EDITORIAL

Nanoscience *vs* Nanotechnology—Defining the Field

The scope of *ACS Nano* is succinctly addressed on our journal Web site: we are "an international forum for the communication of comprehensive articles on **nanoscience and nanotechnology** research at the interfaces of chemistry, biology, materials science, physics, and engineering." We see ourselves, as stated on each of our issue covers, as publishing "defining nanoscience and nanotechnology". One of the questions that often arises among researchers and authors alike is, how do we *define* "nanoscience" and " nanotechnology" and how do we distinguish between these terms?

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Although Feynman's lectures[1] or Norio Taniguchi's original use of the term "nanotechnology"[2] are often cited as the starting points for the concept, scientists have long investigated nanoscale materials and wondered about the nature of materials on small length scales. The most famous case is the color of small gold particles, which appear ruby red once the metal particle is smaller than around 30 nm in size. These particles were used adventituously by Roman glassblowers, who found that glasses impregnated with gold chloride turned red during annealing—probably due to reduction of the gold salt by carbon monoxide.[3] In 1857, Michael Faraday concluded that the unusual colors displayed by his solutions of gold salts (reduced with phosphorus) were due to the presence of highly dispersed metal particles of gold.[4] Gustav Mie pointed out in his seminal 1908 paper on the absorption and scattering of light by gold nanoparticles that, although the ruby red color of finely dispersed gold particles could be explained using the optical properties (dielectric function) of **bulk** gold, it must be the case that if the particles were made small enough, their properties would begin to differ from the bulk.[5] So it is clear that scientists have long considered the fact that, at small length scales, materials must be different from the bulk.

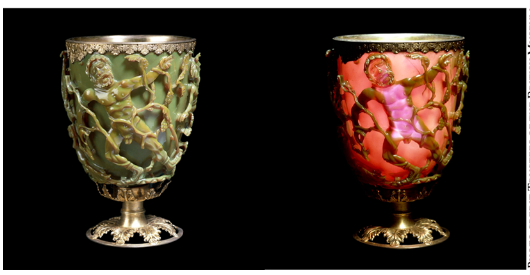
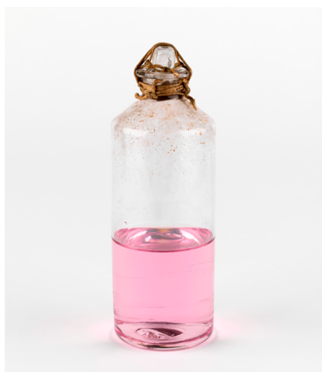


Photo credit Trustees of the British Museum



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The Lycurgus cup (left) is made from dichroic glass, which changes from opaque green to translucent red when light is shone through it. (right) Gold colloids created by Faraday.

Nanoscience is the study of the properties of matter at the nanoscale; in particular, it focuses on the unique, size-dependent properties of solid-state materials.[6] New methods of synthesis are required to make materials at the nanoscale—both bottom-up and top-down techniques are employed. Equally important is that new characterization approaches are needed.[7] Nanoscience can be carried out by studying particles in glass, as the Romans, Faraday, and Mie did. One can still deduce interesting, size-dependent properties

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of materials from ensemble, test tube measurements. So "nanoscience" has been around for at least 150 years, ever since the sizes of atoms were first determined.

So what is "nanotechnology"? As far as we know, Norio Taniguchi was the first person to use the word "nanotechnology" (readers are welcome to correct this!).[2] His definition remains germane today: ""Nano-technology" mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule."

In other words, nanotechnology is the ability to manipulate a single nanoscale object. It is the presence of the word "single" that makes all the difference. Noriguchi wanted to make a single, addressable electronic element that was at the nanometer scale. It is true that the molecules in a glass of water are less than a nanometer across, but one could not address, pick up, or manipulate individual water molecules. That all changed in 1981 with the advent of the scanning tunneling microscope and later with the invention of the atomic force microscope.[8] These revolutionary tools allowed scientists the ability to see molecules under ambient conditions (more or less) and, for the first time, not just to observe them, as had been possible in ultrahigh vacuum with electron and ion microscopy, but to pick them up and to move them as single building blocks. Nanotechnology became possible with the advent of single-molecule manipulation, which only became possible in the 1980s.

Hence, strictly speaking, nanotechnology is technology using *single* nanoscale building blocks, but nowadays, it is used more loosely. An ensemble of nanoscale objects may still have unique size-dependent properties, and it is often easier to label this as nanotechnology, though it is better to call it "nanomaterials technology".

There have been many discussions about the rise of nanoscience and nanotechnology as fields and how the field relates to other emerging fields such as mesoscale science,[9] bionanotechnology,[10] and conventional materials chemistry and physics.

An interesting question for a journal that defines its subject by the size of the objects under investigation is whether it is "just" a chemistry journal. Our answer is no. There are nanoscale questions about light, biomolecules, mechanics, and electromagnetic fields at the nanoscale. Chemistry often figures prominently since virtually all chemistry occurs at the nanoscale, but many high impact papers will focus on areas that are outside the domain of traditional chemistry: in agriculture, biology, engineering, materials, medicine, physics, regulation, toxicology, and other areas. The true test is whether a manuscript teaches us something new about the nanoscale world.

Announcement. Beginning in April, *ACS Nano* is pleased to welcome Dr. Sharon Glotzer as our newest associate editor. She joins us from the University of Michigan, where she is the Stuart W. Churchill Collegiate Professor of Chemical Engineering. Dr. Glotzer and her group use theoretical simulation to understand the fundamental properties of self-assembly and toward controlling the assembly process.[11]

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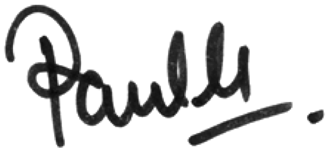
Prof. Sharon Glotzer of the University of Michigan joins *ACS Nano* as an associate editor.

Disclosure: Views expressed in this editorial are those of the author and not necessarily the views of the ACS.



Paul Mulvaney
Associate Editor

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2. Taniguchi, N. On the Basic Concept of 'Nano-Technology'. *Proc. ICPE*; Tokyo, Part II, Japan Society of Precision Engineering, **1974**. "'Nano-technology" mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule.
3. The most famous case is the Lycurgus Cup in the British museum. Chemical analysis reveals that the glass's red color is due to particles, probably alloys of gold and silver. See http://www.britishmuseum.org/explore/highlights/highlight_objects/pe_mla/t/the_lycurgus_cup.aspx.
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6. Molecules can exhibit size-dependent properties. Conducting polymers of different chain lengths are an obvious example, while the physical properties of nanoscale water droplets are also size-dependent.
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8. Binnig, G.; Rohrer, H.; Gerber, Ch.; Weibel, E. 7 × 7 Reconstruction on Si(111) Resolved in Real Space. *Phys. Rev. Lett.* **1983**, *50*, 120–123.
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11. Damasceno, P. F.; Engel, M.; Glotzer, S. C. Crystalline Assemblies and Densest Packings of a Family of Truncated Tetrahedra and the Role of Directional Entropic Forces. *ACS Nano* **2012**, *6*, 609–614.