CONNECTING TECHNOLOGY: CATALYSING INNOVATION

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Nanotechnology is used in the development and manufacture of products in a number of different areas, including medicine, materials, electronics, coatings and energy saving technology, all with positive effects such as decreasing drug side-effects and improving sports equipment performance.

Nanotechnology has been used to increase benefits and improve processes for many years, indeed, long before many people realise. For example, in 400 AD, the Romans unknowingly used nano-particles in the process of glass blowing to produce the Lycurgus Cup that, due to the gold and silver nano-particles contained in the glass, give the cup unusual optical properties. Similarly, medieval stained glass relies on the same size-dependent light scattering properties of metal nanoparticles.

MORE RECENT DEVELOPMENTS AND BENEFICIAL APPLICATIONS IN THE PUBLIC DOMAIN

Earlier this year, Applied Nanodetectors Ltd (AND) released the prototype of a mobile phone that can detect various diseases from the user's breath. The handset manufactured by Nokia Corp, Finland, uses AND's chip that integrates sensors to detect various gases such as CO_2, NOX and ammonia (NH_3). The sensor is capable of detecting the density of each gas by matching results with the characteristics of various diseases. With the ability to detect asthma, diabetes, lung cancer and alcohol concentration, this device can automatically inform the user or their doctor of early detection of an illness.

As well as the medical and pharmaceutical professions, energy and natural resource producers are using nanotechnology to lower costs and improve safety and services to the public.

A direct coal liquefaction plant in China is converting 12,800 tonnes of coal per day into 50,000 barrels of gasoline and diesel by using a carbon nanotube catalyst of traditional vanadium/magnesium oxide complexes. The project in China worth $2 billion has positive impacts for the environment, as well as economically, with a promise to lower the costs and need for imported oil.

The filtration of water through a process of nano-filtration is another nano-process that has positive effects economically. The Generale des Eaux's Mery-sur-Oise plant in France has already adopted nanopore polymer membrane filtration and produces 140,000 m^3 per day of drinking water from the River Oise. Although power consumption is greater, it avoids the use of costly water treatment chemicals.

CASE STUDIES

Sphere Medical

Sphere Medical in Cambridge has combined nano and microtechnologies to develop a tiny diagnostic chip that analyses blood in real-time and gives doctors access to information about critically ill patients. The microanalyser gives immediate access to data, where previously a lab test was required. The technology is based around a microchip, only four millimeters square that hosts up to ten nano sensors, capable of reading a variety of patient information. The Application Specific Integrated Circuit (ASIC)'s functionality allows it to monitor temperature, self check and configure and store individual sensor control settings.

Endomagnetics

Endomagnetics in London has produced a hand-held magnetic probe that can be used in conjunction with a magnetic dye to locate quickly and easily the sentinel lymph node for biopsy in breast cancer patients. The detection of the sentinel lymph node is one of the most important actions in the identification and treatment of breast cancer and the nanotechnology device eliminates the use of radioisotopes, thereby avoiding exposure of patients and surgeons to radioactivity. As well as this the costs of treatment are greatly reduced.

These are just a few of the exciting and beneficial developments happening in the field of nanotechnology right now. Whilst Japan and America are clear market leaders when it comes to the number of patents submitted per country, the number submitted from the UK is now growing.

BIO & PHARMACEUTICAL SECTOR ADOPTION

A number of commentators over the past few years have speculated that nanotechnology is the wave of the future in biotech and pharma. However, there is a large disparity between these predictions and actions of the very companies that are in a position to make them come true.

Nanotechnology appears to be following the classic bell-shaped adoption curve for any technology. When a new technology appears, there is initial excitement created, which hypes its promise to be the next great answer to all our problems.

Usually the hype is caused by the fact that the technology and its applications aren't actually understood and so the imagination allows one to think of numerous areas where it could add value, resulting in overstatement of its promise. This is then followed by disillusionment as people see the hype not matching the reality. Finally, full adoption is achieved as the technology proves itself in the market. The authors believe that nanotechnology has passed through the low point of the trough and that we are now seeing real products being developed, which will fuel further investment. It is at this point where the UK companies should invest in the technology to ensure we ride the wave and benefit from the technology.

In the current market climate, companies need to get their products to market quickly to allow as much market exclusivity time as possible – not to recoup their investment, as this is a sunk cost, but to recoup the cost of developing future drugs, the cost of which is becoming ever more expensive.

Given these issues, companies won't adopt new technology, however brilliant the science is, unless they know that the technology has a clear and fast route to approval. This is particularly poignant in drug formulation and other rate-limiting activities that occur post-patent filing. Once a patent is filed, the clock is ticking on the product's life. If a product is going to be a $1billion a year blockbuster, lost revenues will be at least $2.7 million for every day a product is held from the market. This produces a catch 22 scenario; no-one will take the risk to demonstrate a new technology, especially if it is competing with existing and proven methods, so no-one will see a clear adoption path and use it.

FUTURE OF NANOTECHNOLOGY

The future of nanotechnology has been at the centre of many discussions in recent years. Ideas have gone from the far-fetched and elaborate to more realistic patents with beneficial and revolutionary effects.

Recently, scientists have constructed functioning vascular systems that are capable of supplying nutrients and oxygen to tissue, a crucial step towards being able to build functioning organs. Tissue engineering methods have successfully produced skin and cartilage within laboratories as well as one-layer systems of kidney and liver cells that have been successfully implanted in rats.

Nano-particles are being developed to detect physiological changes within the body and can release drugs at certain times depending on these changes.

There are still many areas where nanotechnology can be predicted to provide signifcant benefits. Some will come to fruition, some won't. The important thing is that we should explore these ideas so that we do benefit from technological advancement.

DO WE NEED TO WORRY?

As with all new technologies, we don't know everything about a product until it has been developed, characterised and extensively tested. There are significant efforts in the UK and globally to study any possible dangers of nanomaterials as they are produced and there are also strong safety systems in place, ensuring any threats are detected and countered.

Given the number of benefits nanotechnology can bring to the UK and the positive socio-economic effects it can have on the country, the only matter it seems that we should really be worried about, is nanotechnology advancing elsewhere while the UK is left behind.

CONCLUSION

The field of bionanotechnology is clearly moving forward rapidly and there is no doubt that it will enhance our understanding of biology and how biological systems work. Nanotechnology is being used to help resolve some of the pharma and biotech industries' significant problems.

In the future, nanotechnology will enhance the drug discovery process, through miniaturisation, automation, speed and reliability of assays. It will also enable greater selection of the right drug for the right patient and mean that the tests to support this decision process can be done immediately in the doctor's clinic.

Nanotechnology has a lot to offer the pharmaceuticals industry and if it follows previous technology examples such as biotechnology, the successful early adopters will reap the rewards. It still has a number of hurdles to leap, such as a clear regulatory pathway and a demonstration of value above and beyond current technologies, before it can become mainstream, but there are significant efforts by industry and governments to help it to jump the technology adoption gap quickly.

As with most technologies, nanotechnology will develop over time. It is still in its first phase of development and industry leaders believe major growth will occur between 2015 and 2035, providing the UK public, academia and research facilities support it now. A balance needs to be struck to ensure that the science moves forward, but does so carefully with public support. If the UK wants to remain a leading knowledge economy it cannot afford not to be at the forefront of nanotechnology.

SUPPORT BY THE NanoKTN

The Nanotechnology Knowledge Transfer Network (NanoKTN), one of the UK's primary knowledge-based networks for Micro and Nanotechnologies, was set up by the Technology Strategy Board, to promote and facilitate knowledge exchange, support the growth of UK capabilities, raise nanotechnology awareness and provide thought-leadership and input to UK policy strategy.

The NanoKTN has a number of different focus groups working across a number of different areas, designed to act as a three way communication channel between industry, academia and the funding authorities. Focus groups are available to all NanoKTN members and further information can be found at www.nanoktn.com

Membership of the NanoKTN is free. For further information on the UK MNT community and the NanoKTN, please visit www.nanoktn.com or email enquiries@nanoktn.com

USING NANOTECHNOLOGY FOR BETTER BIOLOGY-TECHNOLOGY INTERFACES

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Nanotechnology is in essence a multidisciplinary endeavour, which has already had an impact in most branches of technology ranging from the communication, robotics, and optelectronic industries to biology and medicine. Nanotechnology refers to the engineering and manipulation of materials and structures at the atomic and molecular level, typically ranging from 0.1nm to 100nm. Without doubt, one of the greatest assets of nanotechnology is in combining nanomaterials and related tools with biomedical technology. Accurate and early-on diagnosis, localised and selective treatments, biomimetic and functional repair are the holy grail of medicine. In addition nanotechnology offers the capability to bring the quest at hand.

The human body is complex, multiscale machinery; limbs and organs are macroscopic (>1cm) elements; cells are microscopic (10-100μm wide) structures; and human biology happens at the nanometer scale. DNA strands are about 2.5nm wide; proteins may be tens of nm long; viruses are a few hundreds of nanometers in diameter. Nanomaterials are man-made, engineered materials, which have size scales comparable to their biological counterparts, and may be manipulated both at the nano- to macroscale. With matching geometry, nanomaterials and nanostructures offer a route towards enhanced biocompatibility and interaction between engineered and biological systems.

A few examples of recent studies using nanotechnology in medical sciences are highlighted in figure 1. Nano-tools such as atomic force microscopy allow for the study of the biological and physical properties of structures such as amyloid fibrils (which most likely play a role in neurodegenerative diseases). Micro- and nanofabrication tools eg electron beam lithography provide new design approaches to develop faster computing circuitry and engineer 3-dimensional biosensing devices. Furthermore, nanomaterials offer not only improvements in current medical diagnosis and therapeutic techniques but also may provide new solutions for physiological repair.

IMPROVED DIAGNOSIS

Cancer is often detected using imaging techniques such as Magnetic Resonance Imaging (MRI). Contrast agents may be preliminary injected intravenously to the patient to enhance the appearance of specific tissues such as blood vessels or tumours. The technique is usually non or minimally invasive for the patients. Nanoparticle based contrast agents such as. quantum dots – nm size diameter spheres made of semiconductor material, colloidal metal or magnetic particles have shown great promise for high resolution and sensitivity imaging of cancers. For example, superparamagnetic iron oxide nanoparticles have been successfully used to visualise cancerous cells in the liver.

Other imaging techniques eg Computed Tomography (CT)

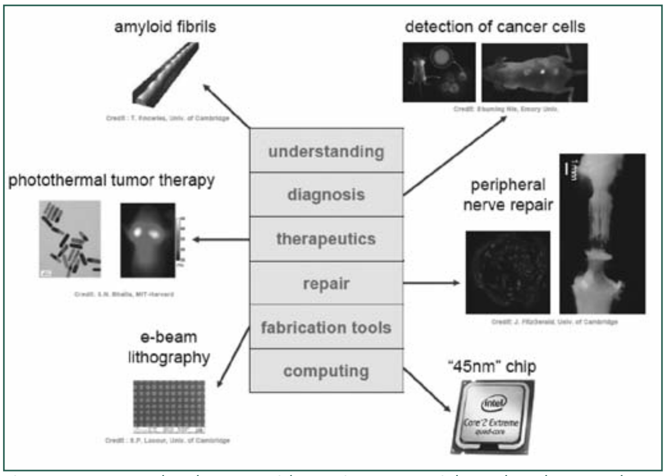

Figure 1. Nanotechnology provides unique materials and tools to explore, diagnose, treat and repair biological systems.

and ultrasound scanning also benefit from nanoparticle contrast agents. For instance, gold nanoparticles provide enhanced imaging in CT scans compared to standard iodine contrast medium.

As nanoscientists design and engineer the nanoparticles, there is a vast library of available materials for disease specific enhanced imaging. Equipped with smart nanoparticle contrast agents, optical imaging techniques have most certainly the potential for early cancer detection. Furthermore, as nanoparticle contrast agents have a better optical stability than conventional organic dye contrast agents, recording of "live" biological events may become available, and therefore provide unique information about inflammatory development, angiogenesis and thus disease progress.

TARGETED THERAPEUTICS

Drug delivery is one of the most advanced applications of nanotechnology in medicine. In this case, nanoparticles are designed not only to bind to specific cells in the body but also to deliver one or more bioactive molecules to those cells. The nanoparticles are taken up by the cells due to their small size. The activation of the nanoparticle, ie the release of the drug, may be spontaneous or triggered by pH change, near-infrared light, enzymatic response inside the cells, etc.

Whilst successful, targeted therapeutics is not without challenges. Numerous mechanisms may prevent the nanoparticles from reaching their target in high enough concentration to treat efficiently the malignant cells. The circulation in the body of the nanoparticles, their elimination and eventual accumulation in specific organs are additional concerns. Further improvements of nanoparticles' geometry, architecture and biochemical properties are currently part of active research.

FUNCTIONAL REPAIR

Unlike the salamander, humans don't have the ability to self-repair and regrow injured or missing biological tissues. Nanotechnology may not change that statement but offers promising alternatives based on tissue engineering, smart prosthetics and regenerative medicine.

For example, scaffolds for tissue repair have been developed for decades. They include matrices for bone, cartilage, teeth, skin, cardiac and vascular tissues, and the nervous system. But none of the current implants offer long-term endurance and true functional recovery. One recent route of investigation is the biomechanical interface between the cells and the "man-made" surfaces. This is being explored with nano-tools such as atomic microscopy which allows for the study of the physical properties of cells and their response to the mechanical compliance of the surrounding medium. Data shows that cells differentiate surface elasticity and topography, and therefore proliferate preferentially on certain ranges of compliance. Based on these findings, the design and fabrication of scaffolds and prosthetic implants are being revisited and will hopefully provide improved biocompatibility.

CONCLUDING REMARKS

For the first time, scientists have the ability to select, manipulate and/or interact with cells and biological structures at the molecular and cellular levels. Still there is a lot of uncertainty associated with this. The good news is that the scientific community, governments and the public are not only aware of the high-end promises of nanotechnology but have already stepped aside to anticipate potential health, environmental and societal risks associated with by-products of nanotechnology. Worldwide studies are conducted to evaluate and quantify potential hazards associated with nanotechnology and its derivatives. This is a lengthy and non trivial process given the wide range of engineered nanomaterials and nanostructures, and the plethora of exposure modes.

Although comprehensive data are not yet available, strict guidelines must be drawn up and applied regarding the handling, the modes of exposure, and the disposal of nanomaterials. Moreover, given the pace at which nanotechnology develops, such protocols must be revisited and updated regularly, every few months or yearly, in order to incorporate new research and practice findings, and offer the most up-to-date code of behaviour.

Science and innovation are always associated with potential risks, but those related to nanotechnology are anticipated and thus should be controlled.

Professor Vicki Stone of Napier University, who attended the meeting, continues the debate in an article on pages 38 and 39.

DURING DISCUSSION THE FOLLOWING POINTS WERE MADE:

The setting up of the Human Genetics Advisory Council was an example of ways one can use to try to allay public fears. A question whether regulation is needed and whether it should be developed locally or worldwide was raised. REACH already exists to regulate chemicals on a Europe-wide basis but only deals with substances that occur in volumes exceeding one tonne. However nanoscale products are usually produced on a much smaller scale that do not fall under REACH. Nanoscale products which are embedded are safer whereas freestanding nanoscale products are different as they have potential for release into the environment. Nanotechnology is an enabling technology concerning a limited size range of particles which extend across the range from biology to quantum physics. For example, solar cell efficiency can be increased from 8-10% by the use of nanostructure in the cell, resulting in transfer of this technology to industrial production in the near future. Energy storage in super capacitors is another area of current interest. Turbine blade performance can be greatly improved by surface treating the blade with nano-structured diamond. Nanomembranes also provide opportunities to clean up water supplies and reduce, for example, the amount of medication in water supplies contaminated by waste from upstream sources.

The KTNs are a very useful way of getting knowledge out of universities and into industry. Rationalisation, which is the responsibility of the Technology Strategy Board, will not affect the NanoKTN.

Regeneration of the spinal cord is an area of current work also undertaken by the Regenerative Medicine Network which is about to embark on clinical trials. Gene therapy is another area of current interest requiring care especially when inserting a new heritable gene capable of transfer to subsequent generations. Clearly nanotechnology is a topic of global importance with great potential to bring benefits to humankind provided the necessary precautions are taken.