Smart fibres in forensics

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Abstract:

In a publication titled *„Smart fibres in forensics"* contains collected information on modern textile products such as smart textiles and their connection to special-purpose garments such as military or medical clothing. According to the literature, specialised modifications are quite often used in such clothing, giving the textiles special properties, for example, antiseptic, i.e. bactericidal and fungicidal. This publication presents the main applications of modified fibres and interesting areas of this field that in the future may pose a real challenge in the work of experts involved in the forensic analysis of textiles. Since the population of special-purpose „smart" fibres is quite rare, the evidence secured at the scene of the crime may prove to be very strong material evidence in the case, which seems to be particularly important for those collecting and analysing the collected research material.

Keywords: textiles, fibre, fibre modifications, bioactivity, bactericidal, smart textiles, medical clothing, military clothing; forensics

Introduction

Based on the available literature, it is known that the textile industry continues to thrive. Numerous studies are being conducted in many countries around the world to find new, efficient and low-cost ways to produce „smart" textiles, such as bioactive or environmentally benign textiles. The nuances of production and details of textile modification, e.g., bioactive materials, for the ordinary user/consumer are inaccessible and diligently guarded by patent secrets, nevertheless, the data clearly indicate that in the near future, the apparel industry will move towards increasingly better properties of textiles and knitted textiles, with the inclusion of features hitherto unknown, e.g., bioactive properties or three-dimensional graphics, and thus will be a real challenge in the forensic examination of micro-traces in the form of fragmented modified textile fibres.

The purpose of the article is to expand the knowledge, based on the latest literature, about the so-called smart fibres on the basis of changing technological trends, as well as to relate them to specific special-purpose clothing, such as military or medical clothing. The success of the analysis of micro-traces with potential evidentiary value depends to a very large extent on the correct detection and securing of them at the scene of the incident during the forensic inspection conducted, i.e. process-criminalistic activities, as defined in the Code of Criminal Procedure (CCP) in accordance with Articles 207 § 1 and 209, but also on the knowledge of the experts themselves who give opinions on micro-trace analysis studies. Therefore, awareness of the progressive changes and technological developments in textile products is necessary in ongoing forensic research. We know that sometimes the evidence is analysed only after a long period of time has passed since the criminal event, e.g. when new circumstances arise in the case, after many years, within the framework of the so-called X-Files. The results of the analysis of fibres of significant evidentiary value play a particularly important role especially in crimes against health and life and are the basis for findings, if only on the issue of *modus operandi* in the criminal-material sense, i.e. the manner of action and detection of the perpetrator. They also provide circumstantial evidence to help understand the behavior of the perpetrator or often reflect his individual characteristics and many times contribute to pointing out a clear answer, resolving doubts for the purposes of law enforcement or justice.

Modern weaving products – smart textiles

From the point of view of routine micro-trace examinations performed in police forensic laboratories, it is appropriate to devote a moment's attention to the subject of new-generation fibres and textiles called „smart". So what are smart textiles?

Extensive literature on the subject most often cites the definition according to which, a smart textile is a material that changes its properties in a controlled manner under the influence of external factors. Such material has the characteristics of a sensor, processor and actuator. As a rule, these systems respond to external factors such as heat, light, pressure and chemical changes by changing shape, colour, size, state of matter, absorbing solar energy, conducting electricity and light, and processing data. There must be three components in smart textiles, namely sensors, actuators and control units. E.g., the operation of sensors is ensured by the nervous system responsible for detecting signals. Some of the materials act only as sensors while others act as sensors and actuators. Smart textiles are a combination of textiles and electronics. Modified textile material and miniaturised electronic devices create a smart textile product, usually textile. Clothes made of this type of textile have a special function in various human life situations, depending on the design and application. The manufacture of smart textiles is currently one of the most intensively developing branches in the global industry, both textile and textile[1](Syduzzaman et al., 2015).

Raw materials used in the production of smart textiles

The plastics of our environment are „intellectualised", and thus their functionalisation required the use and combination of up to a dozen different components, with today's technology making it possible to achieve the same functionality by significantly reducing their number. Such materials, for example, can interact, communicate and „sense". Miniaturisation means not only producing smaller components, but also eliminating individual components. Mechanisms that previously had to be manufactured by combining different materials can now be made from one and the same component. An example of such a reduction in the number of components and materials used is, for example, a complex sensor system, with a piezoelectric film and mechanical keypad replaced by a special membrane. Nowadays, conductive metal threads such as textile yarns made of silver, stainless steel, carbon fibres with electrical properties are also frequently used. Threads coated with polymers, yarns, rubber and ink, on the other hand, can act as sensors or find use as bonding substrates. Pure metallic yarns can be made of composite stainless steel or a fine, continuous, conductive metal alloy.

There are the following types of connections between fibres and conductive materials:

- fibres filled with conductive material (such as carbon or metal particles),
- fibre coated with conductive polymers or metal,
- fibres spun with thin metallic or polymeric conductive threads.

Metallic silk, organza, stainless steel fibre, metal-coated aramid fibre, conductive polymer fibre, polymer coating and special carbon fibre are most commonly used for textile sensors. Metallic fibres, optical fibres and conductive polymers can be integrated into the textile structure, thus providing high electrical conductivity, sensing and data transmission capabilities. Organic polymers can replace inorganic crystals such as silicon. These materials tend to be lightweight, flexible, resilient, exhibit interesting mechanical properties, while being inexpensive and easy to process[2]. Metal threads, on the other hand, consist mainly of extremely thin metal fibres. They are usually produced by either pulling out a metallic bundle or cutting them off the edge of a thin metal sheet. Metallic threads and yarns can be knitted or woven into textile and used to create connections between components, while metals, which provide high conductivity, are less compatible and difficult to integrate into garments. Metallic threads tend to be heavier than most textile fibres, and their brittleness can cause damage to spinning machines over time, and they can also be a discomfort to the user due to their excessive tendency to abrade and delaminate.

Fig. 1. Metal yarns

Another novelty in the textile industry is arguably Angelina fibres, which are made from polyester, with

[1] http://textilelearner.blogspot.com/2013/04/applications-of--smart-and-interactive.html.

[2] http://textilelearner.blogspot.com/2013/04/applications-of--smart-and-interactive.html.

the addition of various metals such as copper, aluminium and silver. These fibres are distinguished by their intense luster and colour, as well as their holographic effect. They are characterised by easy air permeability, softness and ease of bonding with other fibres, while being very strong, anti-static, conductive and form an electromagnetic shield[3].

Fig. 2. Angelina fibres: optical and technical and hot melt

Fig. 3. Angelina fibres: optical and technical and hot melt

Optical fibres derived from plastic, on the other hand, can be easily integrated into textile material. They have the advantage that they do not generate heat and are insensitive to electromagnetic radiation. Fibre optics can perform many functions in a „smart garment": among other things, they can transmit data signals, transmit light necessary for optical sensing, detect deformations in textiles due to stress, and respond to chemicals. Polymer optical fibres can be woven into a textile material, but they are not flexible and therefore easily subject to permanent damage such as bending which can lead to mechanical damage and eventually loss of signal[4].

Fig. 4. Optical fibres

Electronic textiles

E-textiles, or electronic textiles, are among the innovative smart textiles that are also popular with users. These materials are electrically conductive due to appropriate surface modification and are ideal as data relays. Data is recorded and transmitted thanks to conductive pathways, diodes, detectors and electronic systems that respond to physical and chemical changes in the environment around the textile. Thanks to nanoelectronics, the sensors integrated into the textile are virtually invisible and undetectable. The field of e-textiles can be divided into two main categories:

- E-textiles with classical electronic devices such as conductors, integrated circuits, LEDs, OLEDs and conventional batteries embedded in clothing,
- E-textiles with electronics integrated directly into textile substrates. They can include passive electronics, such as wires and resistors, or active components such as transistors, diodes and solar cells.

Most e-textiles are hybrids, in which electronic elements embedded in textiles are combined with classical electronic devices or their components. Touch buttons, for example, are constructed entirely in textile form, with conductive, textile strands that are connected to devices, music players or LEDs mounted on braided, fibre-optic networks that form the structure of the displays. Timeless, then, is the claim of Pailes-Friedman of the Pratt Institute who said that „what makes smart textiles revolutionary is that they have the ability to perform many functions that traditional textiles cannot: communication, transformation, energy conduction and even growth".[5] (Grenda, 2016).

[3] https://meadowbrookglitter.com/angelina-fibre.

[4] http://textilelearner.blogspot.com/2013/04/applications-of-smart-and-interactive.html.

[5] http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile i s. 2019.

Nanotechnology in textiles

Nanoparticle coatings are increasingly being used in the textile industry because of their many advantages, which undoubtedly include enhanced textile performance and functionality. Standard methods of adding various substances to textiles to alter certain fibre properties produce effects that usually fade or completely disappear over time after repeated washing and long use. However, through the use of nanotechnology, unique special features can be achieved and textiles with high durability can be obtained. This is due to the high surface-to-volume ratio and high surface energy of the nanoparticles. Coating with nanoparticles can improve textiles with antimicrobial properties, their water resistance, provide UV protection and self-cleaning, while maintaining the textile's breathability and tactile properties. Nano-Tex is a technology that improves textile properties at the molecular level. It makes the textile resistant to moisture absorption, dirt adhesion, neutralizes electrostatic charges and allows for self-cleaning textiles. At the same time, the material retains its natural softness giving a feeling of comfort. It is more durable and practical, and the fibres breathe freely. Preventing staining ensures the textile looks nice and lasts a long time. The technology was inspired by the cleaning process of the leaves of certain plants, to which dirt simply does not adhere or is easily removed with the rain. Thanks to the use of nanotechnology, the textile has the ability to neutralize static electricity. Nano-Tex eliminates electrostatic interactions from the surface of the textile, and thus does not attract dust and dirt and increases the comfort of use. The textile retains its appearance, elasticity and air permeability(Syduzzaman et al., 2015).

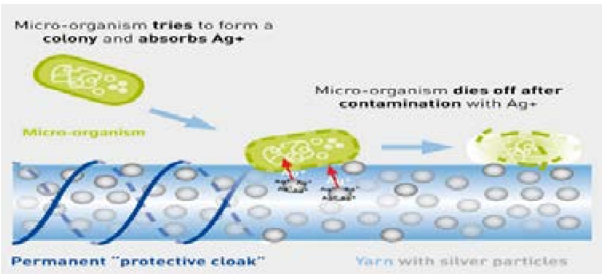

Fig. 5. Nano-Tex textile, principle of operation

An example of the use of nanotechnology is the C_change textile, a bionic climate membrane. It is a wind- and water-resistant membrane that responds to changes in temperature and activity. Depending on the situation, air permeability or heat retention increases or decreases, so that the textile always provides comfort. It mimics the way a fir cone responds to changing weather conditions by closing or opening (Grenda, 2016).

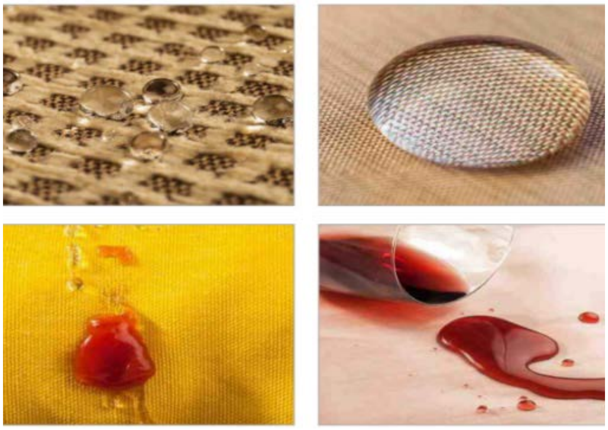

Fig. 6. Self-cleaning textiles

The hallmark of 3XDRY® textile is that it repels water and dirt on the outside of the textile and absorbs moisture on the inside. Clothes made from this textile provide a cooling effect and keep the surface of the skin dry, thus minimizing the appearance of visible sweat stains on clothing (Grenda, 2016).

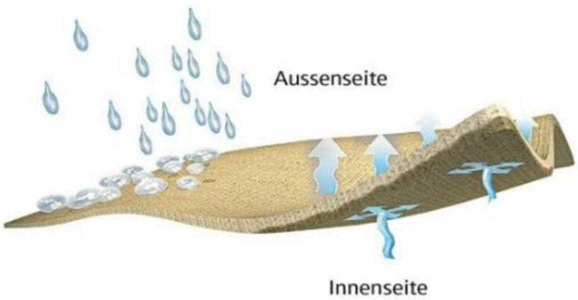

Fig. 7. Textile with comfort technology, principle of operation

As we know, dark colours heat up faster with direct exposure to the sun than light ones, because they absorb both visible and invisible beams of light rays. Coldblack® is a textile finishing technology that reduces the heating effect of dark colours. The textile remains cool to the touch even in bright sunlight and provides protection against ultraviolet radiation.

Fig. 8. Coldblack textile

Shape memory textiles

The real revolution was triggered by SMM (Shape Memory Materials) materials capable of changing shape, size or internal structure under the influence of a specific stimulus, such as a change in temperature, relative humidity, pH, the influence of an electric field, magnetic field, radiation, or the action of a chemical substance. During SMM activation (at a certain activation temperature), air gaps between close layers of clothing increase. This is to provide better insulation and protection from extreme temperatures and cold. In clothing, the temperature of the activated shape memory effect should be close to body temperature. There are thermoplastic polyurethane films that can be inserted between layers of clothing. When the temperature of the outer layer of clothing drops enough, the film reacts so that the air gap between the layers of clothing becomes wider. This out-of-plane deformation must be strong enough to withstand the weight of the garment and the wearer's movements. If the outer layer of clothing becomes warmer, the deformation should be reversed. Some metal alloys are capable of bidirectional activation induced by changing weather and varying physical activity[6]. Dutch designer Mariëlle Leenders is the author of Moving Textiles. With Nitinol wires woven into the structure, the textile shrinks and stretches. These textiles automatically unfurl when exposed to warm daylight and curl up when the temperature drops (Grenda, 2016).

Fig. 9. Moving Textiles

Colour-changing textiles

Colour-changing textiles, the so-called chameleon, offer a great deal of scope for creating extremely interesting visual effects, hence they are a fascinating field for designers of world fashion. The colour change of these products occurs under the influence of ambient temperature, light or electric current. For example, electrochromic textiles change colour when exposed to electric voltage, thermochromic textiles when exposed to temperature, and photochromic textiles when exposed to sunlight or ultraviolet light. Recently, a market hit is Fabcell textile module characterised by extraordinary flexibility, while it is non-light emitting and multicoloured. The fibres of this module are dyed with liquid crystal ink, and conductive yarns connected to electronic components are woven into a square textile. With increasing tension, the temperature of the textile increases, changing its colour. Square pieces of textile can be joined together to form a pixelated mosaic. The user can also assign a colour to each textile, controlling the colour by programming the microcontrollers. The system allows the user to easily construct and reconstruct garments without unnecessary interference[7] (Grenda, 2016).

Fig. 10. Fabcell – electrochromic textile

Designer Linda Worbin has done a lot of research into creating innovative smart textiles, which include textiles: Tic tac, Textiles and Rather Boring Table Cloth, printed with thermochromic and conventional inks, so that different patterns appear on their surface when exposed to heat, for example. The thermochromic dyes that make up the outer layer become transparent when

[6] http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile i s. 2019.

[7] http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile i s. 2019.

heated to about 30°, revealing the pattern printed with traditional pigments (Grenda, 2016).

Fig. 11. Thermochromic textile

Algaemy is a project exploring the potential of microalgae as a pigment used in textile printing, and consists of living, self-collected material. The result of a research collabouration between Blond & Bieber, and the Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), is a microalgae-based project developed to create environmentally friendly textiles. These colours are not resistant to light, so they change over time, unlike common chemical dyes. For example, the colour green becomes intensely blue, and light pink turns bright red and then orange. In this way, textiles convey their history based on exposure and use (Grenda, 2016).

Fig. 12. Algaemy textile – photochromic

Chromosonic is a programmable textile interface that changes its colour and pattern. The discolouration of the heat-responsive material changes dynamically in response to the processed sound files, which are transformed into heat energy, as well as through direct contact with the heat of the users' hands. Chromosonic explores how the world of digital media becomes tangible through textiles. The slowly changing textile responds to the surrounding environment with impulses and direct user interaction, demonstrating that digital interfaces need not be defined solely by illuminated glass planes[8].

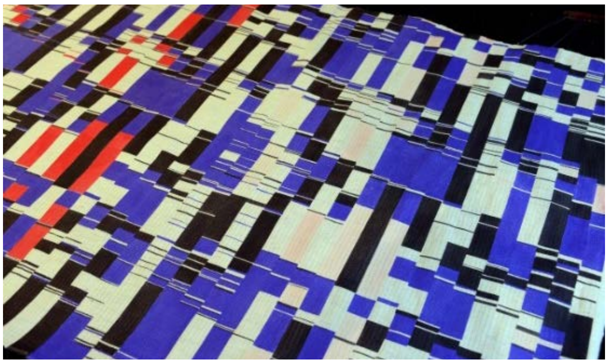

Fig. 13. Chromosonic textile

Light emitting textiles

Light-emitting textiles include electroluminescent textiles and photoluminescent textiles. Luminescence refers to optical radiation caused by electrical voltage, in the case of electroluminescence, and light exposure, in the case of photoluminescence. This technology makes it possible to achieve entire surfaces glowing with uniform light. Luminescent materials emit cold light, converting energy with virtually no loss, making them efficient. Light-emitting diodes (LEDs), organic light-emitting diodes (OLEDs) and electroluminescent films are the basis of electroluminescence technology. Photoluminescent surfaces glow due to light exposure. In the category of photoluminescent materials, fluorescent and phosphorescent materials are distinguished. In the case of fluorescence, the glowing effect disappears with the disappearance of the external light source, while phosphorescent materials continue to glow for many hours (Grenda, 2016).

Fig. 14. Photoluminescent textile

The use of smart textiles

Healthcare

The smart garment, which can be worn during daily activities, allows continuous monitoring of physiological signals. This is an interesting way to reduce medical visits. These garments can play an important role in the remote monitoring of patients who are chronically ill or

[8] transmaterial.net.

undergoing rehabilitation. It also promotes the concept of preventive health care. Given the current global demographics, there is an apparent need to shift the focus of healthcare delivery from treatment to prevention, and to promote and monitor health rather than disease diagnosis. SFIT is used for personal health monitoring and mainly includes monitoring of electrocardiogram and respiration (and access to other physiological and physical parameters depending on the target applications) through the use of sensors and textile electrodes. Examples of SFIT applications include:

- clothing with built-in textile sensor for continuous monitoring of ECG, respiration, EMG and physical activity. The smart textile includes a textile strain sensor based on piezoelectric resistance fibres and textile electrodes made of metal yarn,
- a vest containing fully woven textile sensors for ECG and respiratory rate recognition and a portable electronic card for motion assessment, signal pre-processing and Bluetooth connection for data transmission,
- a handy, sensitive garment that measures a person's heart rhythm and respiration using a three-wire ECG shirt. The conductive fibre optic mesh and sensors are fully integrated into the garment (e.g., smart shirt)[9].

Fig. 15. Smart shirt

The life belt (life belt) is a device designed to be worn by pregnant women, and is used for long-term monitoring of the health of the fetus and its mother. The life belt contributes to reducing the burden and increasing the efficiency of hospitals and the quality of services, moreover, by remotely monitoring the patient, it supports the work of gynecologists, and alerts during emerging deviations and anomalies such as fetal heart rate.

A life jacket, on the other hand, is a medical device worn by patients that reads blood pressure or monitors heart rate. The information is sent remotely via computer and monitored in real time by medical personnel qualified to do so.

Fig. 16. Lifejacket

Shape memory osteosynthesis clamps are used wherever osteosynthesis is performed with Blount clamps made of traditional implant metal. The advantage of shape-memory clamps over traditional Blount clamps is that they can achieve a tight and firm fusion of fractured bones. This allows for a fast and reliable course of treatment, especially of complex fractures and bone injuries.

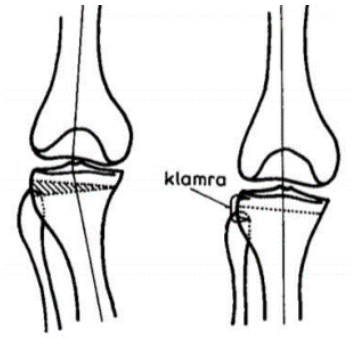

Fig. 17. Osteosynthesis clamps

The smart bandage, meanwhile, improves control over the wound by communicating problems as it heals, such as from an emerging infection. Developed by the Australian Science and Industry Community, the dressings consist mainly of fibres with an inner sensory layer, liquid crystal thermochromes. When illuminated with white light, the textile of the bandage shimmers in different colours due to the reflected light of the crystals, increasing the contrast of the core of the individual fibres. The fibre's colour gradient operates between 25 and 45°C, while the colour changes with temperature fluctuations as small as 0.5°C. A bandage can therefore indicate the emerging development of an infection, facilitate its diagnosis and

9 http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile

enable its rapid treatment by reducing other unnecessary actions[10] (Grenda, 2016).

Fig. 18. Smart bandage

Hygiene and comfort

Researchers at Philadelphia University have developed fibres and materials permanently impregnated with fragrances, which are used in the production of scented blankets, bedding or odorless gym outfits. The research team focused on solutions for athletes, but the concepts can be successfully implemented for textiles used in military applications, for example. The technology, developed by U.S. Air Force scientists, has already been used to produce shirts and underwear that remain hygienic for several weeks without washing, thanks to the attachment of nanoparticles to the fibre structure using microwaves. Nanoparticle-bound chemicals can repel water, grease and bacteria. This type of coating has an antibacterial effect and forces the process of liquids condensing and flowing down the surface. With an eye toward people battling bad eating habits, specialists at the Fuji Spinning Company, conducted research on textiles containing selected vitamins. Such clothing allows the body to absorb the daily requirement of a particular vitamin even after dozens of washings. Developed, the shirt also measures the level of UV radiation and, in cases of vitamin E deficiency in the skin, supplements it with the simultaneous application of enzymes that protect the skin from aging. For those who are active in sports especially in winter or during the hot summer, such as cyclists, active thermal clothing is a good option. Different knit structures tailored to the muscle system, provide the right microclimate, release moisture, and thus provide a pleasant feeling of freshness (Goss & Szubska, 2009).

Military use

In extreme environmental conditions and dangerous situations, there is a need for real-time information technology to enhance the protection and survivability of those exposed. Revisions in performance and additional textile capabilities have found application especially in professions such as defense forces and emergency services. Requirements for the aforementioned occupational groups are related to, for example, monitoring vital signs or mitigating injuries, as well as controlling environmental hazards such as toxic gas environments on an ongoing basis. Wireless communication with the central unit allows, for example, medics to carry out remote coordination of emergency medical units in the field and exchange information extremely quickly, which enables effective and safe work of rescuers, especially in situations and conditions particularly difficult, extreme, dynamic or unusual[11].

The vapor-resistant Self-Flexing Membrane artificial skin is an example of an innovative synthetic skin developed by scientists at the Max Planck Institute for Colloids and Interfaces. The membrane used in this skin is extremely sensitive to solvent vapors and quickly curls in the presence of acetone and other organic solvents. Its reactive film has an additional layered functionality: when it comes into contact with chemicals, its upper surface (perforated with small pores) stiffens as the lower layers remain soft, allowing the membrane to roll up directionally and thus detect vapours quickly. The self-sealing membrane has a faster response time than other known actuators and has been used in sensors, as well as in artificial mechanical skin and musculature (Grenda, 2016).

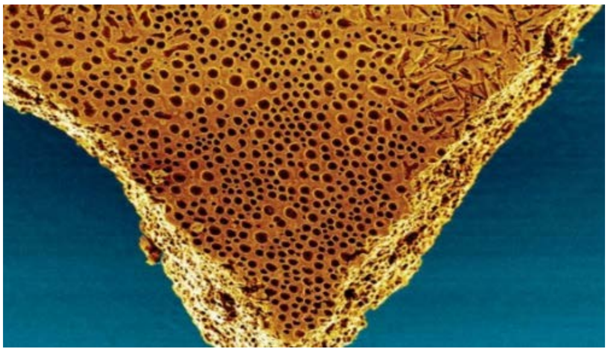

Fig. 19. Self-Flexing Membrane

Zetix is an auxetic material (a tendency for the material to change size) that is so mechanically durable that it absorbs and dissipates energy from explosions without breaking. Zetix combines expensive, high-performance materials with cheaper bulk components in a ratio of 1 to 100, highlighting in particular the properties of high-performance impact-resistant materials.

[10] http://textilelearner.blogspot.com/2013/04/applications-of-smart-and-interactive.html.

[11] http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile i s. 2019.

Zetix is used in many products, including armor, seat belts, windows, military tents, hurricane protection, dental sutures, and medical sutures that do not damage body tissue (Syduzzaman et al., 2015).

Sportswear

Sports enthusiasts can use integrated textile sensors and display panels to monitor heart rate and blood pressure during a workout at the gym or a morning jog, and are able to analyse performance information and use music to improve mood or performance. Some sportswear used for car and motorcycle racing, as well as astronaut suits, contain integrated electronic components[12].

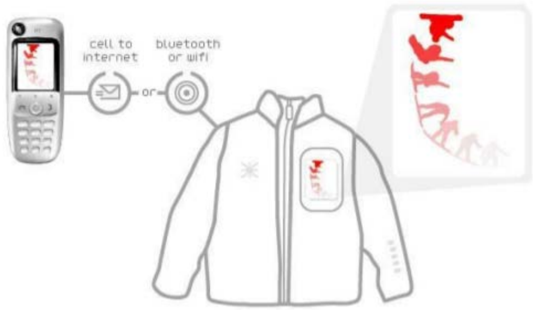

Fig. 20. Smart snowboard jacket

Heartbeat Hoodie is a hoodie with a built-in camera, allows you to automatically record the most important events of the day. The camera is controlled by a sensor that measures heart rate and excitement levels and in the event of an excited state of use and an accelerated heartbeat, photos are automatically taken. In this way, the camera independently recognizes and captures the most exciting moments of the person wearing the snowboard jacket.

Fig. 21. Phony Glove 16

The Phony Glove, a glove with a built-in headset, allows you to talk on your cell phone without having to hold it in your hand. Interestingly, the microphone is embedded in the little finger of the Phony Glove and the earpiece in the thumb, so you talk while holding your hand in a gesture position symbolizing the use of the phone (Goss & Szubska, 2009).

The fruit of Nike and Apple's collaboration is Nike+ technology, which allows a person to monitor, for example, calories burned while running and process the data using an iPod. The package includes a sensor and receiver. The sensor, along with the built-in battery, form a waterproof design. It is placed under the insole of the left shoe of the Nike+ running collection. A receiver connected to the iPod receives the information sent wirelessly from the sensor and then transmits it to the device. For example, GPS built into walking boots allows mountain rescue services to track users, and installed in ski jackets, helps locate users in case of avalanche threats. It can also be used to monitor the place where small children are staying. Gloves are also known to contain heating elements or built-in LED light-emitting diodes to distinguish and illuminate the cyclist while riding in the dark, making him visible to other road users thanks to them (Goss & Szubska, 2009).

Environment

Fig. 22. Dirt-absorbing jacket

Palladium chloride $PdCl_2$ is a compound used in carbon monoxide detectors and to test the corrosion resistance of stainless steel. Coloured ink containing palladium salt reacts to the presence of CO_2 in the atmosphere, undergoing a reversible colour change from yellow to black when the CO_2 concentration rises above a certain level. London-based fashion designer Lauren Bowker has developed a dye with $PdCl_2$ for use

[12] http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile i s. 2019.

in textiles and created a pollution-absorbing jacket that indicates the presence of carbon dioxide. Bowker's invention is part of a trend of growing awareness of global environmental risks, concerning not only greenhouse gas emissions, but also toxins directly affecting human health, resulting from, for example, second-hand smoke (Syduzzaman et al., 2015).

3D Printing

Fig. 23. Freedom of Creation Products

3D printing is revolutionizing and completely changing the way we think about creating textile products. The high cost of implementation means that this technique is not generally available, but it is attracting attention due to its immense possibilities. The current level of technology makes it possible to print objects from materials such as plastic, metal, wood, ceramic, rubber or even chocolate. 3D printing is not taken as an alternative to prevailing technologies, but is a new possibility and has unique properties. The possibility of having any products that perfectly suit our needs is very encouraging. A breakthrough in a world tailored to individual human needs is forecast.

Fig. 24. Spacer Chair

Dutch design studio Freedom of Creation, founded by Janne Kyttanen and Jiri Evenhuis in 2000, is a pioneer in 3D printing technology. Laser-printed textiles have opened up new possibilities in the production of textiles of the future. Instead of producing textiles with a yardstick and then cutting and joining them, finished products can be made to measure right away. It is very likely that in the next few years everyone will be able to have a 3D printer at home and print designs downloaded from the Internet on it themselves, but it is not expected to give these materials special properties (Bilisik, 2009).

3D textiles

Three-dimensional textiles are textiles that can be formed in the shape of a mesh, without additional reinforcement. 3D weaving allows the production of textiles up to 10 cm thick. Three-dimensional woven structures can form composite materials with fibre volume fractions of about 50% in both 3D units and 3D orthogonal structures (Bilisik, 2009). Three-dimensional textiles have a high deformability, meaning they can easily take the shape of a form for complex composite designs. There is no need for layering, as the single textile has a substantial thickness that provides full three-dimensional reinforcement. The 3D textile can be molded into various shapes and can be used in biological applications to create tissue replacements (Campbell, 2004). Three-dimensional textiles are attracting the attention of a growing number of designers and users. The advent of new textile-making technologies has allowed the development of spatial textiles. They are used in automotive, sports, insulation materials and fashion. Three-dimensional structures can be achieved using weaving, knitting, embroidery or composite materials (Grenda, 2016).

Of interest is the spacer textile, which is a 3D textile consisting of two layers of textile interwoven with flexible synthetic fibres. The special vertical arrangement of these fibres forms the core and provides excellent stress distribution and ensures good ventilation. It was used in the prototype of the Spacer Chair for Droog Design. It is made of fibreglass, nylon spacer textile and polyester resin. The design takes advantage of the characteristic flexibility of spacer textile, creating a soft form that is then hardened with resin. The rigidity of the form is also given by the use of two layers of textile made using the double weaving technique used in the production of carpets[13].

3D nonwoven polyester is a lightweight, expandable 3D textile system that provides visual impact with minimal material use. Made of 100% non-woven polyester, this flexible textile can be used in a variety of residential or commercial applications where rich visual texture is required. The material can be used as a shading

[13] https://www.droog.com/project/spacer-chair-next-architects-samira-boon (accessed January 2019)

device, space divider, light diffusion panel or screen for rapidly reconfigurable spaces[14]

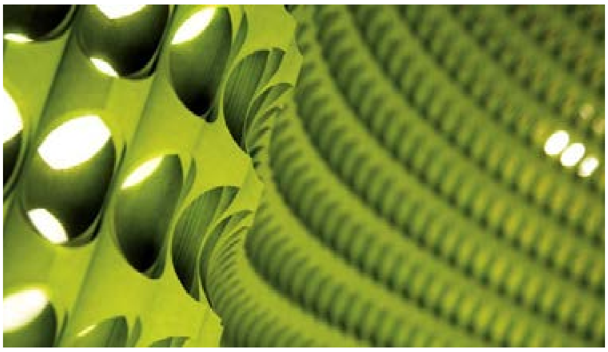

Fig. 25. 3D nonwoven polyester

3D textiles is a fairly new and interesting area suitable for research, as the number of publications on the subject is negligible. At the moment there are no proposals to give 3D textiles antiseptic properties, but in the future this possibility cannot be ruled out either.

Conclusions

The knowledge collected and compiled, based on an extensive literature review, made it possible to present textile products hitherto rarely encountered in forensic practice, which can appear in the laboratory at any time as an order in a specific case. The discussed examples of modern textile products from the group of smart materials pay special attention to their diverse, often unique characteristics and unusual purpose of the product. Such products as evidence, in the form of contact micro-traces, can be a formidable challenge for experts due to their type, quantity and quality, imposing the need for a non-routine approach to the submitted traces in order to use them effectively in unraveling the case. The evidentiary value of transferred forensic traces in the form of single fibres or fragments of smart textiles can be crucial in ongoing criminal proceedings, due to their unusual colouring or specific properties and modifications towards, for example, personalisation of the perpetrator's or victim's clothing, which is worth bearing in mind.

Source of figures:

Fig. 1, 4, 16, 18: http://textilelearner.blogspot.com/2013/04/applications-of-smart-and-interactive.html.
Fig. 2, 3: https://meadowbrookglitter.com/angelina-fibre.
Fig. 5, 22: Syduzzaman, M., Patwary, U., Farhana, K., Ahmed, S. (2015).
Fig. 6, 7, 9, 11, 12: Grenda, M. (2016).
Fig. 8: www.schoeller-textiles.com
Fig. 10: http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile, Grenda, M. (2016).
Figs. 13, 14: transmaterial.net.
Fig. 15: http://www.lighting.philips.com/main/systems/lighting-systems/luminous-textile
Fig. 17. Ćwikła, 2008
Fig. 19: transmaterial.net
Figs. 20–21: Goss & Szubska, 2009
Fig. 23: https://www.trendhunter.com/trends/freedom-of-creation
Fig. 24: https://www.droog.com/project/spacer-chair-next-architects-samira-boon
Fig. 25: https://www.aleksandragaca.eu/

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