

Special Section Guest Editorial: Nanoengineering: Fabrication, Properties, Optics, and Devices

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Nanoengineering is the controlled placement or removal of material on the atomic, molecular, or small granular scale. The term has typically encompassed the engineering of materials at dimensions of 100 nm or less. The beginning of nanoscience, or nanoengineering, is not really clear. Metallurgists and glass formers have been making specially engineered sintered and nanocrystalline materials for many decades. Chemists have also synthesized molecular clusters and enzymes for many years. Watson and Crick proposed molecular templating in “Molecular structure of nucleic acids: a structure for deoxyribose nucleic acid” (*Nature*, 1953). However the emergence of the fields of nanoscience and nanoengineering is widely attributed to the famous speech by Richard Feynman, “There is plenty of room at the bottom,” given at the American Physical Society Meeting, December 29, 1959.

The growth and blossoming of the nanoengineering field over the past 50 years has indeed proved that there is plenty of room at the bottom. Engineered two-dimensional nanostructures have become part of our everyday life, such as the CMOS chips in our electronic devices, the high-mobility transistors in our cell phones, and giant tunneling magnetoresistive heads for the disk drive in our computer and digital video recorders. In order to make products ever more widely used and low cost, nanoengineering in all three dimensions has become critical to many applications. Mature technologies such as logic, memory, and data storage have been rapidly thrust into the sub-100-nm regime. Existing processes of record have been extended well beyond the ranges deemed feasible or reliable. New technologies such as sensors, systems on a chip, biotechnology, photonics, photovoltaics, molecular electronics, and optics are emerging. The upcoming synthesized nanomaterials, nanotubes, and nanowires, offer extremely attractive physical features and great opportunities. Continuing improvements in the design and fabrication of miniature optical elements have driven the development of micro/nano/quantum-scale optical and optoelectronic elements in ever more diverse applications. Application areas include telecommunications, data communications, consumer electronics, microwave photonics, optical computing, neural networks, optical storage, information display, optical imaging, printing, optical sensing, optical scanning, renewable energy harvest and storage, medical diagnosis, and chemical/biological sensing. The upcoming nanotechnologies present new opportunities and challenges in materials processing, device design, and integration. Drivers for commercial deployment include functionality, space, performance, reliability, and cost, as well as energy independence and climate change mitigation.

The papers in this special section show some of the novel applications of nanoengineering. Many of the mature technologies extend existing patterning processes of record, such as lithography and etching—a top-down patterning approach. The papers here illustrate both new methods and applications of nanoengineering. Some of the applications are best served by a bottom-up, self-organization, or templated growth approach to material control. “Optical characterization of silicon-on-insulator based single and coupled racetrack resonators,” by Mattia Mancinelli et al., shows the use of nanoengineering to make conventional semiconductor electronics faster

by the integration with optical interconnects. One can envision an entire new realm of devices for displays, sensors, and photonic system-on-a-chip devices. “Nanotechnologies for efficient solar and wind energy harvesting and storage in smart-grid and transportation applications,” by Louay Eldada, shows some of the applications of nanoengineering to alternative energy. With today’s energy costs and political crises, it is clear that energy alternatives to petroleum are vital to our society’s future. “Lithography-free glass surface modification by self-masking during dry etching,” by Eric Hein et al., is an approach toward low-cost nanofabrication. There are several applications that require large areas of controlled nanofabrication, such as solar energy, energy storage, and solid-state displays. “Spatially parallel control of DNA reactions in optically manipulated microdroplets,” by Yusuke Ogura et al., is an early example of use of the ultimate computer, a molecular computer that utilizes DNA. “Optical properties of microstructured surface-grown and transferred organic nanofibers,” by Jakob Kjelstrup-Hensen et al., demonstrates a new type of optical material patterned by the bottom-up approach. The technique may be an enabler of integrated optoelectronics in which the optics is of nanoscale dimensions and nearfield optics will become very important.

We hope that you enjoy this brief survey of new applications and fields in nanoengineering.