

Executive Summary

Nanotechnology has found applications in many industries. Nanomedicine has grown as a discipline in itself and the development of novel structures and advances in nanomaterials are fuelling growth and innovation in the area.

The potential of nanotechnology in medicine has been recognised and a significant amount of funding has been provided to the sector. The number of conferences taking place around the globe on nanotechnology in medicine is an indicator of the interest and potential offered by nanoscience and nanotechnology. The Cancer Nanotechnology plan by the National Cancer Institute in US and the Nanomedicine Technology Platform in the Europe have set out plans for the future research activities needed in the area. A roadmap project which sets out the timeframe for nanomedicine applications has been supported by the European Commission (EC). Several other projects relating to nanomedicine have been funded by the EC 6th Frame Work programme. Many national and pan-European networks also exist, with the aim of bringing together stakeholders to discuss and share information. Nanomednet in UK, Nanoned in Netherlands, Spanish nanomedicine platform, CC-NanoBioTech in Germany, CLINAM etc. are examples of such networks which aim to bridge the gap between different groups including scientists, industry, clinicians, investors and policy makers.

This report looks at developments in nanomedicine and reports some of the novel innovations nanotechnology had brought to health and medicine. The report subdivides nanomedicine into five sectors; Therapeutics, Diagnostics, Regenerative Medicine, Implants, Surgery and Coatings, and Novel Bionanostructures. A sixth sub-sector, Cosmetics, has also been added under nanomedicine due to overlap with technologies covered in Therapeutics. In each of the sub-sector reviews, key technologies and their descriptions are provided. The state of R&D in that particular area is described and additional demands for research are briefly outlined.

Therapeutics: Many drugs have been shelved or are difficult to administer due to their poor solubility. A number also have side-effects associated with them due to non-specificity. Nanotechnology can offer solutions to these problems. Many different drug delivery systems have been investigated for the reformulation of existing drugs to overcome these issues e.g. Abraxane (albumin nanoparticles-paclitaxel conjugate), however if successful new drugs could also be formulated in this way. Other systems described include NanoCrystal (Elan), gold nanoparticles (CytImmune), lipid nanoparticles, dendrimers (Starpharma) and carbon nanotubes.

Diagnostics: This covers the different in vivo and in vitro diagnostic methods enabled by nanotechnology and also looks at imaging techniques. These new methods are driven by novel fabrication techniques, development of new materials and surface modification methods. Nanotechnology can increase sensitivity, lower detection limits and shrink the size of sensors enabling integration into hand held devices. Advances in lab-on-a-chip, and nanofluidics are driving integration. Novel sensors that can detect nano and femto molar concentrations of analytes are important in the early detection of disease. Carbon nanotubes, carbon nanofibres and nanowires have been used for sensing due to their electrical properties. Nano-cantilevers have been used to create nanobiosensors and are relatively simple to scale up. A number of other sensing techniques are discussed. Established imaging techniques such as MRI can be enhanced through new contrast agents and new probes for enhancing SERRS (Surface-

enhanced resonance Raman scattering). Quantum dots have been utilised for molecular imaging (as well as in photodynamic therapy). Other advances in techniques such as AFM are discussed.

Surgery, Implants & Coatings: Novel nanomaterials and advances in characterisation have enabled the construction of artificial extracellular matrices (ECM) with improved cell growth, adhesion and biocompatibility. These can be used for bone, cartilage and dental implants. Carbon nanotubes can be used for improving strength of implants. Nanocoatings can improve the integration and biocompatibility of implants and stents, and increase endothelial growth. Advances in batteries will increase the lifetime of implanted devices such as pacemakers. Novel surgical tools have been developed using nanotechnology to improve accuracy and minimise invasiveness.

Regenerative Medicine: Nanomaterials make efficient scaffolds for tissue and cell engineering. Nanofibres have been used to create scaffolds for cell sheet engineering that can have integrated control measures and time-release growth factors. Bioreactors for growing tissues can be monitored much more efficiently using nanosensors.

Novel Bionanostructures: Nanotechnology has been used to create synthetic cells which can mimic the natural cell structure and carry out normal cells operations including self replication. Novel tools which can fabricate cells using different synthetic materials have been proposed. Membranes that can communicate with each other have also been developed. DNA nanocages formed by self assembly have been utilised for drug and nanoparticle encapsulation. Similarly, DNA has been manipulated to create DNA switches and nanomotors. Novel energy sources for these motors are being developed such as ATP hydrolysis or DNA hybridisation. The self assembling properties of molecules such as catenanes and rotaxanes, have been used to create molecular switches and molecular motors.

Cosmetics: Nanotechnology in cosmetics aims to improve the texture, appearance and skin penetration of ingredients. Liposome and niosome-based creams have been available for many years. Newer lipid structures such as solid lipid nanoparticles (SLNs) and nanoemulsions are now being incorporated into products. These, and others, are discussed in the report. The other main use of nanotechnology in cosmetics is nanoparticulate TiO_2 and ZnO in sunscreens. These can filter and scatter UV while eliminating the white, chalky appearance of traditional sunscreens.

The review of R&D in this sector reveals the huge potential that nanotechnology can offer healthcare in a vast number of ways. However further research into the toxicity of nanomaterials is required, as in many applications they are applied or administered into the body. Suitable models and methodologies for the scale up and manufacturing of nanomaterials and nanodevices are also important for faster commercialisation. The stability of the materials inside the body is important and mechanisms to achieve that extra stability are required. Integrating new nanostructures like nanowires into handheld devices for commercial use is still a challenge. It is also vital that new software for capturing and processing the enormous amount of data provided by nanoscale devices and tools are developed. Essentially, the sector has a number of first generation products but future development will offer much greater opportunities. For example, many sensor platforms are currently still at the research stage. Setting the right priorities and providing adequate support in a timely fashion means that nanotechnology could significantly impact upon the healthcare and pharmaceutical industry.

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