Nano Materials

Henne van Heeren
enablingMNT
Drakensteynlaan 34
3319 RG Dordrecht
The Netherlands
Henne@enablingMNT.com

Introduction

Nanomaterials is a new step in the evolution of understanding and utilization of materials. Material science started with the realization that chemical composition is the main factor in determining what a material is. Hereafter it was discovered that the fabrication and after fabrication steps could influence those properties substantially. Also small additives proved to be able to modify these properties. Finally with the arrival of nanotechnology, it was discovered that the ability to create small particles could expand the capability to create and modify materials.
Nanotechnology is as well as evolutionary as revolutionary in nature. Evolutionary are the many applications where the same material is incrementally improved by using nanotechnology. (Examples of this are seen in cosmetics). Revolutionary it can be called where new (enabling) properties originate from nanotechnology like for example in quantum dots. Those new properties can be divided in:

- Properties based on the fact that the surface is large compared to the weight/volume.
- In addition to size, low energy dissipation and high processing speeds are important.
- New properties not found in bulk or micro sized particles.

Nanotubes

From a Mancef patent investigation it was learned that carbon nanotechnology (mainly nanotubes, but also fullerenes and nanodiamonds) and cosmetic applications are the focal points of interest. Carbon nanotubes are produced in many variants, the most important classification is in single or multi wall nanotubes: A single-walled carbon nanotube (SWNT) consists of a single cylinder, whereas a multi-walled carbon nanotube (MWNT) comprises several concentric cylinders. It depends on the fabrication method which one is produced in chief, although always a mixture can be expected and separation/cleaning is a very important part of the fabrication process. Nanotubes can be made application specific by adding chemical groups to them, and they can also be made out of other materials than carbon. They have outstanding properties when compared to other materials:

- Electrical conductivity -- probably the best conductor of electricity on a nanoscale level that can ever be possible.
- Thermal conductivity -- comparable to diamond along the tube axis.
- Mechanical -- probably the stiffest, strongest, and toughest fiber that can ever exist
- Chemistry of carbon -- can be reacted and manipulated with the richness and flexibility of other carbon molecules.
- Molecular perfection -- essentially free of defects.
- Self-assembly -- strong van der Waals attraction leads to spontaneous alignment of nanotubes.

It must be stated that uniformity and price still is an issue. It is very difficult to produce pure samples and prices, although rapidly decreasing, are therefore very high for high purity nanotubes.

van Heeren, H. (2007) Nano Materials. In *Nanotechnology Aerospace Applications – 2006* (pp. 3-1 – 3-4). Educational Notes RTO-EN-AVT-129bis, Paper 3. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

At this moment nanotubes are studied for a number of applications like:

- electron emitters for flat-panel displays and cold cathodes,
- mechanical improvement additive for plastics,
- Li-ion batteries for portable electronic devices,
- ultra-strong high-tech composites,
- conductive composites and coatings for lightning protection,
- EMI shielding,
- supercapacitors,
- fuel cells,
- hydrogen storage, and
- semiconductors.

Nanoparticles

Particles in the nanorange are being investigated for a number of applications, like: wear resistance, scratch protection, blocking of light. A good example of this last application is the blocking of ultraviolet light by zinc oxide particles for cosmetics. The blocking power is directly related to particle size, size distribution, particle loading and the dispersion.

Other application examples of nanoparticles are:

- Filter media. The active component is an alumina (AlOOH) fiber two nanometers in diameter. The nano alumina fiber is highly electropositive, and will attract and retain particles.
- Silver has long been known to inhibit oxygen exchange, effectively killing bacteria. Nanosilver has been demonstrated to enhance that effect, and is currently being used in wound dressings for critical-burn victims but also in textile for preventing smelling.
- Other nanoparticles can be used as pharmaceutical carriers to specifically deliver disease-fighting drugs to afflicted body areas, thus minimizing secondary effects.
- In fuel cells perovskites are being discussed as electrode materials for use as cathodes. Specifically the high surface area and the high ionic conductivity of the material are of interest.

Other materials

Besides these general classes, there are many other nanomaterials. To name a few:

- Metal rubber, a self-assembled nanocomposite material that combines the high electrical conductivity of metals with the low mechanical modulus of elastomers.
- Nanoclay: a 2-to-1 layered smectite clay mineral with a platey structure having an unusually high aspect ratio.
- Nanoshells: optically tunable nanoparticle composed of a dielectric core coated with an ultra-thin metallic layer. Tuned to absorb or scatter certain wavelengths.
- Quantum dots, being semiconductor nanostructures that act as artificial atoms by confining electrons and holes in 3-dimensions.

Future expectations

In the future much is expected from Molecular Nanotechnology to make chemical reactions happen under programmed control. In theory, this allows to build a large range of molecular shapes. To make the creation of new materials a more planned activity, several companies are offering SW for the modelling and simulation of chemical and biochemical substances and a few start-up companies are working to develop specialized SW for nanotechnology .

Concluding remarks

The area of nanotechnology is a fast growing one, and many materials are newly introduced or dramatically improved by it. From our investigation we can identify a number of focal points as shown in the following picture.

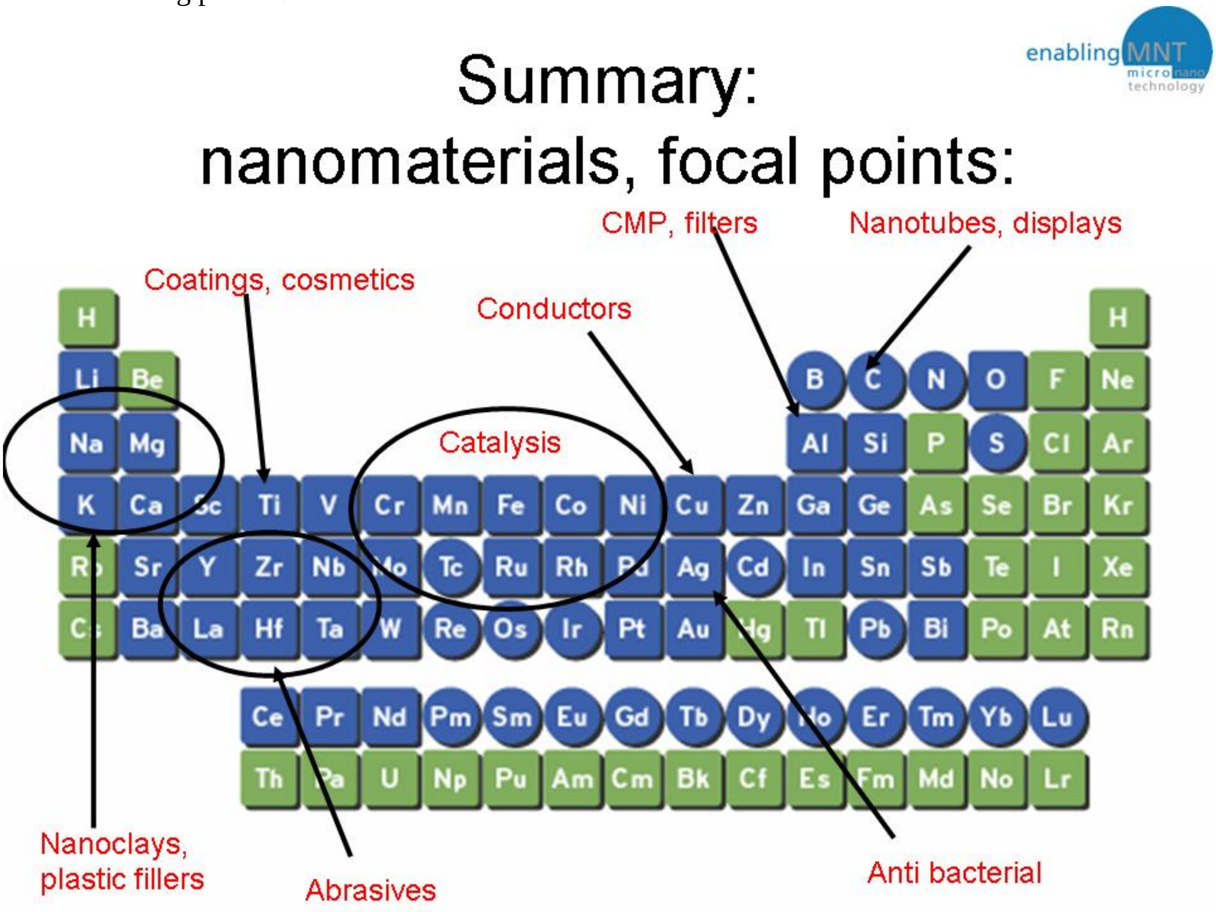

Figure 1: Focal points of nanomaterials