Small things may make a big impact on energy

It has become a global priority to develop sustainable, efficient and inexpensive energy to meet demands. Every nation is grappling with the issue of energy supply and security as well as the possibilities of a "green" economy. The productive capabilities of emerging economies are dependant on a secure supply of safe, clean and affordable energy. Many governments are reducing their dependency on single energy sources such as oil and are investing in alternative energy sources. In 2008, the South African government identified energy as one of the five "Grand Challenges" in its ten-year innovation plan that builds on and expands our current research strengths to steer South Africa towards a sustainable and developed economy.

Working closely with industry, South Africa is exploring opportunities in clean coal technologies, nuclear energy, renewable energy and hydrogen and fuel cell technologies. One of the new and exciting technologies that may make a significant impact on our energy future is nanotechnology. Energy is one of the six focus areas of the National Nanotechnology Strategy (NNS) which was launched by the Department of Science and Technology (DST) in 2005, with the aim to co-ordinate nano research and development at a national level.

What is Nanotechnology?

Nanotechnology is the act of manipulating material at very tiny (nano) scales, essentially at the level of atoms and molecules. At these small sizes, the normal rules of physics and chemistry no longer apply and materials often display unique and surprising properties. Materials in the nanometer scale exhibit physical properties distinctively different from that of the bulk and are influenced by size, shape, structure, and orientation of the nanomaterials. They possess superior electrical, magnetic and mechanical properties as well as higher surface areas. The ability of scientists to create and manipulate matter at the nanoscale offers previously unenvisaged possibilities for scientific discoveries and technological applications. Nanotechnology has been hailed as the "leading technology of the 21st century". It is an enabling technology, recognised as an important tool for innovative development and as a means to improve the lives of ordinary people.

The past two decades have seen rapid global advances in nanoscience and nanotechnology in all spheres of science, engineering and technology. Scientists, including chemists, biologists, physicists and engineers continue to explore the potential positive and negative effects of nanotechnology-based materials and devices. South Africa is not an exception. Leading South African universities, the DST's Nanotechnology Innovation Centre's and the industrial and private sector are engaged in nanotechnology research and development.

Nanotechnology and Energy

It is expected that nanotechnology will facilitate cheaper, cleaner, more efficient and renewable energy. Research is well advanced enough to establish that nanotechnology can offer a great contribution to viable alternatives to non-renewable fossil fuel consumption, as well as improve conventional energy processes. Nanotechnology can be applied in energy production, conversion, distribution, storage and usage. Nanotechnology research in South Africa can contribute towards energy technologies in the development of solar photovoltaic cells, the hydrogen economy, as well as more efficient conventional energy production and energy saving for industry and consumers.

Solar Cell Technology

Nanotechnology and nanostructured materials are already contributing to the development of solar power technology. Photovoltaic (PV) cells are being used in electricity production. Currently, the dominant materials used in PV cells are mono or multicrystalline silicon. Solar cells are produced by sawing 0.2 mm to 0.3 mm thin wafers from lumps of silicon. The problem is that this uses a lot of expensive material. Nanotechnology can provide a cheaper alternative. Nanostructured alternatives which are currently on the market use an active layer down to microns in thickness, deposited on a cheap substrate such as glass. Amorphous silicon is cheaper than crystalline silicon, because it uses 300 times less active material. The challenge of thin films based on nanotechnology is that energy conversion is less efficient than that of crystalline silicon.

The most developed solar cell technology is the Graetzel cell, invented by **Michael Graetzel**. This cell relies on nanostructured titanium dioxide whose surfaces are coated with a dye. The nanoparticles are then embedded in a polymer electrolyte to make a thin film which can be coated onto a plastic sheet. This process is already being commercialised by a number of companies in the US and Europe. Considering the significant amount of money spent on nanotechnology research for energy-related applications, many of these benefits are likely to be realised sooner than expected.

Hydrogen Fuel Cell Technology (HFCT)

Currently there is much talk about the hydrogen economy, where hydrogen is expected to be the dominant fuel converted into electricity in fuel cells. Hydrogen Fuel Cell Technology is a technology which uses both hydrogen and fuel cells to generate electricity. Hydrogen is the simplest element and most plentiful gas in the universe. It is used as an energy carrier which stores and delivers energy in a usable form. Using hydrogen as an energy carrier of many energy sources will reduce the country's dependence on importation of oil and also reduce greenhouse gas emissions that cause global warming. Fuel cells directly convert

Nanotechnology research can contribute towards energy technologies in the development of solar photovoltaic cells

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the chemical energy to electricity with water and heat being the by-products. A fuel cell operates like a battery but unlike a bactery, it does not run down or require recharging. With over 75% of the worlds platinum reserves (the key catalytic component of Proton Exchange Membrane (PEM) fuel cells), South Africa is ideally positioned with both the raw material and the scientific expertise to drive a developing hydrogen economy.

How can Nanotechnology Improve Fuel Cells?

Nanotechnology will play an important role in efficient energy conversion in hydrogen fuel cells, by optimising membranes and electrodes. It will play a role in more efficient production of hydrogen from other energy sources. In the storage of hydrogen in the form of metal hydrides, the focus has shifted to nanostructured hydrides including carbon nanotubes, nanomagnesium-based hydrides, metal hydride-carbon nanocomposites and nanochemical hydrides. The development of hydrogen and fuel cell technology is currently under investigation by South African researchers.

Catalysts are used with fuels such as hydrogen or methanol to produce hydrogen ions. Platinum, which is very expensive, is the catalyst typically used in this process. Companies are using nanoparticles of platinum to reduce the amount of platinum needed, or using nanoparticles of other materials to replace platinum entirely and thereby lower costs.

Fuel cells contain membranes that allow hydrogen ions to pass through the cell but do not allow other atoms or ions, such as oxygen, to pass through. Companies are using nanotechnology to create more efficient membranes; this will allow them to build lighter weight and longer lasting fuel cells.

Small fuel cells are being developed that can be used to replace batteries in handheld devices such as Personal Digital Assistants (PDAs) or laptop computers. Most companies working on this type of fuel cell are using methanol as a fuel and are calling them DMFC's, which stands for direct methanol fuel cell. DMFC's are designed to last longer than conventional batteries. In addition, rather than plugging your device into an electrical outlet and waiting for the battery to recharge, with a DMFC you simply insert a new cartridge of methanol into the device and you're ready to go.

Fuel cells that can replace batteries in electric cars are also under development. Hydrogen is the fuel most researchers propose for use in fuel cell powered cars. In addition to the improvements to catalysts and membranes discussed above, it is necessary to develop a lightweight and safe hydrogen fuel tank to hold the fuel and build a network of refuelling stations. To build these tanks, researchers are trying to develop lightweight nanomaterials that will absorb the hydrogen and only release it when needed. It is estimated that widespread usage of hydrogen powered cars will not occur until approximately 2020.

Efficient Energy Use

In addition to its role in innovative new materials and processes, nanotechnology is playing an important role in improving current processes, making them more energy efficient and reducing the burden on fossil fuel resources as well as alternative fuels. Lightweight nanomaterials for cars and other means of transportation can save on conventional fuel. Better insulation of buildings by nanoporous foam, and better management of light and heat by, for example, electrochromic windows will reduce energy requirements of buildings. Nanotechnology can also provide more energy efficient lighting through LEDs.

Is Nanotechnology Safe?

Some drawbacks of nanotechnology may exist. There are concerns that the same properties (size, shape, reactivity, etc.) that make nanoparticles so useful could also make them harmful to the environment and toxic to humans, for example, if they accumulate in drinking water supplies and the food chain. These concerns are exacerbated by the current poor understanding of the fate and behaviour of nanoparticles in humans and the environment. Risk assessment research is crucial for establishing the potential impacts of nanoparticles upon human health and the environment: the technology's benefits must be balanced against any unintended consequences. This is a massive challenge, since it is very difficult to monitor the possible impact of the huge volume of diverse nanoparticles being produced and used in different products and applications. There are currently no nanotechnology-specific regulations in South Africa other than general standards such as those set out by the South African Bureau of Standards (SABS) and the Medicines Control Council (MCC), due to the relative infancy of this emerging technology and the lack of evidence and scientific data to demonstrate the impact of products already in use. The government, through the DST, is funding a research platform to investigate the environmental, safety and health aspects of nanotechnology.

Fuel cell batteries

The Nanotechnology Public Engagement Programme (NPEP) is an initiative funded by the Department of Science and Technology (DST) and implemented by the South African Agency for Science and Technology Advancement (SAASTA), a business unit of the National Research Foundation (NRF). Launched in early 2008, the NPEP aims to promote credible, fact-based understanding of nanotechnology through awareness, dialogue and education to enable informed decision making on nanotechnology innovations to improve the quality of life.

The objectives of the Nanotechnology Public Engagement Programme are to:
- **Create awareness around nanotechnology;**
- **Educate the public on, and enhance their understanding of nanotechnology;**
- **Enable and stimulate meaningful public debate around nanotechnology; and**
- **Stimulate interest in nanotechnology and nanoscience as a career in order to ensure long term capacity building in the field;**
- **Get industry involved in the development of nanotechnology and take the lead in nanotechnology innovation.**

For more information on the NPEP, visit www.saasta.ac.za or email info@saasta.ac.za.

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