AN OVERVIEW ON FAR-INFRARED FUNCTIONAL TEXTILE MATERIALS

OVIDIU IORDACHE, ELENA CORNELIA MITRAN, IRINA SANDULACHE,
MARIA MEMECICA, LUCIA OANA SECAREANU, CRISTINA LITE, ELENA PERDUM

*National R&D Institute for Textile and Leather, Lucretiu Patrascanu 16,
Bucharest, Romania, office@incdtp.ro*

The present study was aimed at highlighting the applicability of novel generations of functional textile materials based on incorporation of safe, pyroelectric nanoparticles into fibers. The synthetic fibers with negative ions emitting properties contain semiprecious stone particles (tourmaline, monazite, opal), ceramic, charcoal, zirconium powders, aluminum titanate and mixtures of such minerals. Currently, the synthetic fibers generating pyroelectric effects are obtained by introducing minerals (e.g. superfine tourmaline powder) into melted polymers before spinning or by dispersing the minerals into the spinning solution. As polymers, polyethylene terephthalate, polyvinyl acetate, polyamide and viscose have been used. In low quantities, these minerals have almost no effect on human health. Included in large quantities, they tend to be too expensive (tourmaline, opal) and the fibers become harsh and fragile. The current generation of FIR functional textile materials faces a series of technical challenges: some of the of the used compounds are radioactive (monazite); if the particles size is too large (0.2-0.3µm), it may result in the production of highly non-uniform fibers and early wear of the mechanical parts producing installation; most of commercial pyroelectric fabrics emit a low amount of negative ions (500-2600 anions/cc) and FI rays, inducing a low health effect. Clinical studies involving exposure to pyroelectric compounds have highlighted positive effects on: blood circulation, skin cell re-vitalizing, collagen and elastin production, sleep modulation, wounds healing and acceleration of micro-circulation, chronic pain management, improvement of vascular endothelial functions, atherosclerosis and arthritis affections etc.

Keywords: far-infrared, textiles, functional

INTRODUCTION

Discovered in 314 BC by Theophrastus, pyroelectricity has been used from ancient times, to heal a variety of diseases, such as anxiety, sleep disorders, cellulite, rheumatism, cardiac problems, brain dysfunction, bacterial infections, reduction of inflammation & oxidative stress, improvement of endothelial function, increase of blood circulation and lymphatic flow, and even cancer (Lang, 2011). Such functional textiles, consist of synthetic fibers, emitting Far-Infrared-Rays (FIR), based on negative ions emitting particles, from se semiprecious stones (tourmaline, monazite, opal), ceramic powders, charcoal, zirconium, aluminum titanate and mixtures of such minerals. Currently, the synthetic fibers generating pyroelectric effects are obtained by introducing minerals (e.g. superfine tourmaline powder) into melted polymers before spinning or by dispersing the minerals into the spinning solution (Taekyung *et al*., 2020). As polymers, poly(ethyleneterephthalate), polyvinyl acetate, polyamide, viscose is widely used. Due to the growing health awareness and fitness activities, the global sports apparel market is estimated to generate about $184.6 billion by 2020-2021, registering a CAGR of 4.3% during the forecast period 2015-2020 (Allied Market Research). The work-related stress and lifestyle disorders generate a growing demand of fashionable sports apparel to maintain or improve the health state. When heat of about 37°C (normal body temperature) is applied to the far-infrared radiation, light energy in the range of 6 to 14µm causes resonance within constitutional molecules of the human body, by radiation, leading to molecular movement within the substrate, which is further converted into thermal energy, enhancing metabolism functions (Dyer, 2011).

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PYROELECTRICITY

Pyroelectricity is the ability of certain materials to generate an electrical potential when they are heated or cooled. As described by Lang, pyroelectricity is the manifestation of the temperature dependence on the spontaneous polarization of certain solids which may be either single crystals, or poly-crystalline aggregates (Lang, 1974). Pyroelectricity provides one of the best performing principles for the detection of temperature changes. Pyroelectric crystals, ceramics of ferroelectric materials, as well as polymers, have therefore been used since the 1960s in thermal infrared (IR) detectors, joining the earlier thermal IR detection techniques of bolometers and thermopiles (Muralt, 2005). FIR induces strong vibrational and rotational and effects at molecular level with the potential to be biologically beneficial, based on the ability of penetrating skin barrier and the underlying tissues (Figure 1), and generating heat by vibration of various structural components (fat molecules, subcutaneous proteins, water molecules).

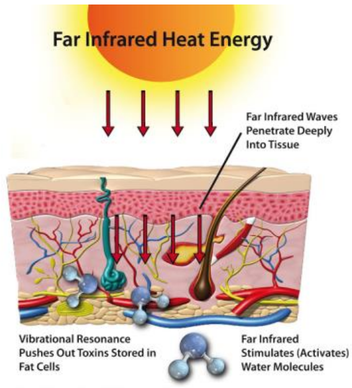

Figure 1. Representation of FIR penetration through skin (Source: www.innovationintextiles.com)

Far-infrared rays (Figure 2) increase the temperature of absorbed materials by inducing thermal energy through radiation (emission), penetration, and resonance absorption caused by the vibration of molecules among electromagnetic waves, leading to vibration of both electric and magnetic fields at the same time.

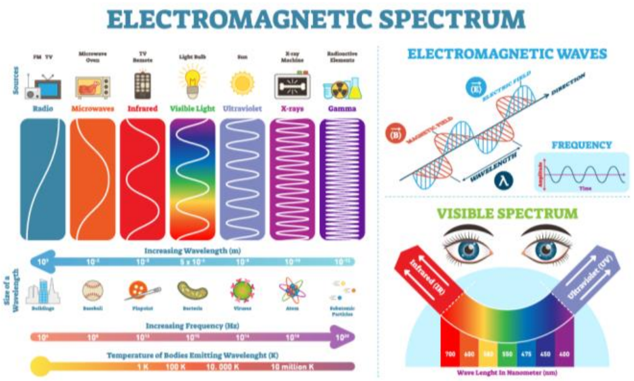

Figure 2. The electromagnetic spectrum (Source: www.muellersportsmed.com)

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FAR-INRARED FUNCTIONAL MATERIALS

Pyroelectric materials are functional materials that can generate an electrical response upon a temperature change. Modern solutions often include a combination of polypropylene and special lead-free bio-ceramics, to create special FI functional garments, which are materialized into already commercially available products, such as socks, cushion, undergarments, knee pads, trousers, bedspread, bedding and shoulder pads etc.

Functionalization materials of FIR functional products consist of a wide range of inorganic bioceramic compounds, such as: bamboo charcoal, pearl powder, tourmaline, carbide-based materials (ZrC, SiC), oxide-based materials (magnesium, zirconium, alumina, various iron oxides, germanium), photocatalytic compounds (TiO_2) (Best *et al*., 2008), which confer controlled infrared radiation (Figure 3).

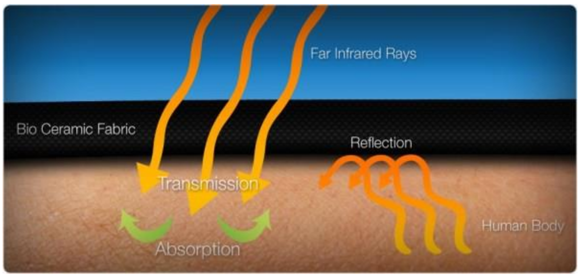

Figure 3. FIR garments functioning principle (Source: www.evidentlyhealthy.com.au)

Commercial solutions are offered by several companies, such as: Hologenix, being one of the first companies to market FIR textiles, with their Celliant products, which satisfy several criteria that regulate medical devices (Figure 4); PUMA, with its line of men’s athletic apparel; French company, HT Concepts, being one of the first to create such materials, by mixing over 30 metallic oxides (from volcanic rocks) in a breathable polyurethane binder which can be coated, laminated, or printed on a fabric to reflect FIRs back to the body; titanium-mineral mix based garments, from Swiss company Schoeller; Chinese company Voll Will Enterprise, with its FIR-SKIN line of products, boasting a wide range of products, with knitted textiles infused in liquid titanium and graphite and patented bio-ceramics FI particles, such as their 3-layer edition of T+Polar product (Figure 5).

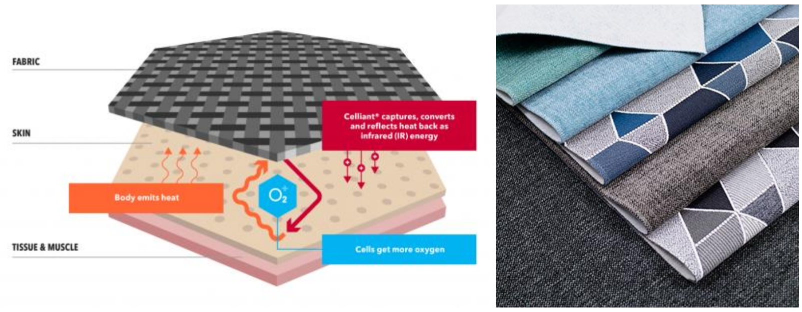

Figure 4. Celliant materials technology (by Hologenix) (Source: www.celliant.com)

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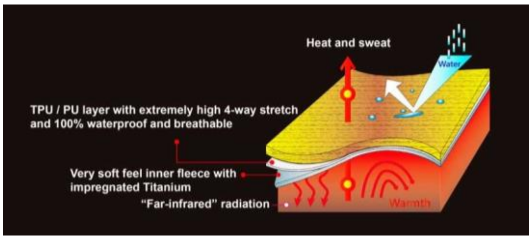

Figure 5. FIR-SKIN 3-layer edition of T+Polar (by Voll Will Enterprise) (Source: www.fir-skin.com)

Other commercially available solutions are offered by companies like: Under Armour – Athlete Recovery Sleepwear; Solvay – Emana line of products; NILIT – Nilit innergy functional materials; Toyobo – Ceram A (Figures 6-9).

Figure 6. Athlete Recovery Sleepwear by Under Armour (Source: www.underarmour.com)

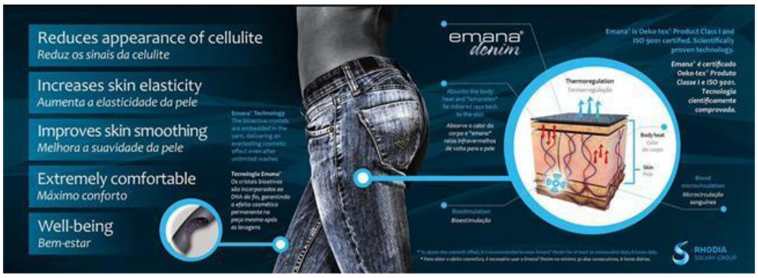

Figure 7. Emana by Solvay (Source: www.solvay.com)

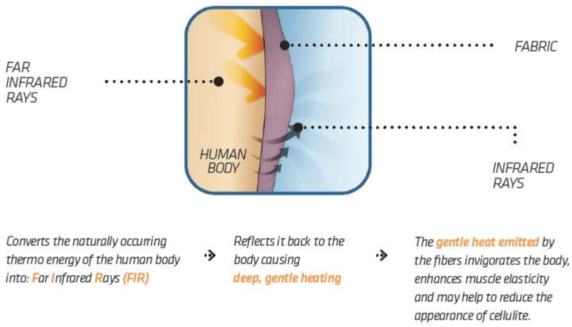

Figure 8. Nilit innergy by Nilit (Source: www.nilit.com)

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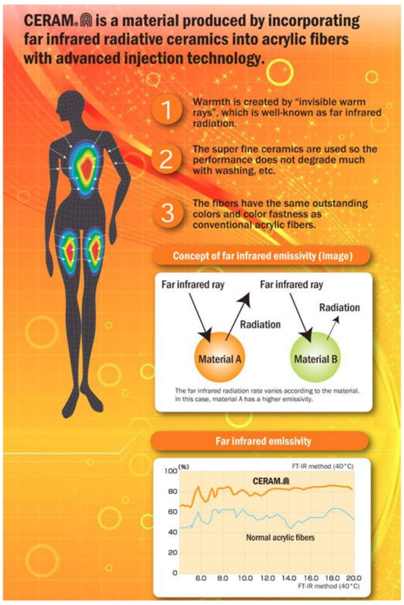

Figure 9. Ceram A by Toyobo (Source: toyobo-global.com)

The base principle for FIR functional textiles is based on two ways mechanism, once by are absorbing energy, from sunlight, and then radiate this energy back onto the body at specific wavelengths, and second, by being activated by the body's dissipated heat energy (Song *et al*., 2020). Thermophysiological comfort is affected by many factors, such as fiber type, yarn properties, fabric structure, finishing treatment (Sankauskaitė *et al*., 2020). In order to obtain highly efficient functional materials, manufacturing process tends to be extremely complex, as in low quantities, the properties inducing compounds have almost no effect on wearer's health, which leads to emission of a low amount of negative ions quantity (500-2600 anion/cc), inducing a low, if any, health effect. Included in large quantities, they are too expensive (tourmaline, opal) and the fibers become harsh and fragile. Many of the used compounds have radioactive potential (monazite) (Lapidus and Doyle, 2015). Also, if the size of particles is to large (more than 0.2-0.3 µm), this will lead to obtaining of highly non-uniform fibers and early wear of mechanical parts of a textile production facility. Low cost technologies, such as polymer melt blending techniques used to incorporate minerals in nylon and poly(ethyleneterephthalate) fibers, may prove difficult to implement, due to the poor particle dispersion and weak mechanical characteristics of the fibers. Consequently, the main technical challenge is the need to efficiently blend the polymers and particles into the polymer matrices.

National R&D Institute for Textile and Leather, INCDTP Bucharest, is running an Eureka Traditional research project, entitled "Far Infrared Rays and Anion Releasing Fabrics", acronym FairTex, consisting of six partners, from Romania and South Korea. The main objective of the project is the development of new textiles providing health and wellbeing to the users based on tailored multi-functional nanocomposites generating negative ions and far infrared rays and, protecting humans against UV-rays and microbial infections (Figure 10).

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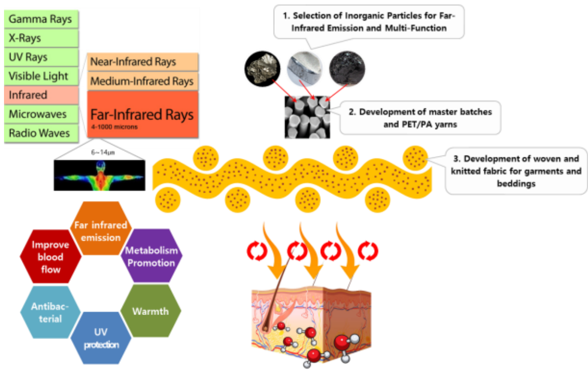

Figure 10. Overview of FairTex project

CONCLUSIONS

FIR functional textile may represent the future for alternative therapies, as they have great health benefits of FIR, ranging from regulating body heat, restoring physical function, muscle pain relieving, arthritis pain management, bronchitis etc. Even though health benefits of far infrared rays (FIR) and anion releasing fabrics are demonstrated throughout several studies, these are relatively new materials, with great potential applicability towards treatment of numerous and various health conditions.

Acknowledgments

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