# Nanotechnology—The New Chemistry

*In an earlier article (Jan-Feb 2006* CI*, p. 8), the author asked "Does Nanotechnology Have a Sporting Chance?" and reviewed briefly the hype surrounding the field. In a later article (Nov-Dec 2006 CI, p. 10), he illustrated how lessons from Mother Nature are resulting in the design of new nanotechnology applications. In this third piece, Smith reviews how the subject of nanotechnology has penetrated each divisions/discipline represented in IUPAC.*

*by Alan Smith*

**Although nanotechnology is not something new, the term itself is a relatively recent way of describing work at the atomic or molecular level. If you look back at the Nobel laureates in chemistry or physics, many of the recipients could be described as nanotechnologists. Physicist Richard Feynman, who received the Nobel Prize for Physics in 1965, is regarded as the father of nanotechnology since he had the vision to realize that changes in properties would be found at the nano-scale. However, it was not until 21 years later, in 1986, that two other Nobel laureates in physics, Heinrich Rohrer and Gerd Binnig, used scanning tunnelling microscopy to observe objects on the nano-scale.**

Another 21 years on, and we wonder how we managed without the term nanotechnology. In the interim, some chemists have received the Nobel Prize for their nano-scale work, the most notable being Rick Smalley, Harry Kroto, and Robert Curl for their work on fullerenes.

We hear so much about the flagging popularity of chemistry, but it is encouraging to see that nanotechnology is spicing things up for the chemist. There is not one division or standing committee in IUPAC that is unaffected by the advances in nanotechnology. In this feature, I would like to review how nanotechnology relates to the many disciplines represented in IUPAC.

### Physical and Biophysical Chemistry (Division I)

Physical chemistry is an essential part of understanding the interactions that go into achieving novel properties that are now being found at the nano-scale. Practical applications range from modelling to produce nanoparticles of a consistent size to examination of interactions at interfaces that provide improved biocompatibility for tissue engineering.

### Inorganic Chemistry (Division II)

Nanoparticulate titanium dioxide is being used in a diverse range of products, from sunscreens that offer protection from cancer causing ultraviolet (UV) radiation to nano-coatings on windows where the titanium dioxide actually uses UV light to break down dirt in self-cleaning windows. There also are air purifiers on the market that use similar catalytic processes, such as NanoBreeze.

Other examples include the cerium oxide nanoparticles used in diesel fuel, which make it more efficient for engines, provide better mileage, and reduce emissions from exhaust pipes.

Precious metals offer another interesting area of nanotechnologoy in chemistry. Scientists have found, for example, that gold nanoparticles offer significantly improved catalytic properties. And nanoparticulate silver, which provides anti-microbial properties, is being used in a variety of products, such as wound dressings, baby milk cartons to prevent cross-contamination, food storage containers, and in the plastic parts of refrigerators to prevent mold formation. If Napoleon only knew that he lost his campaign in Russia because (although he had silver cutlery) his troops were using wooden spoons that supported microbial growth!

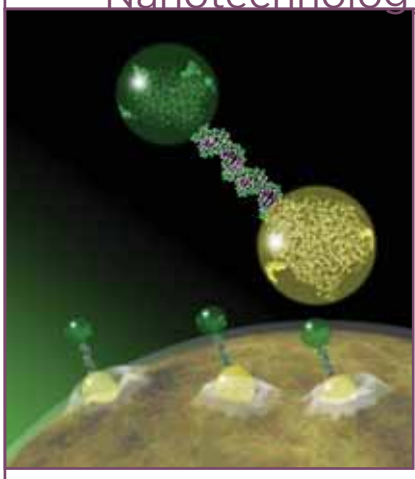
### Organic and Biomolecular Chemistry (Division III)

Organic chemistry is having a large influence on the pace of nanotechnology development. For example, improved composites are not achievable if the nano-ingredient is not dispersed well in the polymer, so selection of the right "compatibilizer" is essential. There also is a great deal of work going on related to functionalizing carbon nanotubes for sensors.

A roadmap for the application of dendrimers into new materials—another discovery produced by nanotechnology—has been produced by scientists in Europe, and it describes their use in new inks, paints, and composites. Medical applications are at an early stage for these organics, but they offer great potential since dendrimers represent engineering at a biological-size scale. They show excellent potential as carriers for imaging contrast agents for enhanced organ, vascular, or tumor imaging, and for diagnostics.

### Polymer (Division IV)

Nanocomposites are already finding extensive applications, where modified clays, carbon nanotubes, and particulates are providing barrier properties, lighter weight and stronger polymers, and functionalized surface applications. In order to save energy, most car manufacturers are using clay composites to replace



***Dendrimer complex docking on cellular folate receptors.*** *Source: Michigan Center for Biologic Nanotechnology.*

heavy metal parts in cars. Even the fuel lines in new cars are going plastic through the incorporation of carbon nanotubes into the polymers to dissipate a charge. However, it is with carbon nanotubes that we will see real weight reductions because they may offer components that are 50 to 100 times stronger than steel, at one sixth the weight. The implication of this for the aviation industry is revolutionary.

It is interesting to note, too, that car tires have been using carbon black nanoparticles for about a century now. This is the largest use of nanoparticles worldwide, at 6 million tonne per annum. Clay-based nanocomposites also provide barrier properties, and are being used in food packaging applications to give longer shelf life by eliminating oxygen and UV. Functional films are just thin nanocomposite layers, which offer surfaces that are anticorrosive, antiglare, antimicrobial, antiscratch, and heat resistant.

The Polymer Division's project in nanoscience is aimed at proposing a list of terms and definitions for aggregation and self-assembly in polymers.

### Analytical Chemistry (Division V)

There is considerable analytical activity in nanotechnology, especially with developments in atomic force microscopy. Viewing nanoparticles, for example, is essential, since novel properties are only achieved at the nano-scale. In addition, there is a need to develop equipment to assess the extent and variety of new properties that are achievable with nanotechnology. Although there is currently emphasis on particle size and distribution, it is becoming clear that surface area is a crucial factor.

### Chemistry and the Environment (Division VI)

In 2002, Michael Crichton (author of Jurassic Park and other science fiction books) published *Prey*, a story that depicted clouds of nanorobots turning every living thing into grey goo before the hero manages to stop them. Unfortunately, many people thought that this type of catastrophe was possible, and nanoparticles became the focus of environmental and health groups and non-governmental organizations. The resulting publicity led some groups to demand a complete moratorium on manufactured nanoparticles, while others suggested that the best policy is to proceed with caution.

The essential point is that the majority of what is described as nanotechnology has been around since creation. However, for certain nanoparticulates we need to carry out the usual tests and risk assessments that would be carried out with any new substance. Free nanoparticles, as opposed to those locked into a composite, for example, are more likely to be a problem, and manufacturers are most likely to be affected. In the same way, major companies are not going to take risks by putting untested material into their products.

Many developments in nanotechnology are viewed as having a beneficial effect on the environment. Pesticide companies are looking at nanotechnology to ensure that their products reach the intended targets, eliminating waste and soil contamination. Longer-lasting surfaces, improved by particular nanocoatings, should extend the life of many products and processes.

IUPAC chemists are involved with these issues as well; at the recent IUPAC Congress in Torino, Italy, scientists described how nanoparticulate titanium dioxide is incorporated into cement for buildings thereby helping to break down environmental pollution in the atmosphere.

### Chemistry and Human Health (Division VII)

Some of the most significant developments in nanotechnology will come in the field of healthcare. Work on new diagnostics indicate that increased sensitivity at the nano-scale will enable problems to be detected before they have affected the body, thereby reducing patient suffering and the length of hospital stays. Developments in nanotechnology also are benefiting tissue engineering, with new materials and surfaces that are more biocompatible. Nanotechnology also is providing benefits to the field of drug delivery.

Nanotechnology is being focused on some of the most significant healthcare problems, including cardiovascular diseases, cancer, musculoskeletal and inflammatory conditions, neurodegenerative and psychiatric diseases, diabetes, and infectious diseases. In the USA, significant funding is going to nanotechnology and cancer therapy, some of which is directed toward investigating better targeting of problematic cells.

Division VII has a project that could be described

as nanotechnology entitled Prototype Analysis of Molecular Biomarkers in Cancer.

### Chemical Nomenclature and Structure Representation (Division VIII)

This division has undertaken the complex task of nomenclature for rotaxanes and for fullerenes.

### Committee on Chemistry Education (CCE)

CCE has nanotechnology on their agenda. It is estimated that there are now over 500 products on the market that are based on nanotechnology. These are interesting and varied products, so it is easy for both children and the general public to grasp the significance of nanotechnology.

### Chemrawn Committee

CHEMRAWN XIV: Towards Environmentally Benign Processes and Products, described new catalytic routes to chemicals, but more recent work on nanoscale catalysts suggests that there is great potential here for new production routes. Chemrawn XV: Chemistry for Water, discussed using nanotechnology membranes to provide clean water.

Because there are concerns in some quarters about nanotechnology, reports about its beneficial effects are being issued, specifically as they relate to the developing world. These effects have the potential to be a future CHEMRAWN conference topic.

### Committee on Chemistry and Industry (COCI)

Some people have suggested that nanotechnology is the next industrial revolution, and there is not one industry sector that is currently unaffected by nanotechnology.

Although it is not possible to mention all the exciting nanotechnology developments in this space—we are only seeing the "tip of the iceberg"—it is likely that many more Nobel Prize winners will be nanotechnologists.

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See also www.iupac.org/publications/ci/indexes/stamps.html

# Stamps International

## For a Healthy Smile . . .

The addition of fluoride to drinking water supplies, at a level of ca. 1 ppm, is a health practice prevalent in communities across the USA and other countries that has undoubtedly contributed to the reduction of tooth decay in the general public since its inception in the 1940s. Even though water fluoridation is not universal, fluoride is also often added in small amounts (ca. 0.5%) to toothpastes and other oral hygiene products and thus its beneficial effect does reach a large segment of the population.


The stamp from Iceland that accompanies this note was issued on 9 October 1987 to promote oral hygiene and shows a girl brushing her teeth with a fluoride-containing toothpaste before going to sleep, a pretty clear message about the importance of such practice. On the other hand, the Brazilian stamp was issued on 15 July 1977 to celebrate the 3rd International Congress of Odontology, held in Rio de Janeiro on 15–21 July of that year. It prominently displays a rod of Asclepius, the emblem of the medical profession. The Portuguese words for water and fluorine (agua and fluor, respectively) and the chemical formulas of water and sodium fluoride appear several times in the background, thereby underscoring the value of water fluoridation to prevent dental caries. Sodium fluoride, together with stannous fluoride ($SnF_2$) and sodium monofluorophosphate ($Na_2PO_3F$), are the three most common sources of fluoride currently added to toothpaste formulations.


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