ObservatoryNANO

BRIEFING No.7

TEXTILES

NANO-ENABLED PROTECTIVE TEXTILES

SEVENTH FRAMEWORK PROGRAMME

ObservatoryNANO Briefing December 2010

Rising health and safety concerns for those exposed to dangerous environments or high risk professions has increased demand for improved protective apparel and accessories. Protective textiles are part of the Personal Protective Equipments (PPE) family and represents a specific area of the advanced technical textiles sector, a strongly growing market for the textile industry, satisfying an increasing demand for high performance requirements. Personal protective textiles are produced with the aim of eliminating or minimising the risk of injuries, accidents and infections, acting as shields against chemical, biological and nuclear hazards, high temperatures and fire, sharp objects, and ballistic projectiles.

Protective textiles have been selected by the European Commission as one of the areas of the Lead Market Initiative for Europe, aimed at creating an innovation-friendly market framework to re-launch conventional industrial sectors and reduce time to market of new goods and services. In this context, nanotechnologies may play a fundamental role. Novel surface treatments and coatings, nanocomposite and nano-scale fibres, and functional nanoparticles offer textile products providing improved levels of protection together with a lower weight, higher comfort, new or multi-functionalities, or more environmentally friendly processes. The use of dynamic materials integrated in clothing can enable safety products to react to chemicals, biological agents, or changing external conditions. Smart materials combine electronics with textiles allowing for tracking of the wearer, monitoring of physiologic parameters, and energy provision for communication functions. This BRIEFING, that follows five reports devoted to the nano-enhanced textiles[1], summarises the advantages offered by nano-enabled technical textiles in the protective textiles sector.

Who needs PPE?

Personal protective equipment is required in a number of settings including:

- Professionals and workers operating in hazardous environments or dangerous situations such as the security and emergency services;
- Hospitals, for effective hygiene and comfort of patients and healthcare workers, providing protection from bacterial contamination and providing new functionalities;
- Sport and outdoor activities to protect from injuries and/or extreme climatic conditions;
- Defence and military personnel, to protect soldiers from enemy and environmental threats.

Currently available protective textiles (aramids such as Kevlar) are often heavy, bulky, and uncomfortable with limited protective performance. These characteristics limit their use; this is where nano-enabled textiles may provide a solution.

Nanotechnologies add value

Due to their enabling character and the unique properties of materials at nanoscale, nanotechnologies are particularly suitable for use in technical protective textiles. Their use in this sector is still at an early stage, with research following two main paths:

1. Upgrading functions and performances of existing PPE.
2. Development of products with unprecedented characteristics and performance.

These development streams gives rise to two main classes of products: functional protective textiles and smart/intelligent protective textiles. Some of these materials have reached the market, but it must be stressed that many with the most innovative features have not been tested at full scale, remaining in the early stages of development.

Functional Protective Textiles

Although still at a preliminary stage of development, examples of nano-enabled PPE abound in many fields of application including:

- ***Protection from chemical toxins, toxic agents and poisonous gases:*** PPE, which protects against harmful agents such as mustard gas or carbon monoxide, have been realised with textiles containing nanoparticles of magnesium oxide, dendrimers or gold and have been shown as more effective than the more commonly utilised charcoal. Further single walled carbon nanotubes (SWCNT) based sensors have been developed for detection of nerve gas agents.
- ***Impact protection*****:** Textiles containing inorganic fullerenes, or multi-walled carbon nanotubes, have shown a superior protection from ballistic impact, in laboratory compared to current materials. Under development is an intelligent fabric called “Liquid Armour” consists of 3D spacer textile treated with a specially formulated silicon coating; it remains soft and flexible under normal conditions but becomes instantly rigid when stressed by an impact before returning immediately to a flexible state.

- ***Protection from heat and fire:*** Many nanomaterials (including titanium dioxide, silicon dioxide, clays, and layered double hydroxide) have shown promise as flame retardant additives, enhancers of flame retardant coatings, and providing flame resistance.
- ***Protection from extreme temperatures:*** Textiles with exceptional insulation performance, providing protection against very low or high temperatures, have been obtained with aerogels (nanoporous structures of amorphous silica gel). These textiles will be advantageous for those working in harsh environments, but also for extreme sport/outdoor activities
- ***Protection from UV radiation:*** Textiles exhibiting UV blocking properties find wide application, mostly in sport/outdoor garments. Such properties are obtained by coating textiles with nanoparticles of zinc oxide, or titanium dioxide, and represents one of the first examples of the application of nanotechnologies to the textile sector.
- ***Protection against microbes and bacteria:*** This feature will provide protective clothing for patients and medical workers, wound dressings, bed linen, masks amongst others but may also be applied to sportswear particularly in terms of odour control. Antimicrobial/antibacterial activity is obtained using silver nanoparticles. Copper and titanium dioxide nanoparticles have also been tested for this purpose.
- ***Water repellent and stain resistant clothing*:** Breathability and comfort is highly desirable for a workplace, sport/outdoor activities, combat situations, but also in everyday clothing. Water-repellent and self cleaning textiles can be obtained by nanoscale modification of the surface roughness resulting in water and dirt rolling off the surface; however, water vapour may still pass through ensuring breathability. Such products are already on the market.

These properties may be combined in multifunctional textiles allowing for protection against extreme environmental conditions combined with light weight, antibacterial properties, protection against biological, chemical threats, and ballistic impact. Such products have undergone testing, most notably within the military sector, but there is potential for exploitation in the civilian sector opening wider market opportunities.

Smart/Intelligent Protective Textiles

Smart and interactive/intelligent textiles are the next challenge for nano-enhanced PPE. Nano-enabled fibres and fabrics allowing for the integration of sensors and electronic devices make the development of garments with new, intelligent functions possible. These garments have the capability to capture inputs (electrical, thermal, chemical, magnetic or other) from the surroundings or the wearer, and respond accordingly to them. They can also self-generate (by incorporating photovoltaic devices for example) or store energy for powering communication functions Such innovative products, some already quite close to large production but mostly still at experimental level, can help to provide personalised control and healthcare to patients by allowing the monitoring of physiologic parameters. These capabilities offer an important survival tool to professionals operating in dangerous situations (firemen, policemen, rescue teams etc.) where the monitoring of physiologic parameters, position and/or tracking can be of paramount importance.

The activity in this field involves both academia and industry, but the US army has been historically the leader in this field. Nevertheless, the technologies developed have potential for wider commercial application providing attractive business opportunities; for example extreme sports consumers are often willing to pay a premium in return for higher product performance.

Impacts

Economic/Industry

According to *Nanotechnology: a UK Industry View* [2], nanoscale technology related market revenue for the textiles sector in 2007 was valued at $122m (nanocoatings $120m, smart materials and sensors $1m, and nanofibres/nanotubes $2m). The growth of this sector is expected to be important. The forecast figure for 2015 is $2170m (coatings $1850m, smart materials and sensors $125m, and nanofibres/nanotubes $195m).

Approximately 200,000 jobs are thought to exist in production of PPE and related industries in Europe, including 35-40,000 employees in firms which provide related services. The EU market for PPE has been estimated to be worth €9.5-10 billion. Recently PPE-related job growth in Europe has stabilised due to the economic crisis and indeed industrial production of PPE decreased by 2.4% during 2009. In the short-medium term, the market for these products is expected to grow with a relative stability, due to a positive upward trend underpinned by a rising awareness of personal protection and some catch-up demand in the new Member States, which are pushing the demand for a new generation of protective products. Overall, the PPE market is expected to grow by 7.6% in the 2012-2016 period.[3]

Moreover, the development of innovative technologies in high-tech domains such as the space and defence industries is driving the development

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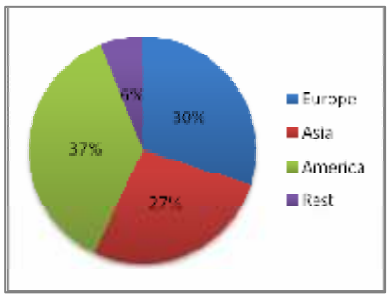

Fig 1a: *PPE world demand*

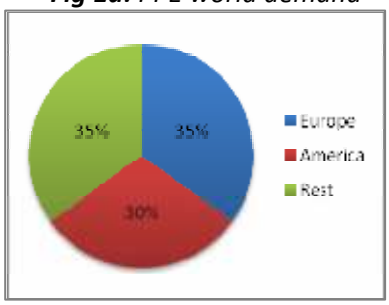

Fig 1b: *PPE world production*

transferred to other textile sectors, including non wearable interior textiles (buildings and transport vehicles) and consumer products (sport and outdoor garments and fashion). These markets are much larger than the core market, thus providing further opportunities for such enhanced textiles.

Manufacturing of protective textiles is distributed across Europe. Textile finishing operations are generally concentrated in Central and Western Europe, and garment making is more widely found in Southern and Eastern Europe as well as some neighbouring countries in the Pan-Euro-Med zone; however, some small scale, specialised garment making operations are present in north-western Europe.

The outside-EU market doubles that of the Europe, offering possibilities to increase EU exports substantially[4]. The new EU Member States in Eastern Europe, Ukraine, Russia and Asia are the fastest growing areas. Market access in Asia is restricted in terms of exports and public procurement (public administrations have a strong impact in the economy and it is a potential market for innovative products and services in sectors such construction, defence, security and emergency operations). If access to such markets is improved, EU exports could grow by 50% over the next 5 to 10 years.[5]

Societal/Impact on European Citizen

Increasing consciousness of risk prevention for those working in dangerous conditions (for example in smelters or contaminated environments) or emergency services such as firemen, policemen and security services has created a strong societal 'pull' for innovative products providing high quality, performance and greater protection.

The EU strategy for 2007-2012 on workplace health and safety sets out a requirement to identify situations of exposure and to design preventive solutions and innovative technologies to deal with new risks. A high level of competence and excellence in textile and multidisciplinary research is crucial to respond quickly to security needs with strong quality and innovation capacity. Europe's advanced textile industry claims to be qualified to respond to this challenge. The increasing demand for high added-value protective textiles is a driver for the modernisation of the more traditional textile manufacturing industry producing a clear positive impact on the competitiveness of the sector.

As with all technological developments, nano-enabled protective textiles should be developed in a responsible and sustainable way. No information has been identified which suggests that the developments highlighted will give rise to specific ethical or societal issues.

Technology Readiness Levels

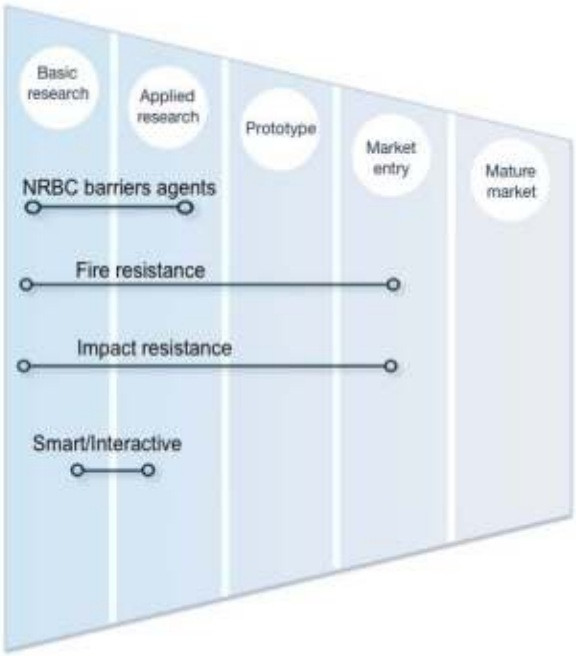

Fig 2: *TRL for nano-enabled protective textiles*

Challenges

To ensure industrial commercialization of nano-products and development of an advanced European textile industry a number of issues must be addressed:

- The cost of manufacturing and selling prices must be reduced to ensure cost effectiveness;
- Affordable enforcement of intellectual property protection is required;
- A need for improved marketing capabilities at the (high tech) supplier side;
- The bottlenecks of public procurement which often slow/stifle the adoption of the most innovative solutions must be overcome;
- A need for widely adopted nano-related Standards and Regulation.

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- Control and evaluation of the effects on human health and the environment of nano-related products are necessary.

The last two challenges above, crucial to the success of these products, refer to their entire life cycle from production to disposal[1e]. So far, existing regulation is considered sufficient to deal with nano-related products; however, continued research to clarify the effects of nanomaterials on human health and the environment is advocated together with the adoption of a precautionary approach when a potentially high risk is envisaged.

EU Competitive Position

In the frame of the initiatives taken to strengthen and promote the European competitive position, the European Commission has selected protective textiles as one of six markets, considered to be responsive to consumer and societal needs and capable of reshaping an industrial sector important to the European landscape. An action plan has been set up that acts at various levels: legislation, public procurement, standardization, labelling, intellectual property, and financial instruments. It is believed that, due to the strong growth forecast in some areas of the world, European PPE exports could grow by almost 50% in the coming years [6].

Compared to Asia and the USA, Europe has a strong position both in terms of research capabilities and private enterprises, as well as in terms of markets driven by safety regulations. Of course, the defence market in the USA is substantially larger than that of Europe (or of Asia) offering US based competitors an attractive launch market for advanced high cost technologies. Nevertheless the EU sector is considered competitive and of above critical mass size and diversity.

Based on several industry inventories one can identify a number of key companies such; Elmarco (CZ), TenCate (NL), d3o(UK), Peratech(UK), Smartex (IT), Slam (IT), Grado Zero Espace (IT), Mectex (IT), Thuasne France (FR), Intelesens (UK), Steiger (CH), iXscient (UK), Nanocyl (BE), Devan Chemicals (BE), Norafin Industries GmbH (DE), Vandeputte Safety (BE) and Bekaert Textiles Group (BE).

Summary

- Personal Protective Equipment (PPE) is increasingly important in the quest to eliminate or minimise the risk of injuries, accidents, and infections rising from a variety of threats and environments. Protective textiles/clothing represents a growing component of this sector.
- Protective textiles have been selected by the European Commission as one of the areas of the Lead Market Initiative for Europe, aimed to create an innovation-friendly market framework and to re-invigorate and increase competitiveness of traditional industries.
- Nanotechnologies can play a fundamental role in the development of improved or novel multifunctional protective textiles by providing higher levels of protection, lower weight and bulkiness, and higher levels of comfort. Moreover, nanotechnologies, by facilitating the integration of electronics into garments, make possible the development of smart/intelligent textiles that allow tracking, monitoring and control of physiological parameters, generation of energy for powering wearable equipments and communication functions.
- Approximately 200,000 jobs are thought to exist in production of PPE and related industries in Europe, including 35-40,000 employees in firms which provide related services.
- The EU market for PPE has been estimated to be worth €9.5-10 billion.
- Compared to Asia and the USA, Europe has a competitive position both in terms of companies and R&D, as well as in terms of a market driven by increasingly rigorous safety regulations.
- Economical and industrial challenges must be overcome to attain the full success of nano-enabled protective textiles, which have to assure their safety with respect of EHS issues, along their entire life cycle.

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