GUEST EDITORIAL

Nanoscale Materials

Few terms in the chemical and physical sciences have seen more use (and abuse) in recent years than "nanoscience" or, even worse, "nanotechnology". Why all the interest and hype? Explaining the *interest* in this subject is relatively easy. The past 15 years or so have witnessed an explosion of relatively inexpensive analytical tools, such as scanning probe microscopies, for interrogating and manipulating materials on the nanometer length scale. At the same time, several previously unrelated fields have begun to focus on understanding and controlling physical and chemical phenomena on nanometer length scales. In electrical engineering, complimentary metal oxide semiconductor (CMOS) based transistors have been fabricated with gate widths of 50 nm. The same lithographic techniques that defined the features of that transistor have been utilized to attach two electrodes to a single molecule. In biology, experiments that probe the dynamics of single cells, single proteins, and single DNA strands have been carried out, and the operational mechanisms of certain biomolecular motors and gears have been elucidated. At the same time that scientists and engineers are planning to build terabit (10^{12} cm^{-2}) memories, the sequencing of the human genome is nearing completion. In addition, nanoscale materials have truly come of age. Physical scientists have learned how to manipulate crystallization processes such that nanometer- or even angstrom-level control over size and shape is now possible for a wide variety of materials. Nanocrystals that are of the quality of high-grade electronic materials are now prepared by routine synthetic procedures, and single-walled carbon nanotubes have been demonstrated to be stronger fibers with better electronic properties than anything previously known.

How about the *hype*? This, of course, relates to the "technology" part of nanotech. On the one hand, it is easy to point to industrial processes, such as reprography, catalysis, xerography, and even toxic waste remediation, in which nanostructured materials play some key role. On the other hand, most of these existing applications are not new, and do not utilize the "high technology" that many people envision as the promise of nanoscience. What exactly is this "high technology"? This is where the definition of nanotechnology gets a little fuzzy. I am personally involved in nanoscience from the aspect of electronic devices and electronic materials. In that field, researchers over the past few years have demonstrated electronic devices that are faster and smaller and, quite often, are characterized by fundamentally different (and possibly better) operational characteristics than existing technologies. However, existing technologies have a well-established manufacturing paradigm—known as a "top-down" approach, while nanoscience is typically based on a bottom-up approach. Herein lies the primary challenge in the development of nanotechnology. Consider the fascinating mesoscopic molecular sieve material MCM-41 that was discovered at Mobil Corporation in the late 1980s. If MCM-41 had been crystalline rather than amorphous, it would likely have stepped right in to hydrocarbon refining processes as a substitute for existing zeolite materials, similar to how nanocrystalline zeolites replaced amorphous materials many years before. However, a chemically-fabricated transistor, no matter how good it is, can not just be slipped into the next generation of microprocessors. Such a transistor would not be compatible with top-down manufacturing. However, the whole promise of nanoscience is that it will eventually produce a bottom-up manufacturing paradigm for the inexpensive fabrication of electronic devices, sensors, motors, etc. Such a paradigm may allow for the fabrication of mesoscopically complex, atomically precise, true three-dimensional architectures. I personally believe that this is the hype and hope of nanoscience, and if this promise is met, then nanoscience will certainly revolutionize many of our current industries.

Although a bottom-up manufacturing paradigm does not yet exist, the tools which will be used to develop such a paradigm are being discovered and characterized at a breathtaking rate. In this special issue of *Accounts of Chemical Research*, only a small subset of those tools is reported on. Most areas of nanoscience are not represented in this issue, and this is intentional. It would simply not have been possible to put together an issue that gave the entire field a fair shake. Instead, this issue is primarily focused on the chemistry and physics of isolated and assembled inorganic quantum structures. This is an area in which top-down and bottom-up approaches are beginning to meet each other head-on, and I believe that the resulting science is absolutely terrific. I hope you agree.

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Guest Editor

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