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Nanoscience and nanotechnology

Nanomaterials, and the technology associated with these materials, nanotechnology, is well under way to change our lives. It has already modified the way academicians, scientists and engineers approach areas such physics and chemistry at low dimensions, structure and strength of materials and their production, biotechnology and medicine.

This is not the first time in the history of humankind that the power of materials in the nanometer scale will be trapped to enhance our daily lives. The application of *kajal*, nanoparticles of carbon, is one such instance where the beneficial effects of these novel materials have been utilized. In the decorative staining of glass with brilliant colours, nanomaterials of gold have been used over the centuries. Nature has also been quietly employing these materials in its backyard, and it is our enhanced understanding that has brought such instances to light. The brilliant colours of some butterflies are today recognized as arising from diffraction of visible light from patterned biomaterials whose size and inter-particulate distances are of the order of the wavelength.

For nanomaterials to become useful in society, experiments that are being conducted in laboratories should be repeatable so that quality products can be obtained in reasonable quantities. A robust infrastructure is required to achieve these goals. As for looking at some new properties and their potential applications, one can only say that some will be conjured based on our present understanding of physical principles and some will be pure surprises.

Gedanken (**page 1720**) has introduced the subject of sonochemistry – a technique based on the application of ultrasonic waves to induce chemical reactions. The technique is discussed first with a brief attempt at describing the present theoretical description of the process that ruptures chemical bonds. The precursor state to a reaction using ultrasonic radiation has been described as the formation of a bubble which collapses producing an implosion which raises the local temperature to 5000 K providing the much needed activation barrier for the reaction to proceed. This nonequilibrium technique thus produces various unique products, which are described.

Sen and Akhtar (**page 1723**) have presented the application of MeV ions to produce nanostructures in a single crystalline material, here silicon. Such structures are highly desirable in devices that would eventually employ the power of nanostructures for producing tailor-made properties. One application that comes to mind is to induce light emission from silicon, which in the bulk form does not produce light. It is expected and found in some cases to produce light when the size of silicon particles comes down to the nanoscale. However, such particles are always produced as free-standing entities. In order to have a device, such particles or entities need to be integrated to the device, which is largely a single crystalline material. The technique discovered by these authors allows them to produce silicon nanomaterials inside a single crystalline silicon matrix through modification of the single crystalline silicon, by selective trapping of part of the energy of impinging high energy (several MeV) heavy ions, so as to deposit the energy at predetermined locations.

Komarneni (**page 1730**) has reviewed the process of preparation of nanophase materials in general, prior to focusing attention to the particular method of preparation of nanophase materials employing the hydrothermal route. Hydrothermal synthesis is normally a low temperature process by which the products are prepared below the supercritical temperature of water at 374°C. Komarneni describes how this technique suffers from low kinetics and hence is aided by microwave radiation both when the medium of reaction is aqueous (microwave hydrothermal) and when the medium comprises organic solvents like methanol, ethanol, polyol, etc. (microwave solvothermal). The preparation methods of various materials have been described with focus on the synthesis of nanophase oxide phases using conventional-hydrothermal and microwave-hydrothermal processes and the synthesis of nanophase metals by solvothermal process using polyols or alcohols. The article carries real-space images of the particles with a description of the relevant preparation process.

Murali Sastry (**page 1735**) stresses the requirement of preparation methodology that would produce precision in nanomaterial sizes, shapes and chemical compositions. Such precision would be required for homing on to nanosystems, tailor-made to achieve a particular physical property. According to the author such synthesis protocols are well developed for the production of nanoparticles in purely polar such as an aqueous medium or purely non-polar such as organic solvents. While both these methods have their advantages, the transfer of already formed nanoparticles from a polar to non-polar environment (and vice versa) are beneficial for specific applications, thereby maximizing the advantages of both methods. Sastry outlines the advantages of carrying out phase transfer of inorganic nanoparticles (gold nanoparticles in particular) from aqueous to non-polar organic environments and vice versa and discusses how such nanoparticle phase transfers may be accomplished through imaginative use of capping molecules that modify the hydrophilicity/hydrophobicity of the nanoparticle surface.

Tolles and Rath (**page 1746**) present an overview of the application of nanotechnology in areas such as electronics, materials and chemicals, biology and medicine and energy, environment and transportation. The authors view the development of nanotechnology as a natural progression stimulated by various requirements worldwide in science and technology. This review aptly summarizes the socio-economic impact of nanotechnology in the 21st century, whereby we look forward to smaller devices, new materials with anticipated greater strength, sensors based on molecular interactions and efficient drug delivery systems, improved batteries and materials for fuel efficient vehicles.

Thomas and Kulkarni (**page 1760**) have reviewed the current status of nanoscience research in the field of monodispersed metal nanocrystals. They then go on to describe in detail the magic of the nanocrystal called Pd_{561} with a tiny metallic core, of size 2 nm and which can be topped with various coatings. The authors demonstrate that this magic nanocrystal acts like a capacitor when covered with an insulating polymer (PVP) which has a tendency to self-assemble into giant clusters whose nuclearity follows a magic number series. The Pd-magic crystal can also be topped with Ni to form compounds such as $Pd_{561}Ni_n$ depending on the nickel loading, n. When topped with chain-like ligands, both Pd_{561} and its sister compound $Pd_{561}Ni_n$ demonstrate 2-dimensional patterning which hold promise in nanotechnology applications.