given the level of interest in nanoscience and technology from almost every existing sub-discipline, funding agency, and industry, it seems appropriate to create a journal that focuses on what are considered the biggest advances in the development of miniaturized structures that could impact electronics, photonics, chemistry, physics, biology, materials science, chemical, mechanical, and electrical engineering, as well as medicine, but to avoid a specific link to any one of these sub-disciplines. Although preference should be given to advances that involve sub-100 nm architectures, it is important to not limit contributions to work that pertains to a particular size cutoff, rather to highlight

excellent studies where miniaturization leads to novel and important properties and capabilities—hence, the choice of the journal title, *Small*. *Small* will be a collection of short Communications highlighting the hottest advances in nano and micro science and technology, a limited number of Full Papers of outstanding quality, Review articles that familiarize readers with a broader set of topics, Highlights and Concepts that provide third-party accounts of advances either reported in *Small* or other journals or provide a viewpoint on a particular aspect of the field, and News articles that discuss science, policy, and business issues of importance to those following the development of this field.
