Project summary

1. Project's context and main objectives

The concept of SMARTPRO lies in the development of lightweight and flexible protective clothing, incorporating smart functionalities and designated for law enforcement authorities.

Up to now, research on the protective gear of this group concentrated on the ballistic properties of the body armour. However, in spite of the improvements, modern body armours still have some of the same drawbacks as the old ones, as they are mostly heavy, bulky and rigid. Therefore, they limit wearer's mobility and agility and are impractical for use on joints, arms, legs etc. Moreover, body armours have traditionally been designed to protect the wearer against ballistic threats and, thus, they provide only a limited level of protection against knives, sharp blades or sharp tipped weapons. Recent studies, however, reveal that stab and puncture have become a main cause of police officers' injuries. Therefore, there is an obvious need to develop materials that combine stab and ballistic protection, while retaining their flexibility and low weight.

In this context, SMARTPRO aims to develop optimized ballistic textiles – both woven and spacer knitted fabrics – and apply innovative surface treatments to improve their performance on an areal density basis. Thus, fewer fabric layers will be required, which is expected to result in increased flexibility and reduced weight of the armour. Alternative surface treatments explored include application of shear thickening fluids, dilatant powders, ceramic coatings, carbide and graphene-coated carbide particles and cross-linkable side functionalized aromatic polymers.

Main parameters to consider also include physiological comfort and ergonomic design. In fact, up to now, the increased physiological strain which is imposed by protective vests due to added load, increased clothing insulation and vapour resistance, has received limited attention, despite the fact that in many cases law enforcement officers refuse to wear their armour because of the acute discomfort induced. In respect to the design, this should allow adaptation of the protection level to the risk level encountered in distinct situations. Therefore, modularity of the body armour is a key demand. Of course, the design should also consider the ergonomic requirements of the end users. Concerning the outer fabric of the body armour, its surface functionalization to provide self-cleaning and de-polluting properties is herein proposed, in order to reduce maintenance requirements.

Additionally, smart functions, including positioning systems, heart rate sensors and nanowire gas sensors are being developed to be integrated in the body armour, aiming to increase awareness of the users, eventually leading to reduced casualties.

Finally, while a main limitation is that existing protective gear is usually limited to the body armour, innovative solutions will be proposed for the protection of vulnerable body parts, other than the torso.

2. Description of the work performed since the beginning of the project and the main results achieved so far

Summary of the work performed during the previous period

During the first period of the project, different types of protective fabrics, including woven and 3D knitted ones, were developed using aramid yarns. These were used as substrates for the development and application of alternative surface treatments, aiming to increase their efficiency on an areal density basis. In fact, already during the first period, significant progress was reported towards the development of shear thickening fluids (including early trials for their application on textiles), the application of ceramic and metallic materials on protective textiles by thermal spraying, the application of SiC or graphene-coated SiC particles (graphene deposition on SiC was in fact an important outcome of the 1st Period) on textiles coated with a nanofibrous web and towards the synthesis and application of crosslinkable side functionalized aromatic polymers. On the other hand, difficulties were encountered in identifying a dilatant material available in powder form to be applied on textiles by electrostatic spraying, while coating of textiles with graphene (a treatment studied at first aiming at conductivity) proved to be interesting as a means to improve their ballistic or stab resistance. Stabbing (and a few ballistic) tests were performed on early panels to evaluate their protective properties and gain an insight on how each treatment affects the textile's response upon ballistic or stab impact. Some of the panels tested passed the requirements concerning stab resistance, although they were heavier than the limit set by the end users. Meanwhile, a photocatalytic polymer, in particular SPEEK, was synthesized and its synthesis was successfully scaled up to be applied on the outer fabric of the armour to induce self-cleaning and de-polluting properties. In parallel, conductive textiles and smart systems were developed and characterized. More specifically, the design and the production technology for textile antenna were developed, while possible concepts and suitable materials for sensors were identified. Synthetic routes for the controlled growth of nanowire gas sensors were also successfully developed. Finally, the end users' requirements (regarding ergonomics and protection levels) were defined in detail and validated through a questionnaire survey and a dedicated workshop. Preliminary work had started for the life cycle analysis of existing protective garments for law enforcement personnel, which will serve as a benchmark for comparison to the environmental impact of the new solutions developed in the project and early design concepts were developed and communicated to the end users participating in the consortium.

Summary of the work performed during the 2nd reporting period

During the 2nd Reporting Period, selected protective textiles (Kevlar®-based woven and 3D knitted fabrics) were produced in industrial scale in adequate amounts for subsequent treatments and developments. The deposition of nanowebs on woven textiles was optimized since it was shown that it can enhance the adhesion of particles subsequently applied on the fabrics and scale type composites to be used for protection of arms, legs etc were manufactured using optimized materials and geometry.

The alternative surface treatments studied in WP2, aiming to improve the performance of protective textiles on an areal density basis (so as to ultimately be able to achieve a specific level of ballistic and/or stab protection using fewer fabric layers) were optimized, resulting in a series of alternatively treated fabrics. These were used in various combinations for the assembly of protective panels which were tested in terms of ballistic and stab resistance. The end users' requirement regarding ballistic resistance was achieved with panels satisfying also the maximum allowable weight limit. Next challenge is to design and implement panels simultaneously fulfilling the requirement in terms of stab resistance.

In parallel, various designs of the carrier have been developed, relevant prototypes were produced, presented to the end users and adjusted based on the feedback received. The outer fabric selected for specific body armours has been successfully functionalized with a photocatalytic polymer to exhibit self-cleaning and de-polluting properties, leading to lower maintenance requirements.

The development of smart systems, namely textile antennas, heart sensors and nanowire gas sensors was concluded and now work focuses on their integration on the textiles.

Finally, early work has been done towards the development of technical specifications and the life cycle analysis of existing body armour (used as reference) was completed.

3. Expected final results and their potential impacts and use

SMARTPRO is expected to result in the development of lightweight and flexible body armours, incorporating textile sensors and antennas and designated for use by law enforcement personnel. Therefore, the project will offer all intervention personnel greater protection and increased safety in their daily work, while contributing to a growing vibrant and globally competitive European security SME and industry sector and generate employment.

Although logic dictates the routine use of body armour, as supported also by a number of case studies and statistics, there are still those who do not wear it regularly, often despite of departmental legislations to do so. Those who do not wear armour, usually claim that its bulk and weight make it uncomfortable. In fact, impact protective equipment is required to provide lightweight gear allowing for extreme mobility and a high degree of protection, in addition to increased breathability and user comfort. Without such functionalities, emergency responders will be reluctant to use the equipment.

Despite considerable progress in utilizing nanomaterials and nanotechnology for security applications, significant effort is still required for these results to become technologically and commercially viable. One of the ways to speed up the process is to join, where possible, this effort with the development of conventional materials and technologies. For example, the use of shear thickening fluids and other surface treatments based on nanomaterials, as proposed in SMARTPRO, may provide greater protection on an areal density basis.

Similarly, the integration of ICT devices such as sensors to monitor vital body signs, or GPS units to provide rapid locational information to remote locations (such as command centres) into protective clothing, as anticipated in the project, offers many benefits to emergency responders.

Based on the above, through the development of lighter, more flexible body armours exhibiting adequate comfort properties, SMARTPRO will encourage the routine use of body armours. This, combined with the smart functionalities of the newly developed body armours is expected to contribute to a significant decrease in the number of police officers' casualties.

Furthermore, SMARTPRO is expected to have a positive impact on the competitiveness of European security industrial sector. The market of protective textiles for emergency responders (including law enforcement personnel) is part of a larger market for personal protective equipment. Approximately 200.000 jobs are thought to exist in production of PPE and related industries, including 35.000-40.000 employees in firms providing related services. The EU market for PPE is estimated to worth 9.5-10 billion euros. According to EURATEX, € 8 billion per annum is related to PPE products and € 1.5-2 billion to PPE services (distribution, rental, cleaning). The importance of protective textiles is such that it has been identified as one of six lead markets in Europe, with technological and market developments offering the opportunity to renew a traditional industry.

In relation to the US, for the protective materials sector, the EU is ahead in terms of fundamental and applied research. However, US excel at commercialization, technology transfer, routes to market and “supporting mechanisms”, whereas EU has weaknesses in these areas.

Overall, the PPE market for first responders is a relatively stable market with limited demand growth. This is related to the fact that it is mainly a “replacement market” which corresponds to a stable number of policemen with a limited amount of new users. However, the exploitation of SMARTPRO results may increase the exports of body armours from the EU and thus contribute to the generation of employment in the EU Security sector. It is worth noting that at the moment Europe is ranked 2nd in the global security market, after North America, with a market share between 25-35 %. SMARTPRO will contribute to 2020 strategy for “resource efficient Europe” by creating a competitive market through identification and creation of new opportunities for economic growth and greater innovation and ensuring the supply of essential resources.

Finally, it is anticipated that SMARTPRO results will create economic benefits through dual use applications since the materials developed for law enforcement may then be transferred to the general public, through their incorporation in protective gear for extreme sports or motorcyclists.