LIGHTWEIGHT, FLEXIBLE AND SMART PROTECTIVE CLOTHING FOR LAW ENFORCEMENT PERSONNEL

Introduction & concept

SMARTPRO is a collaborative project under the 7th Framework programme that aims to develop 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 and led to the development of several new fibers and construction methods for bullet-proof fabrics. These high performance fibers are characterized by low density, high strength and high energy absorption. However, even using such fibers, approximately 20-50 layers of fabric are required to meet the protection requirements against typical ballistic threats. The resulting bulk and stiffness of the armour limits the wearer's mobility and has restricted its application primarily to torso protection, since such bulk material is impractical for use on joints, arms, legs, etc. Therefore, despite the progress achieved in terms of materials development, the demand for improved flexibility and performance-to-weight ratio of body armours remains high.

Moreover, body armour materials have traditionally been design 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. However, recent studies reveal that stab and puncture are a main cause of police officers' injuries, while the available protective solutions (metal ring meshes, titanium foils, metallic, ceramic or composite plates) are either insufficient or too uncomfortable to wear and difficult to conceal.

In this context, SMARTPRO aims to develop optimized protective textiles 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. At the same time, the project emphasizes on issues often overlooked, namely the physiological comfort and ergonomic design of the armour. Additionally, smart functions are being integrated to further increase the efficiency of the body armour; eventually leading to reduced casualties.

Development of the protective panel

Target:

According to the end-users' requirements, as defined and validated through dedicated workshops and a questionnaire-based survey, the aim is to develop a protective panel that provides simultaneously Level IIIA ballistic resistance and Level 1 stab resistance according to NIJ 0101.4 and NIJ 0115.00, respectively, while having a maximum weight of 5,72 kg/m^2.

1. Textile substrates:

A series of protective, Kevlar®-based textiles, have been developed and evaluated for use in the protective panel. Following the assessment of their mechanical properties two fabrics have been selected to be further explored in the project: a plain woven Kevlar® fabric of 200 g/m2 and a 3D knitted fabric comprising Kevlar® outer layers and PET connecting filaments.

2. Surface treatments:

Aiming to enhance the protective properties of the fabrics on an areal density basis, various surface treatments have been developed and applied on the selected fabrics, including:

- Application of shear thickening fluids (SiO_2 based)
- Deposition of alumina coatings by thermal spraying
- Deposition of carbide or graphene-coated carbide particles along with PA nanofibers
- Application of crosslinkable, side-functionalized aromatic polymers
- Deposition of nickel or/and graphene by electroless metallization

3. Panel assembly

A series of protective panels were assembled by varying the type of fabrics and treatments, the number of layers and the assembly sequence. The panels were "designed" based on the results of preliminary stabbing and ballistic tests on stacks of 20 identical fabric layers, the flexibility of each type of treated fabric (given that to combine stab and ballistic resistance one needs to combine flexible and rigid regions in the panel), considering also the maximum allowable panel weight. Thus, 12 panels were prepared (comprising inner, core and outer sections of layers) by sewing the fabric layers at the four sides.

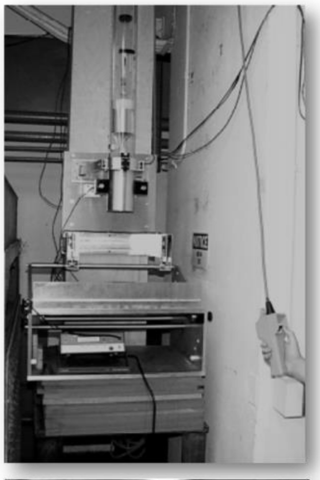
	Inner / Core / Outer	Weight (g/m^2)
1	12 untreated woven / 13 woven treated with graphene-coated carbide particles & nanofibers	5700
2	12 untreated woven / 13 woven treated with carbide particles & nanofibers	5700
3	7 woven treated with carbide particles & nanofibers / 21 untreated woven	5760
4	14 untreated woven / 1 3D knitted treated with STF / 2 woven treated with alumina	5620
5	16 untreated woven / 5 woven treated with alumina	5700
6	21 untreated woven / 3 woven treated with alumina	5700
7	16 untreated woven / 12 woven treated with crosslinked polymer	5720
8	18 woven treated with STF	5940
9	16 woven treated with nickel / 9 untreated woven	5910
10	14 woven treated with nickel and graphene / 9 untreated woven	5755
11	9 woven treated with nickel / 17 untreated woven	5715
12	9 woven treated with nickel and graphene / 16 untreated woven	5745

Testing the protective panel

Tests:

The above panels were subjected to ballistic and stab tests, according to NIJ 0101.4 and NIJ 0115.00, respectively.

	Ballistic test	Stab resistance test
1	-	Fail
2	-	Fail
3	Pass	-
4	Fail	Fail
5	Pass	Fail
6	Pass	Fail
7	-	Fail
8	Fail	Fail
9	Pass	Fail
10	Pass	Fail
11	Pass	Fail
12	Pass	Fail



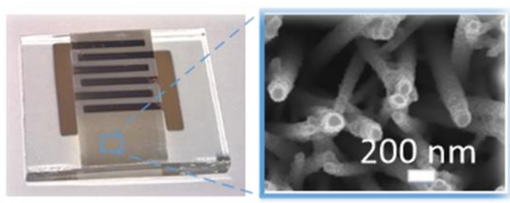
Conclusion and next steps:

The results reveal that so far it was not possible to develop a panel combining the targeted stab and ballistic resistance while maintaining its weight close to the limit of 5,72 kg/m². Several panels, however, passed the ballistic test. During previous trials, on the other hand, we had developed panels that passed the stab resistance test but had a weight of ca. 6,50 kg/m². Therefore, in the upcoming months, the consortium will focus on optimizing the panels structure in order to reach both protective properties with minimum weight.

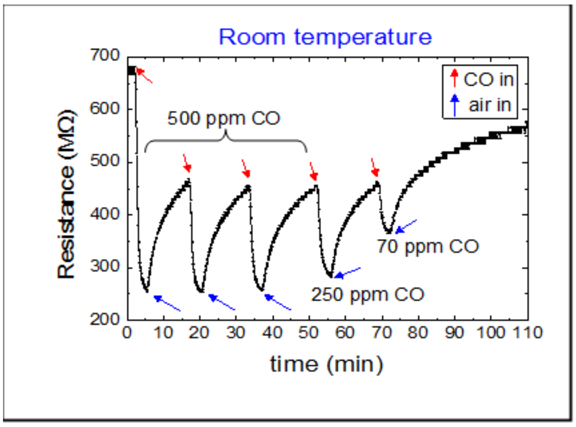
Smart Functionalities

Nanowire Gas Sensors:

ZnO nanowire arrays (NWs) with high aspect ratio and surface area have been prepared, in a controllable manner, by carefully adjusting the growth parameters. Devices for detecting carbon monoxide (CO) were evaluated for different gas concentrations various operation temperatures of the sensing medium. Particular attention was paid to the type substrate (conductive or insulating) and doping level of the ZnO NWs.



Decorating ZnO NWs by tin oxide (SnO_2) nanoparticles and optimizing their loading, we have managed to lower the detection temperature, even for CO gas concentrations as low as 70 ppm. As a result promising devices working at room temperature have already been realized and tested. In addition, the preparation of an experimental prototype to be integrated into the armor vest is in progress.



Heart Rate Sensors:

In order to obtain a good heart rate and ECG signal by using moss embroidered electrodes, the most relevant production parameters for the design of the electrodes have been investigated. Therefore, the number of layers, the material composition of the layers and the commingling feeding system were varied and a final design was found.

The signal of the ECG signal showed a constant high quality with fewer disturbances than other electrode types. The prototype of a so far ECG measuring undershirt was produced and used for further measuring. The next step is to connect the heart measuring sensor to the data processing unit and then send the data via textile antenna.

Textile Antennas:

The work on the design and textile production technology for the antenna has been finished and the evaluation of the HF characteristics of the textile antenna as well as the work on the antenna software has started. The high frequency characteristics of antenna prototypes were evaluated in an anechoic chamber as well as the influence of bending. Therefore, human tissue and humidity on the antenna performance were considered.

The software for the textile GPS antenna receives positioning data from the GPS satellites, which is interpreted by the GPS-Module. The positioning data is then transmitted to a laptop by a Bluetooth module. The antennas were integrated into an armour vest comprising electronics, battery and software. A field test was conducted comparing the textile GPS antennas to conventional GPS antennas and receivers.

Design of body armours

Throughout the course of the project, body armour manufacturers work closely with the end-users on the optimization of the body armours design. A series of body armour carriers have been developed as prototypes and presented to the end-users to receive their feedback and adjustments to previous designs are ongoing.

The latest prototype presented to the end-users in June 2016 consists of a full 360deg Modular Armour Carrier capable of holding 2 x 10”x12” hard armour plates, 2 x side plates and front and rear soft armour inserts. It can adopt on secondary protection Neck and shoulder Brassards and has the load carrying capacity to hold pouches front, sides and rear. It constitutes a wrap-around system for additional strength and comfort. This Combat Carrier has been developed with a quick release cutaway system that can be released in less than 5 seconds and can be reconnected in less than 30 seconds with the minimum of fuss, making this the most versatile combat armour carrier system ever with kinematics and load carriage characteristics. Rifle butt pad area on the shoulders and the front contour of the chest line has been cut and enhanced allowing for shooting accuracy, ease of rifle butt positioning and correct eye to gun sight relief. These cuts stop the user straining and pulling in the front armour carrier when holding a rifle in the firing position. The upper shoulders have 3 molle straps for the attachment of a communications system. The carrier has two double grab handles on the rear allowing for a two men lift making it easier to get the casualty out of trouble fast. A belt can be attached for additional pouches to be carried and in turn can be connected onto the carrier making it interoperable with each other.

For further information visit www.smartpro-project.eu
or contact us at: rnd@ebetam.gr or s.pavlidou@ebetam.gr

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