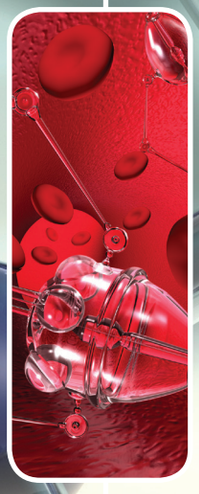
NANOTECHNOLOGY
PUBLIC ENGAGEMENT

Careers in Nanoscience and Nanotechnology

Nanotechnology: a world of possibilities



Imagine being able to build a supercomputer the size of your fingernail, or a device that could travel through the human body to find and destroy cancer cells. Imagine designing clothes that clean themselves, or developing a way to quickly and inexpensively remove toxins or disease from the air we breathe and the water we drink.

With nanotechnology all of this – and more – is possible.

A career in nanoscience and nanotechnology puts you at the cutting edge of scientific discovery and at the forefront of technological developments which hold the potential to change the world we live in.

Endless new products which are smaller, lighter, faster, stronger, cleaner, cheaper, more reliable, smarter and, possibly, safer are on the horizon. Since it involves small amounts of raw materials, less labour, space and maintenance, nanotechnology is seen as a way to increase manufacturing production at a fraction of the cost and with less of a toll on the environment.

A multidisciplinary area of research and innovation, nanotechnology brings together all of the classic scientific disciplines such as maths, chemistry, physics, biology and engineering. But it also provides scope for environmental scientists, microscope engineers and technicians and experts from a wide range of specialist disciplines, including computer science, materials science and medicine.

With the development and improvement of new scientific tools in the past few decades which allow us to observe, manipulate and manufacture at the nanoscale, nanotechnology has come into its own and the opportunities for careers in nanoscience and technology are growing rapidly.

In South Africa, nanotechnology has been recognised as an important tool for industrial development and a means to improve the lives of ordinary people through more efficient health care services, safe water and low-cost, clean energy.

Nano-what?

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 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).

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 African universities, the centres are conducting cutting-edge research to unlock the potential of nanotechnology and to support the training of young nano-scientists and technologists.

NRF National Research Foundation | SAASTA South African Agency for Science and Technology Advancement

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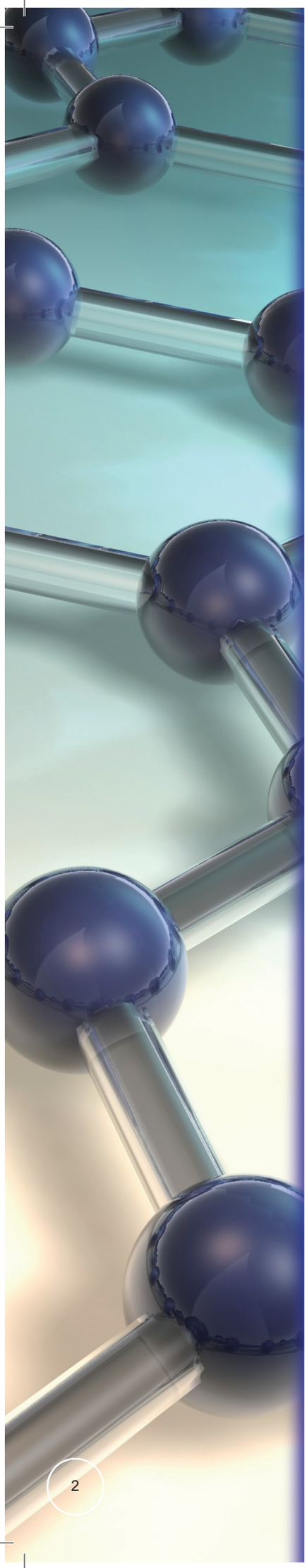


A career in nano? – What you need to know

Nanotechnology is not a single science. It includes aspects of chemistry, physics, material science and even geology. Chemists, physicists, biologists, medical doctors, engineers and computer scientists typically form part of teams that work in the nanotechnology field.[3]

While the worldwide need for nanotechnology workers is expected to reach two million by 2015[4], in South Africa, most of the work being done is still in the arena of nanoscience or research. This is likely to change as more applications are developed.

There are basically two kinds of nano-workers:

- Nanoscientists or researchers who discover new nanostructures and processes. Generally, they have a background in chemistry, physics or materials sciences.
- Nanotechnologists or developers who find ways to use the new properties discovered by scientists in special applications and products including solar cells, fuel cells, sports goods and pharmaceuticals.

In South Africa, nano-workers have the opportunity to use nanotechnology to tailor-make solutions for some of the country's most pressing challenges.

Water

Nanotechnology can be used to monitor water quality in real time and even remove pathogens (diseases such as cholera) and inorganic pollutants (toxic heavy metals) from water, making it possible for even the most remote communities to have safe, clean drinking water.

Environment

South African scientists are looking at using nanotechnology to take the pollution out of the air we breathe and clear out toxic metals from waste streams. Sensors are being developed to detect dangerous gases in mines.

Health and medicine

Scientists working with Mintek are using nanotechnology to design simple point-of-care kits to diagnose diseases such as cholera. They are testing gold and silver nanoparticles for their potential in the early detection of diseases such as cancer. Scientists at the CSIR are working on mechanisms to transport drugs directly to that point in the body where they are needed to fight cancerous tumours or unwanted fat cells. They are developing slow-release drugs for the treatment of diseases such as tuberculosis.

How small is nano?

The prefix "nano" means one-billionth. Thus, one nanometre (nm) is 10^{-9} of a metre or one billionth of a metre, in the international system for units of weights and measures.

In other words …

- The comparative size of a nanometre to a metre is the same as that of a marble to the Earth[1].
- A nanometre is the amount a man's beard grows in the time it takes him to raise the razor blade to his face.[2]
- A sheet of paper is about 100 000 nanometres thick.
- The diameter of a human hair is about 80 000 nm.
- A single gold atom is about a third of a nanometre in diameter.

Energy

Nanotechnology holds enormous potential for clean, affordable and renewable energy sources through the development of improved solar cells, hydrogen storage materials and fuel cells.

Improved materials

Scientists working with the CSIR are using nanotechnology to find ways to improve plastics, making them more biodegradable in the case of packaging materials such as plastic shopping bags, or stronger, in the case of consumer goods such as car parts, sports goods and tools. Nanoparticles are also being used in phosphorescent or reflective paints, in printable electronics and solar cells. Nano-engineered materials could also result in less expensive building materials and cheaper, more durable houses for the poor.[5]

Where did nanotechnology start?

The concepts behind nanotechnology, as we know it today, were first highlighted by Nobel prize-winning physicist Richard Feynman. In a 1959 lecture entitled "There's plenty of room at the bottom", he suggested it was possible to build machines small enough to manufacture objects with atomic-precision. The term "nanotechnology" was defined in 1974 by Professor Norio Taniguchi and explored in more depth in the eighties by Dr K Eric Drexler.

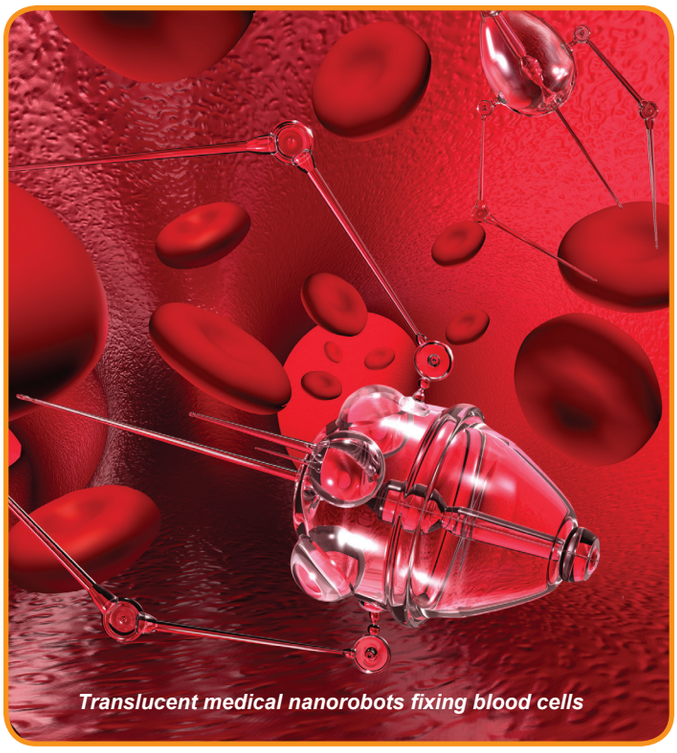
At much the same time as Drexler was popularising the idea of nano, extremely powerful microscopes were being developed. These included the scanning tunnelling microscope (STM) and later the atomic force microscope (ATM), which enabled individual atoms to be clearly identified and thus manipulated.

Is nanotechnology dangerous?

The short answer is: we don't know enough. More research is needed. While the new properties displayed by materials at nano-scale are what make them so fascinating, the behaviour of these particles and their effects on humans, animals and the environment are not yet fully understood. Certain nanoparticles have been found to have toxic effects and research into the health, safety and environmental (HSE) implications of nanotechnology is ongoing – in South Africa and elsewhere in the world. The HSE field itself provides wide-ranging opportunities to researchers.

Where could nanoscientists and nanotechologists find jobs in South Africa?[6]

- In South African universities, many of which are working in partnership with industry and other agencies. In most sciences, particularly physics, an MSc or PhD is needed for a career as a scientist, lecturer or operator of electron microscopes. According to physics professor, Jan Neethling of the Nanoscale Materials Research Centre at the Nelson Mandela Metropolitan University, even service engineers for future high resolution transmission electron microscope (HRTEM) centres will require MSc's followed by technical training.
- National Nanotechnology Innovation Centres based at the CSIR and Mintek.
- Research divisions of companies such as Sasol (which is interested in more efficient hydrogen fuel-cells) and Element Six (formerly De Beers Industrial Diamond Division). Companies such as Plascon and Dulux are using nanotechnology to improve paint properties.
- Statutory bodies such as the Water Research Commission and the Medical Research Council.
- Once commercial applications become more widespread in South Africa, there are likely to be many opportunities for nano-entrepreneurs.



Translucent medical nanorobots fixing blood cells

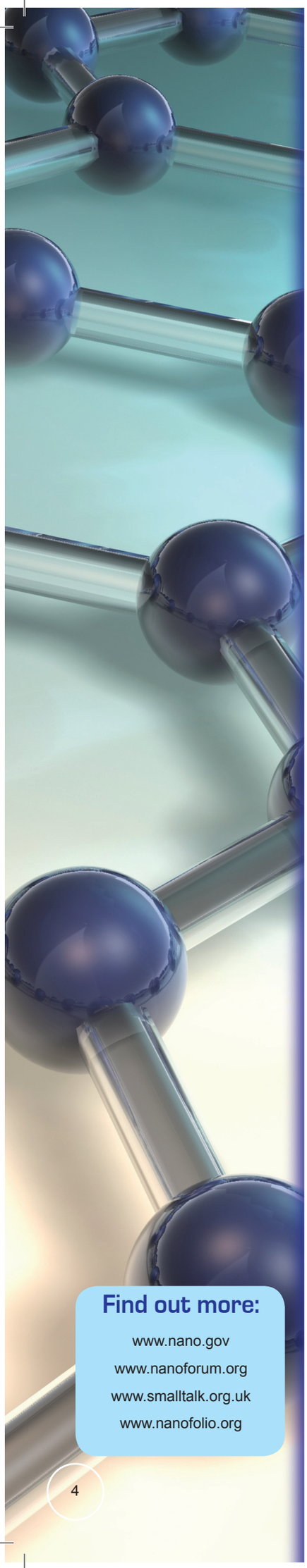
A concept artwork for a hydrogen household fuel cell battery

Nano is ... Teamwork

Head of nanotechnology at Mintek, Dr Robert Tshikhudo is a chemist. But he has a multi-disciplinary team of scientists and engineers working with him. Each of them is vital to the work of his unit. They include:

- Physicists, material scientists and chemists who can synthesise various nanostructures and manipulate or predict their properties at nano-scale;
- Chemists who can design stabilising molecules to control the size and shape of nanomaterials;
- Molecular biologists who can engineer proteins for specific applications;
- Biotechnologists who can engineer biomarkers and validate diagnostic prototypes;
- Micro- and molecular biologists who can understand what happens when nanoparticles enter the body and who also evaluate the health, safety and environmental impact of nanoparticles;
- A full range of engineers, including chemical, biological, electronic, design and material engineers, and metallurgists;
- Microscope technicians.

"Nano is an enabling technology," says Tshikhudo. "You don't have to be directly involved in nano-materials development. As an expert in your own field, you simply need to understand how you can use nanotechnology. Go back to the existing technology and ask: what if we were to incorporate nano-materials? If we take that approach, we can do wonders."



Find out more:

www.nano.gov

www.nanoforum.org

www.smalltalk.org.uk

www.nanofolio.org

A career in nano? – What you need to do

Because it is multidisciplinary, there are many ways to get into a nano-related field. Nano experts in South Africa and beyond agree that studying the sciences – physics, chemistry and biology – is essential. Mathematics is also important.

Focusing on these areas of study and keeping up to date with developments in nanoscience and technology can provide you with a foundation for a wide range of careers.

Quote: "What is necessary is deep knowledge in at least one field of nanotechnology, coupled with the ability to communicate and collaborate with other related nanotechnology areas as well as with experts in other fields."[7]

A comprehensive masters programme based at the University of the Western Cape is planned for the near future (see box), but there are currently no nanoscience or nanotechnology undergraduate degree programmes available. Individual nano-related courses are offered at honours and masters levels at several institutions and there are also post-graduate degrees in materials science.

Where to start?

According to Jean McKenzie, owner of SciStaff, a specialist South African recruitment consultancy for scientists, the first aim for a school learner should be to enter a science degree programme. "From that point on, there are lots of options when it comes to specific fields of study which have nano-applications," she said.

Mathematics and Computer Science, which is used in design and computer modelling of nano-based technologies and extremely useful when combined with another discipline such as chemistry, physics or biotechnology.

Chemistry which has direct relevance for most aspects of nanotechnology, including sensor development, drug delivery, nanoparticle and nanostructure synthesis, energy device (solar cells, batteries and fuel cells) development water purification and filtration, characterisation of nanostructures and devices.

Biochemistry, genetics and other biotechnology sciences, which finds application in the medical industry (nanomedicine), for example, the development of drug delivery systems.

Physics, which can be applied in a range of nano areas, from understanding nanotechnology better to producing sensors. It is also useful in the development of equipment for analysing nanotechnology products and devices, energy device development nanoparticle synthesis and characterisation.

Proposed Masters of Science Degree programme in Nanoscience:

The University of the Western Cape, in collaboration with industry and other academic institutions, has been mandated by the national Department of Science and Technology to design South African's first nanoscience masters programme. Expected to be introduced for the first time in 2011, the curriculum is set to consist of "an interdisciplinary nanoscience foundation followed by specialisation innanobiomed, nanochem or nanophysics". The proposed degree will involve 50% research and 50% coursework and it is anticipated that graduates of the programme would proceed either to PhD or to work in industry as nanotechnologists or entrepreneurs.

(Source: Nano News-South Africa, Volume 6, November 2009)

Engineering (electronic, mechanical, biomechanical) which can be used in sensor development, drug delivery, energy device development, water filtration, fundamental nanoparticle synthesis and characterisation of nanostructures and devices

Material sciences which have relevance to all aspects of nanoscience and nanotechnology.[8]

Nanotechnology draws on numerous disciplines including chemistry

1 *http://en.wikipedia.org/wiki/Nanotechnology*

2 *Ibid.*

3 *C F Schutte and W Focke. Evaluation of Nanotechnology for application in water and wastewater treatment and related aspects in South Africa, Report to the Water Research Commission, August 2007.*

4 *Roco, M.C. & Bainbridge, W. (eds.) Societal Implications of Nanoscience and Nanotechnology (National Science Foundation, Arlington, VA, 2001, quoted in "Nature Biotechnology", volume 21, number 10, October 2003.*

5 *The Water Wheel, March/April 2009.*

6 *Compiled with assistance from Jean McKenzie, SciStaff owner and Dr Robert Tshikudo, Mintek.*

7 *Mihail C. Roco, National Science Foundation, Virginia, United States of America.*

8 *Compiled with assistance from Jean McKenzie, SciStaff and Manfred Scriba, CSIR.*