THE USES OF NANOTECHNOLOGY IN CONTACT LENSES TO MONITOR DISEASE

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Abstract

This paper is about the advances of nanotechnology in medicine to help non-invasive glucose level tests for diabetics. We have based our paper around the ideas of Jin Zhang from the University of Western Ontario, Canada, that nanotechnology can be used in contact lenses which have been developed to register glucose levels in tears. These change colour if there is a large variation in sugar levels, which allows the patient to monitor their glucose levels without the need of a finger lancet, which for the young, old and disabled will be a more user friendly system. We are able to extend this idea for other aspects of disease monitoring, and also consider the ethics of nanotechnology in the future of this rapidly expanding field.

Introduction

The Oxford English Dictionary defines nanotechnology as "*the branch of technology that deals with structures that are less than 100 nanometers long*". This subject, dealing with structures invisible to the naked eye and which can only be viewed through powerful microscopes, may seem to some as science fiction; however it is with us today and very much science fact.

The concept of nanotechnology is a fairly recent one, when in 1959, physicist Richard Feynman gave his famous talk entitled "There's plenty of room at the bottom" in which he described the groundwork ideas of nanotechnology and proposed the design for the entire *Encyclopaedia Britannica* to be written on a pinhead. Yet he did all this without using the word 'nanotechnology' as it then did not exist, that is until 1974, when Japanese professor, Norio Taniguchi published a paper called "On the basic concept of Nano-technology" where he gave the first definition of nanotechnology. The next step was in 1981, when the Scanning Tunnel Microscope (STM) was invented in Zurich by Gerd Binnig and Heinrich Rohrer. This new microscope allowed scientist to see and manipulate individual atoms for the first time ever. After the invention of the STM, breakthroughs came thick and fast, for example in the 1980s alone the discovery of the buckminsterfullerene, invention of the atomic force microscope and the computer company IBM's logo being spelt out in individual atoms.

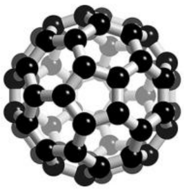

Figure 1: Buckminsterfullerene of Carbon 60

With this new age of the small, the uses and applications for nanotechnology are practically endless and can cover most areas; from titanium dioxide molecules in sunscreen to self cleaning window glass to nanocomposite particles, which are compounds made from a mix of nanoparticles and ordinary material, which improve the properties of the original material. It has kick-started a great leap in engineering, for example the work of Kroto and Smalley (1996), who discovered the Buckminsterfullerene or 'Buckyballs', which are hollow spheres of 60 carbon atoms (figure 1) have opened the doors for the construction of objects like folded sheets of carbon atoms called nanotubes (figure 2) and nanogeared bicycle chains (figure 3) that are only 1 nanometer high.

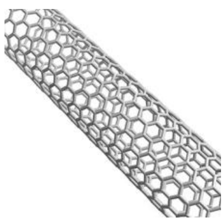

Figure 2: Carbon Nanotube

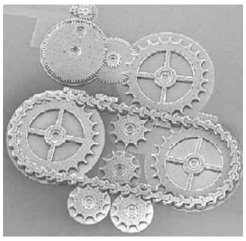

Figure 3:

These techniques can be applied to medicine as there are many and varied uses, for example in drug delivery, medicine is being coated in a nanoparticle that allows it to pass through the stomach into the blood without being digested, or iron oxide nanoparticles which are used for tracking cancerous tumours for MRI scans.

Because of the size of nanotechnological developments, almost anything can be built, which could greatly advance medicine. These include nanotube stents, which would be 100 times stronger than steel yet only 1/6 of its weight, to miniature nanoscaffolds to engineer tissue of organs.

The idea of a non-invasive way to measure blood glucose levels is a welcome one, and with present nanotechnology, it is possible. We have considered the research conducted by Professor Jin Zhang from the University of Western Ontario, Canada who proposed the use nanotechnology to advance treatment for diabetics using finger lancets to measure their blood glucose levels through colour changing contact lenses

Discussion

Below we focus on several areas where nanotechnology may prove potentially beneficial to those suffering from diabetes who need regular monitoring of their disease-control. Work in this area is already being undertaken and the challenge is to provide an effective, efficient and economically viable solution which is universally available.

The contact lenses would be lined with nanocomposite particles that cause a chemical reaction when in contact with glucose molecules. The glucose molecules in tears are not dissimilar to those in the blood, so changes in these glucose levels would trigger the reaction, changing the colour of the lenses (figure 4) and alerting the patient to a change in their blood glucose levels without the need for an invasive finger lancet test, which can distress or inconvenience patients.

Figure 4: The chemical reaction with glucose gives a pink tinge to the lenses, alerting the patient to a change in their blood glucose levels without needing to use a finger lancet

From the research that we have studied, the idea for nanotechnology contact lenses has many exciting ways in which to branch to help not only diabetics, but other diseases as well.

As the lenses are implanted with nanocomposites designed specifically to react to a difference in glucose levels, why not have nanocomposites specific to iron particles, to test for anaemia. Nanocomposites could potentially be used to test cholesterol levels, or molecules of calcium to test for the onset of osteoporosis. In addition, we can go further than using contact lenses sensing tears, and we could have a patch to monitor salt levels in sweat, develop patches to monitor drug levels for chronic diseases for example methotrexate for arthritis. This is the beauty of nanotechnology; things previously thought of as impossible can be made possible, it's just a matter of finding out how.

We can take the whole concept one step further in the way the patient will monitor their condition. With the original design, the reaction causes a change in hue of the lens, alerting the patient to a dip or rise in glucose levels, but it is not accurate, so you know that the level has changed, but not how much it has changed. This heralds the possibility of "reading" the change in lens colour via a camera affixed to a computer or a mobile phone, so that these "readings" can be monitored at a distance by an appropriate expert – checking the colour intensity and producing an accurate reading. The technology for this already exists, and is economically viable. This will link the system to the emerging telehealth services, now a common feature in the NHS and private healthcare. To develop this idea further, the ability to take their own reading empowers the individual, whilst at the same time the health practitioners can monitor changes each time a reading is taken without being intrusive. Data can be built up on individuals, patients of a particular practice, or in a larger area to establish diabetes population densities and trends.

In essence this would work as follows: when the lenses change colour, the patient takes an image of his/her eyes via mobile phone or home pc. This image is then sent to a central monitoring facility (eg a health centre or GP practice). Here the image is automatically downloaded to a "traffic light" program on a desktop. If the reading (calibrated to suit the individual) shows a change in colour i.e. is above or below a set norm, the program will show a variation. If the colour change indicates a serious variation an alert will show and the monitoring health worker can contact the individual and ask for a second reading, or inform the appropriate emergency service. As the change in colour is a possible precursor to a diabetic reaction, the system is predictive.

Initially the research and development (R&D) costs of nanotechnology treatments and processes will be high, but when the technologies are fully mature they will be comparatively cheaper than current treatment. As this is such a precise field, development will be funded only by rich corporations (eg drugs companies, or technology organisations with an interest in breaking into the arena of medical technology). These will be commercially-focused and thus will demand a return on their R&D investment. This could make the unit cost of items such as the contact lenses prohibitively expensive to the majority of users, unless subsidised by governments (eg by the NHS via prescription).

One trend which is emerging is the patenting of technologies, procedures and treatments. Patents have been taken out on gene therapies, by individuals and organisations seeking to capitalise on the processes, rather than share the benefits. This could (and may already) be to the detriment of universal treatments i.e. only the rich could afford some of the treatments developed by nanotechnology.

The future of Nanotechnology
In the future, nanotechnology will accelerate exponentially bringing with it fantastic solutions to old problems and new problems, needing solutions. As we have already mentioned, nanotechnology is having a great impact on medicine, and is the driving force for many new ideas and advances in the field. One big contender is the idea of 'nanofactories' inside the body which are cell-like nanoparticles and would be able to have differentiated target structures (bones, organs, tissue) yet work together and replicate, and be programmed to heal cells or deliver certain drugs or be used as trackers for substances. Despite sounding almost science fictional, serious research is being undertaken into the design of nanofactories (figure 5) so it will only be a matter of time before doctors treat us from the inside out.

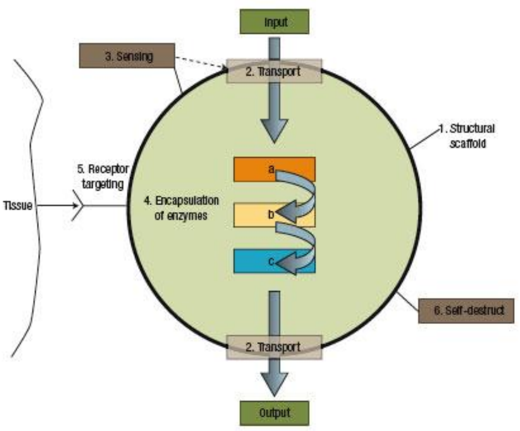

Figure 5: Concept drawing of a nanofactory

Another major near-future goal is to use nanotechnology for therapy techniques. As cancer kills 1 in 4 people, finding an effective, safe way to kill the cancerous cells is almost a holy grail for doctors, but with nanotechnology, this may be well within reach. One way would be the use of nanoshells that attach to cancerous cells, and can concentrate infrared light, which burns the infected tissue away, leaving the healthy tissue intact (figure 6). Another method of nanotechnology cancer treatment is the use of nanoparticles that attach to cancer tumours and, when in the presence of x-rays, generate electrons to destroy the cancer cells. This technique is intended to succeed radiation therapy as it causes much less damage to surrounding cells, however both types of treatments have had preclinical trials and been approved.

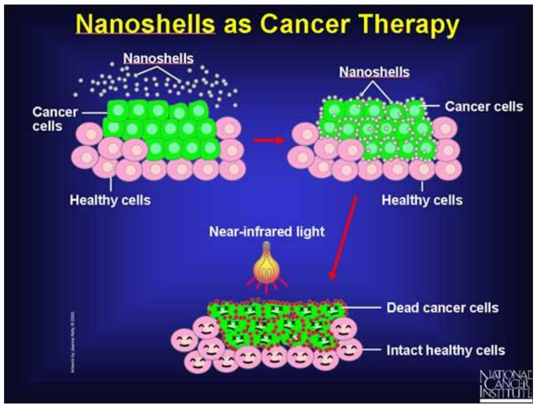

Figure 6: Explanation of how infrared emitting nanoshells can kill cancer cells

Ethics and Nanotechnology
Despite all these wonderful new ideas and methods, there are some major ethical problems that have surfaced with the progression of nanotechnology, and as it gets smaller, the problems get bigger.

One fairly large problem is security and privacy, because if you can make a bike chain that's 1 nanometer high, you will soon be able to make cameras, microphones and tracking devices that size too! This could be construed as a massive invasion of privacy as it would be impossible to know whether what you say is being heard by someone else. Another concern is the size of the nanocomposites in the body as they may be small enough to pass through the blood brain barrier. This worries some scientists because the elements in nanocomposites have different properties compared to their original form, so there is concern that they may be toxic to humans

Conclusion

To conclude, nanotechnology is expanding very quickly and in many directions, encompassing most areas of life. This paper examines only one small facet of this huge subject - the use of nanotechnology in contact lenses. This is where engineering and medicine come together – providing high specification lenses with a purpose to monitor diseases without invasive techniques such as finger lancet tests.

However, although its potential for monitoring diseases such as diabetes is useful, the very science that aided its development may also render it obsolete; as the rapid advance of nanotechnology along with stem cell research may provide a better way to treat or even cure diseases such as diabetes in the future. Furthermore, as the lenses are very specialised and the operational life may not be that long due to the fragility of contact lenses, the continual replacement may prove to be more expensive than ordinary finger lancets; until cheap and effective lenses are developed this may prove a barrier to universal use. In addition, investment would be required by telehealth companies to enable phone cameras to take the required detailed pictures of the eyes to show variations in colour; with the development of highly-defined and increased pixel screens this is currently technologically possible.

Given the rate of research and development the potential uses of nanotechnology are exciting and almost limitless, as it says in the Book of Proverbs “From small beginnings come great things”.

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