European Commission

Report on ObservatoryNANO activities 2008-09

Term 1/2008

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Version: 28.05.2009

http://www.observatorynano.eu/

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1 Introduction

Nanotechnology is a complex and rapidly changing field, which is often difficult to assess in terms of opportunities, challenges and risks. The ObservatoryNANO project is funded by the European Commission (EC) under the seventh Framework Programme (FP7) to address this. It aims to provide the EC and other policy and decision makers with reliable information regarding the development of nanotechnology and its potential impacts on society.

Nanotechnology is not a single technology, but has applications in many different existing industries. At the nanoscale (around 100 nanometres or less, with 1 nanometre equal to 1 billionth of a metre) materials can show marked changes in optical, magnetic, electrical, chemical and physical properties; facts that have been known for some time but are only recently being exploited. Examples include zinc oxide which is used in sunscreen (nanometre sized particles are still able to block UV light, but in contrast to micron sized particles are transparent and not white); and titanium dioxide which has been used traditionally as a white pigment in paints, but at the nanoscale is not only transparent but also highly reactive in UV light, catalysing the breakdown of organic materials (a property that is exploited in stay clean windows). There are many more examples of materials being developed that could have use in medicine, electronics, transport, energy and other industries. In this report we will describe some of these developments.

To put this in a meaningful context, the observatoryNANO is relating nanotechnology developments to market applications in ten broad areas:

- aerospace, automotive, and transport;
- agrifood;
- chemistry and materials;
- construction;

- energy;
- environment;
- health, medicine, and nanobiotechnology;
- information and communication technologies (ICT);
- security;
- textiles.

At the same time the project partners are also looking at the other impacts of nanotechnology developments: on wider society, potential risks to the environment and human health, and evolving regulations and standards for nanotechnology.

The project consortium consists of 16 partner organisations, from 10 different EU Member States, each experienced in a different aspect of nanotechnology analysis. Our work includes a combination of literature review, analysis of information from patent and publication databases, and interviewing and discussing developments with a large spectrum of experts in different aspects of nanotechnology. The output is consolidated in concise reports, freely available on the project website, and interlinked by a series of keywords, allowing the interested reader to access information on a particular material, industrial sector or analysis (technical, economic, societal, etc) from any entry point.

2 Developments in nanoscience and nanotechnology

Most developments in nanoscience and nanotechnology at present are in creating nano-scale materials and applying these to existing materials. For example, adding nanosilica to cement and concrete mixtures to increase the strength and flexibility by enhancing the setting process. In the future we may expect to see nanoscale devices in their own right. Some examples of the recent advances and developments from the ten application areas assessed by the ObservatoryNANO project are described below:

- Novel nanocoatings, such as titanium dioxide nanotubes, can offer improved cell growth, adhesion and biocompatibility (how the material interacts with the human body) for use in bone, cartilage and dental implants. A number of products using such technology have been commercialised and reached the open market.

- Self cleaning, water repellent, wrinkle and static free and stain resistant fabrics are in production. These use nanoparticles either as fillers to obtain nanocomposite fibres or deposited onto the surface as a coating. For example, some coatings are hydrophobic and so act to repel all water based stains.

- Biodegradable nanospheres which remove toxins from blood streams of victims of terrorism faster than conventional methods are in the preliminary experimental stages.

- Prototypes of flexible displays using carbon nanotubes thin film transistor technology have recently been unveiled and are likely to become increasingly available over the next ten years.

Source: http://www.engadget.com/2007/05/24/sonys-worlds-first-16-7-million-color-flexible-oled/

- An upcoming nano-coated plastic, to increase the strength, could potentially replace car glass decreasing the overall vehicle weight by 20 kg reducing fuel consumption and CO_2 emissions.

Source: Daimler AG

- Active or smart packaging providing a visual indication of freshness using sensors containing nanoparticles which change colour if the packaging had been damaged has been developed by researchers.

- Nanomaterials such as thin silver nanocoatings added to glazing products decrease heat loss/gain and can control light penetration.

Source: C Granqvist

- Car mirrors with hydrophobic nanocoatings which repel water improving vision and subsequently road safety.

Source: Toto Ltd

- The increased efficiency and resistance to corrosion of catalysts, such as vanadium oxide nanorods, involved in the production of hydrogen from water allow for the storage of electrical energy. This is particularly useful as renewable energy dependence increases.

- Nanoparticles can perform water or soil remediation more efficiently due to their much greater surface area; however, applications remain far from market due to safety concerns.

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3 How might these developments affect the economy?

The number of publications, patent applications and funding levels are key indicators of nanoscience economic activity. A patent analysis by the observatoryNANO project found more than 130 000 patent documents worldwide assigned to nanotechnology and more than 10 000 new applications annually. For all sectors the EU member states have a 20% share of patent applications, behind the USA and Japan. Within the EU the largest contributors are Germany, France and the UK.

The wide variety of potential benefits of nanosciences and nanotechnologies are well known and, indeed, are driving research and development (R&D) in these areas. It is clear who could benefit from such advances, such as much improved batteries allowing for an expansion of electric vehicles or improved drug delivery systems. However, who will pay for the required R&D costs is less known.

The EU falls behind the USA and Japan in terms of patent applications despite leading in terms of publications. The majority of funding for nanotechnology in the EU is from the public sector with venture capital funding only accounting for as little as 3.6% of the global total. Therefore the EU may be failing to capitalise on its generously funded research and reaching the goal of a knowledge-based economy.

The overall goal of the observatoryNANO project economic analyses is to enable European governments, industry and the financial sector to make informed decisions regarding funding for prioritising R&D and investment (market forecasting).

4 What effects might these developments have on society?

It is clear that there are many potential benefits of the applications of nanoscience and nanotechnologies. Indeed such benefits include a reduction in greenhouse gas emissions from lighter cars, energy savings in buildings and energy storage allowing for greater exploitation of renewable energy sources. These benefits could also extend to the developing world where water remediation could help towards improving the quality of drinking water reducing the likelihood of disease and death.

A central tenet of the observatoryNANO project is to monitor both the ethical and societal impacts of nanoscience and nanotechnologies and the impact that societal developments and ethical reflection can have on their development. The first year has been focused on reviewing individual and collective responsibility.

For example, the advances in medicine as a result of nanotechnology applications are associated with not just the common medical ethics issues but also the question of demand on limited healthcare resources. As the health and safety risks are not yet fully understood a precautionary approach may prevent the implication of nanotechnology applications such as environmental remediation.

Certain applications are not well received by the public such as genetic engineering of agricultural products. Advances in the security sector aimed at the prevention of terrorism have associated human rights and privacy issues which have to be addressed before any products became operational.

Several organisations, including the European Commission, have proposed voluntary codes of conduct for nanotechnology. They can be seen as an interim measure in a stage where it is not possible to introduce or adapt formal legislation due to uncertainty.

5 Concerns for human health and the environment?

Most nanosciences and nanotechnologies pose no great risk to human health or the environment. However, due to their small size they possess new properties and it would be surprising if the potential for toxicity was not altered.

As particles get smaller the total surface area is increased. Therefore nanoparticles and nanotubes may be associated with an increased toxicity; a greater surface area increases the potential area for inflammation leading to disease. Additionally, the small size of nanoparticles means they can cross cell and other boundaries. Carbon nanotubes may potentially have similarities to asbestos.

There is currently a lack of knowledge concerning the:

1. *Hazard*: Harmfulness, toxicity, mechanisms, safe levels, best way to measure.
2. *Exposure*: Whom is exposed to what, at what levels and in what scenarios. Life cycle analysis is required to determine all likely exposure routes.
3. *Risk*: Likelihood of ill-health, environmental.

Exposure to particles may be occupational; as was the case with asbestos and coal dust and their associated diseases; or environmental. The widespread usage of nanoparticles means the potential for exposure is increased.

Further research is required to address these gaps but must be integrated and multi disciplinary. The observatoryNANO project has produced a reference document highlighting major research in the area of environment, health and safety aspects and is reviewing each of the technology areas, to identify potential issues and summarise what is known about them.

6 How are nanotechnologies being regulated?

Although nanotechnology is at an early stage of development, some products are already on the market. However, there are not yet specific regulations for nanotechnology and nano-related products. Regulatory authorities, the European Commission and other stakeholders are relying on existing regulations, which have been adapted, and self-regulating schemes. Therefore many countries involved in nanotechnology have put the need for standards and regulation high on the agenda.

Regulation has been considered a priority for the following sectors;

- chemicals and materials
- foods
- cosmetics
- pharmaceuticals and medical devices
- occupational safety and environmental protection

Gaps in scientific knowledge and a lack of standards are major challenges in the development of regulations for nanomaterials. The diversity of materials and applications involved and a lack of information sharing, due to economic interests, are further hurdles to an effective regulatory framework.

However, as the risks to human health and the environment are not yet fully understood regulatory activities should rely on precautionary vigilance and self regulation. The most important of the self regulating schemes is the EC Code of Conduct for responsible nanoscience and nanotechnologies research that all Member States have been recommended to use. International efforts to address nanoregulation are also underway by the both the OECD and the International Standards Organisation (ISO) and such a global approach is fundamental.

7 Where can you find out more?

The observatoryNANO website (www.observatory-nano.eu) contains regularly updated reports on;

- Scientific and technological trends (covering the ten subject areas)
- Economic data
- Societal issues
- Regulations and standards
- Health & Safety and risk

For each of the above a current executive summary is available with links to more in-depth information. Interested parties may register to be alerted of new reports and material as they become available and also for the quarterly newsletter summarising the latest project output, which includes regular interviews with opinion leaders from academia, industry, government and NGOs. Further information is also available from the observatoryNANO partner websites and general nanotechnology information can be found at the following websites:

- European Commission nanotechnology pages**:** http://ec.europa.eu/nanotechnology/index_en.html and http://cordis.europa.eu/nanotechnology/
- Nanoforum: European gateway for information on nanotechnology www.nanoforum.org
- EuroNanoforum: http://www.euronanoforum2009.eu/

8 About the observatoryNANO

The observatoryNANO project is funded under FP7 for four years from April 1st 2008. Its primary aim is to support European decision-makers with information and analysis on developments in nanoscience and nanotechnology (N&N). It will collate and analyse data regarding scientific and technological (ST) trends (including peer-reviewed publications, patents, roadmaps, and published company data) and economic realities and expectations (including market analysis and economic performance, public and private funding strategies). This will be further supported by assessment of ethical and societal aspects, impacts on environment, health and safety, as well as developments in regulation and standardisation. Although much of this work will be performed within the consortium, the project is working cooperatively with other initiatives to ensure that effort is not duplicated and that resource sharing and output are maximised. To date liaisons have been established with international organisations including the EPO, OECD, and ISO, and will continue to be established with other relevant organisations such as European Technology Platforms (ETPs), ERA NETs, and other EU-funded projects.

The observatoryNANO project is led by the Institute of Nanotechnology (IoN) (UK), and includes: VDI Technologiezentrum (DE), Commissariat à l'énergie atomique (CEA) (FR), Institute of Occupational Medicine (IOM) (UK), Malsch TechnoValuation (MTV) (NL), triple innova (DE), Spinverse (FI), Bax and Willems Consulting Venturing (B&W) (ES), Dutch National Institute for Public Health and the Environment (RIVM) (NL), Technical University of Darmstadt (TUD) (DE), Associazione Italiana per la Ricerca Industriale (AIRI) (IT), Nano and Micro Technology Consulting (NMTC) (DE), Swiss Federal Laboratories for Materials Testing and Research (EMPA) (CH), University of Aarhus (DK), MERIT - Universiteit Maastricht (NL), Technology Centre AS CR (CR). For further information please contact the project coordinator Dr Mark Morrison (mark.morrison@nano.org.uk) or visit the project website: www.observatory-nano.eu. observatoryNANO is funded by the European Union under FP7. Contract number 218528.