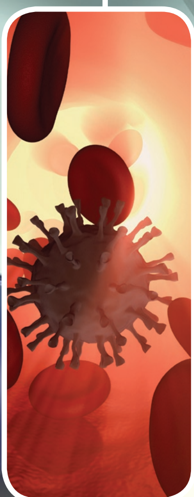
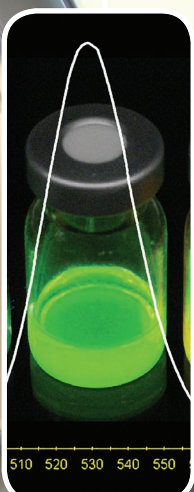
NANOTECHNOLOGY
PUBLIC ENGAGEMENT

Current Applications and Products of Nanotechnology





Today, thanks to nanotechnology, we can buy tennis racquets that are stronger, sunscreen creams that are more transparent, paints that are brighter and longer-lasting, and socks that don't smell. Behind the scenes, nanotechnology is also used in chemical processing techniques, such as filtration and catalysis.

Nanotechnology is already with us ... but its impact on our daily lives is set to grow at a phenomenal rate...

In 2002, the number of nanoproducts in the global market was estimated to be around 200. In 2008, that number had increased to over 800 – an increase of 600% over a relatively short period.[1] Independent research firm, Lux Research has indicated that by 2014, $2,6 trillion in manufactured goods will incorporate nanotechnology[2].

In South Africa, many of the potential applications of nanotechnology are still in the research and development stage, but results thus far point to incredible potential benefits – not only for the country's economic and industrial development, but for the lives of ordinary people, many of whom still struggle to access basic services such as clean water, electricity and effective health care.

Many industries are working with government and academia to unlock this industrial and social potential. In 2005, the Department of Science and Technology launched the National Nanotechnology Strategy, which aims to co-ordinate nano research and development at a national level around six focus areas: water, energy, health, chemical and bio-processing, mining and minerals and advanced materials and manufacturing.

Two Nanotechnology Innovation Centres have been opened – one at the Council for Scientific and Industrial Research (CSIR) and the other at Mintek. In partnership with industry and many of South Africa's universities and bodies such as the Water Research Commission and the Medical Research Council, the centres are conducting cutting-edge research into nanotechnology in order to unlock its full potential.

"The value of nanotechnology is almost everywhere. The challenge, is to ensure that we use nanotechnology to become the architects of a better life, not the architects of our own destruction." Deputy Minister of Science and Technology Derek Hanekom.

"Nanotechnology gives an opportunity to South Africa to be the best in the world in multiple fields of research" – Professor Marcel Van de Voorde, Science Adviser to European Union.

Scientist working in a laboratory.

What is nanotechnology?

Nanotechnology is the act of manipulating materials at very tiny scales – at the level of atoms and molecules.

With materials under 100 nanometres, the normal rules of physics and chemistry no longer apply and many materials start to display unique and, sometimes, surprising properties. They may become very much stronger, more conductive or reactive.

For example, solids like gold turn into liquids at room temperature, silver takes on anti-microbial properties, inert materials like platinum and gold become catalysts, stable materials like aluminium become combustible.

These new properties have opened up exciting fields of study and application.

NANOSCIENCE is the study and discovery of these new properties.

NANOTECHNOLOGY is the use of these new properties in special products and applications.

(Source: Manfred Scriba, CSIR).

NRF National Research Foundation
SAASTA South African Agency for Science and Technology Advancement
SAASTA CERTIFIED
science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA

Nanomaterials – the building blocks of nanoscience – and their range of applications

(Source: CSIR)

In relation to their size, nanoparticles have huge surface areas, a characteristic that makes them very effective in catalysis, absorption and other processes.

FULLERENES

Fullerenes are carbon nanostructures which include nanotubes and bucky balls (more properly known as buckminsterfullerene, are spherical molecules composed entirely of carbon atoms). Synthesised by the condensation of high-temperature carbon vapour, they have diameters ranging from a fraction of a nanometre to 100 nm. This is the material of the future with extraordinary properties to match. Carb on nanotubes, for example, conduct much better than copper and are 100 times stronger than steel, but one-sixth of the weight.

Applications: electronics, energy devices, high-strength materials, super-sensitive nano-sensors and ideal for catalyst support.

NANO DRUG ENCAPSULATION

Using a chemical process, drugs are encapsulated in biodegradable-polymer capsules 100 to 500 nm in diameter. Due to their small size the capsules are taken up by cells. The benefit is a reduction in dose frequency of medication due to the slow release of the drug.

Applications: delivery of TB, HIV/Aids and malaria drugs.

QUANTUM DOTS

A quantum dot is a semi-conductor (between conductor and insulator) with nano-dimensions. Quantum dots and nano phosphors exhibit unique optical, magnetic and electronic properties, due to the quantum confinement effect. Depending on their size, they absorb and emit different colours when irradiated with photons or electrons.

Applications: used in biosensors which can be used to pinpoint disease in the body, solar cells and flat panel displays and special coatings.

NANO COMPOSITES

By adding nanoparticles and nanostructures to a polymer, a nanocomposite is formed. These materials of the future can be super-strong, light, conducting and transparent. A nanocomposite can be much more transparent than a polymer containing micron particles, which is opaque.

Applications: aeronautic and automobile industries scratch-resistant coatings; self-cleaning windows, fuel cells.

Already at pilot stage: Nano-structured membranes for water treatment

In partnership with the government and the CSIR, the North-West University has built a treatment plant that incorporates ultra-filtration membranes to clean brackish groundwater in the rural village of Madibogo in the North West Province where the majority of people depend on groundwater or borehole water for their livelihoods.

Some water sources are contaminated with organic nitrogenous pollutants, chloride, fluoride, calcium, and magnesium ions, which are a health risk.

Using polymeric nanofiltration and reverse osmosis membranes, the treatment plant removes pollutants such as chloride, nitrate, phosphate and sulphate to produce safe drinking water for domestic and community use. *(Source: SciDev).*

NANOPARTICLES

Nanoparticles can be produced chemically in high temperature reactors or through mechanical milling. They are mostly 10 to 100 nm in diameter and often agglomerated.

Applications: coatings, composites, solar cells and medicine. Silicon nanoparticles can be used for printed electronics[3].

South African Nano research areas and applications:

WATER PURIFICATION

Nanotechnology offers a low-cost and effective solution to the challenge of access to clean and safe water for millions of people in South Africa and the developing world. The technology holds the potential to radically reduce the number of steps, materials and energy needed to purify water.

Depending on the kind of water to be purified – ground, surface or waste water – nanomaterials can be tailor-made with specific pore sizes and large enhanced surface areas to filter out certain unwanted pollutants, such as heavy metals or biological toxins.

For example, titanium oxide at nanoscale can be used to degrade organic pollutants. And silver nanoparticles have the ability to degrade biological pollutants such as bacteria.

South African scientists are testing different kinds of membranes and filters based on carbon nanotubes, nanoporous ceramics, magnetic nanoparticles and other nanomaterials which could be used to remove water-borne diseases such as typhoid and cholera, as well as toxic metal ions, organic and inorganic solutes.

Nanotechnology applications include[4] :

- **Nanofiltration membranes** – These are already being applied for removal of dissolved salts from salty water, removal of micro pollutants, water softening, and wastewater treatment. Nanofiltration membranes selectively reject substances, which enables the removal of harmful pollutants and retention of nutrients present in water that are required for the normal functioning of the body. Attapulgite clay, zeolite, and polymer filters are source materials for nanofilters and can now be manipulated on the nanoscale to allow for greater control over pore size of filter membranes. Researchers are also developing new classes of nanoporous polymeric materials that are more effective than conventional polymer filters.

  NB: In South Africa, a water purification system using nano-filtration techniques has already been implemented at pilot stage **(see box, top right, page 2)**.

- **Nanocatalysts and magnetic nanoparticles** – Using catalytic particles could chemically degrade pollutants instead of simply moving them somewhere else, including pollutants for which existing technologies are inefficient or cost prohibitive. Magnetic nanoparticles, when coated with different compounds could be used to remove pollutants, including arsenic, from water.

- **Nanosensors** – Researchers are developing new sensor technologies that combine micro- and nanofabrication technology to create small, portable, and highly accurate sensors to detect chemical and biochemical parameters in water. Several research consortia are field testing devices that incorporate nanosensor technology to detect pollutants in water, and some expect to commercialise these devises.

HEALTH

In both diagnosis and treatment, nanotechnology holds the key to revolutionise health care, particularly in developing countries where access to effective health care is still a challenge for millions of people living in remote areas.

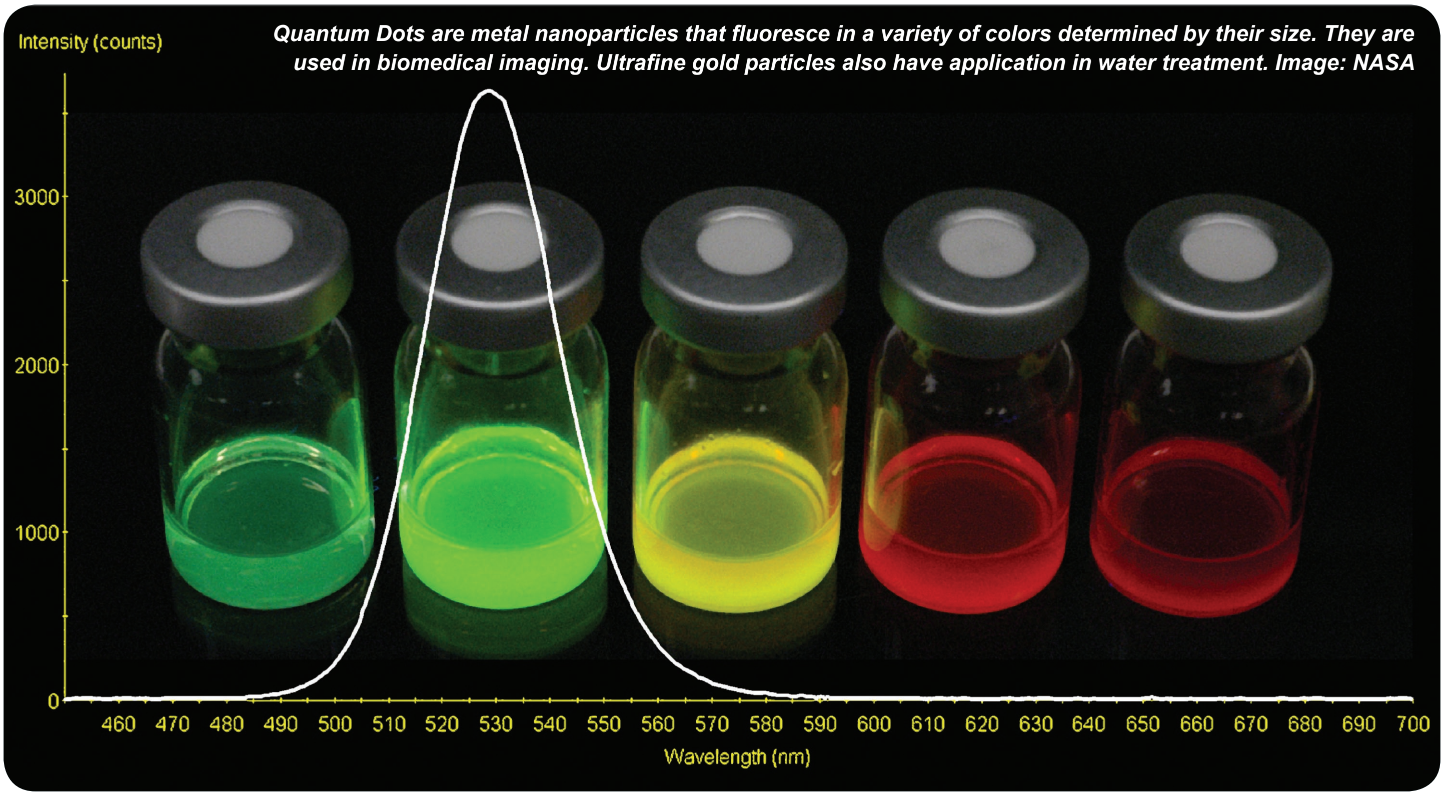
In the field of **diagnostics**, nanotechnology promises quick, early and accurate detection of diseases.

- Portable, but highly sensitive **point-of-care test kits** are under development which will offer all the diagnostic functions of a medical laboratory.

  Depending on how they are designed and the intended application, the hand held kits could be used to test for viruses, bacteria or hormones. Thus they will be able to test – simply and quickly – for infectious diseases such as malaria, cholera, HIV/Aids and other sexually-transmitted infections, and even cancer.

  Also known as the “lab-on-a-chip” because of their ability to emulate the services of a complete medical laboratory, these inexpensive, hand-held diagnostic kits can pick up the presence of several pathogens at once and could be used for wide-ranging screening in remote clinics.

  According to Robert Tshikudo, head of nanotechnology at Mintek, research on using the kits for infectious diseases is in the “final stages” and the ultimate goal is to make the kits available to government hospitals and clinics where they can “reach those who need it”.



Quantum Dots are metal nanoparticles that fluoresce in a variety of colors determined by their size. They are used in biomedical imaging. Ultrafine gold particles also have application in water treatment. Image: NASA

- **Biomedical imaging** – Nanotechnology applications are in development that will radically improve medical imaging techniques. For example, gold and silver nanoparticles have optical properties which make them extremely effective as contrast agents. Quantum dots which are brighter than organic dyes and need only one light source for excitation, when used in conjunction with magnetic resonance imaging, can produce exceptional images of tumour sites.

Nanomaterials are also used in **therapeutics** or treatment:

- **Targeted drug delivery systems –** Nano-structures can be used to recognise diseased cells and to deliver drugs to the affected areas to combat cancerous tumours, for example, without harming healthy cells. In obesity, nano-particles can target and inhibit the growth of fat deposits.
- **Slow-release drug therapy –** Research shows that nano-sized biodegradable polymer capsules containing drugs for tuberculosis treatment are effectively taken up by the body's cells. The effect is a slower release of the drug into the body and a reduction in the frequency with which TB patients need to take his or her medication. In countries where drugs are not readily available and compliance is generally low due to a number of reasons, the technology holds great potential for increased drug compliance and less chance of the development of drug resistance.
- **Photothermal and hypothermal destruction of cancer** – Some nanoparticles, such as gold, possess therapeutic properties based on their magnetic wavelength or optical properties. They absorb light and heat up the surrounding area, killing the cancer cells.

ENERGY

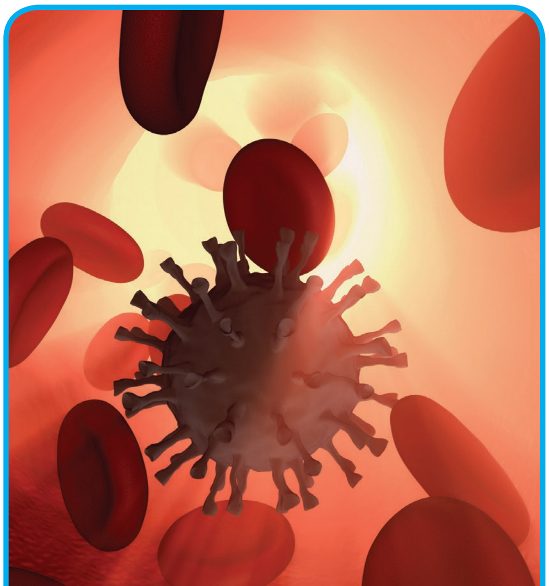
Another impressive application for nanotechnology is energy production, conversion and storage. Research is well advanced enough to establish that nanotechnology offers a viable alternative to non-renewable fossil-fuel consumption and gives us the means to achieve a "hydrogen economy". Nano-applications in this area include: solar cells; fuel cells and new energy production, conversion and storage processes. In all cases, the results are energy that is cheaper, cleaner, more efficient and renewable. In future, nano holds the potential to produce hybrid vehicles with reduced fuel consumption and a lighter motor weight.

INDUSTRIAL APPLICATIONS

- Nanotechnology is set to add value to South Africa's raw mineral resources through beneficiation of gold, platinum group metals and other minerals which are used as high performance catalysts, absorbents in polymer nanocomposites and in energy-saving materials.
- Nanotechnology can produce cleaner process engineering which will in turn produce value-added chemicals and speciality products, including bio catalytic systems and novel heterogeneous catalysts. Nanotechnology can make catalytic converters more efficient, cheaper and more accurately controlled.
- Nanotechnology-based innovations can be designed that will combat air pollution remediation, detect toxic materials and leaks, reduce fossil fuel emissions and separate gases.

Advanced materials and manufacturing applications – the list is endless …

Nanotechnology can produce smart, functional materials, including lubricants and barrier coatings, ultra-hard and super-strong materials, electro and photo-chromic materials with applications in all manufacturing sectors, industry, medical and domestic markets. Nanoparticles can also improve a wide range of properties shown by engineering plastics, such as bio-degradability and improved thermal, mechanical and electrical properties. Thus, plastic bags can be made to bio-degrade and plastic car parts or building materials can be made more fire-resistant. Other areas include the development of nanoparticles for applications in phosphorous paints, printable electronics, inexpensive solar cells and nanotube synthesis for application in sensors and as catalyst support structures.



By operating at the scale of the very small, like this virus in a bloodstream, nanoparticles can be targeted at specific organs of the body. Here their photothermal properties can be used to heat up and destroy cancerous tissues.

1 *Ndeke Musee, CSIR, speech to the First SA National Workshop on Nanotechnology Risk Assessment, March 2009.*

2 *Quoted in The Water Wheel, January/February 2008.*

3 *National Centre for Nano-Structured Materials, CSIR.*

4 *Nanotechnology, Water, Development.*

An electronic copy of this paper can be downloaded at: http://www.merid.org/nano/waterpaper.

Find out more:

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