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Review Article

Analysis of Biomedical Smart Textiles

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Abstract *- This article summarizes the knowledge gleaned from technical and scientific literature on smart textiles used in the medical field, with a view to identifying emerging technologies, solutions, and products in this area. This summary aims to highlight avenues for research and development to better leverage smart textiles applied in healthcare, in order to identify limitations and propose hypotheses for improvement. Biomedical smart textiles combine traditional fibers and sensors/actuators to monitor, diagnose, or assist human health. Additive manufacturing, which is the third industrial revolution after computing, is of paramount importance in textiles because it reduces the loss of manufacturing materials. However, it remains poorly understood in the field of sustainable biomedical textiles. Researchers in this field can focus their thinking on the manufacture of sustainable, bio-based, and biodegradable smart textiles that contribute to human health and well-being.*

Keywords *- Smart textiles, Biomedical, Additive manufacturing, Analysis, Smart Bio-Textiles.*

1. Introduction

Functional textiles in healthcare can be used to prevent infections, as well as improve comfort and enhance safety in hospitals, homes, and other settings [1, 2]. They can also be curative measures used in healthcare [3]. They appeared on the market in 2004 in collaboration with Levi's and Philips, two brands that developed a jacket with a built-in MP3 player and cell phone [4]. During the same period, the chemical industry made it possible to functionalize fibers to give textiles new properties [5]. Next, the miniaturization of electronic components has made it possible to integrate them into clothing. Finally, certain textiles have now become electronic circuits thanks to improvements in manufacturing processes and the integration of conductive materials at the microscopic level within the threads. All these advances have enabled clothing to go beyond its initial role of protecting against the environment, allowing environmental parameters to be measured and analyzed in order to provide an appropriate response or take appropriate action [5].

Smart health textiles represent a convergence between electronics, biomaterials, and textiles, enabling real-time patient monitoring, prevention, and improved user experience [1]. These textiles fall into several categories depending on their level of sophistication: passive fabrics, which offer protection without human intervention, such as UV-protective fibers or antibacterial coatings; active fabrics, which react dynamically to environmental stimuli using thermal sensors, miniaturized actuators, or conductive fibers to regulate temperature or change shape; and ultra-smart fabrics, which incorporate sensor networks, microprocessors, and embedded algorithms to monitor physiological parameters, adapt their response in real time, and transmit complex data to connected platforms[6]. With the advent of sustainable development, the biodegradability of biodegradable and bio-based textiles has become essential. However, there are two main sources of textiles (textiles made from natural fibers taken directly from nature and chemical fibers that can be produced by chemically processing natural base materials before being produced in the form of filaments (artificial textile fibers) or from simple components that are extracted, assembled, and rearranged by polymerization (by addition or condensation) before being spun (synthetic fibers) [6-8]. Synthetic textiles are not biodegradable and are widely used in the field of smart textiles. This work examines sustainable smart textiles (biodegradable and bio-based) in the field of health. It allows us to examine and promote the use of green and biodegradable materials in the combination of functional textiles and environmentally friendly sensors. Its mission is to highlight what remains to be done in the field of biodegradable smart textiles.

2. Methodology

2.1. Data Collection and Synthesis of Knowledge on Smart Bio-Textiles in the Field of Health

A summary of knowledge on smart bio-textiles (plant and animal) has been compiled from scientific articles, patents, and industry reports on the subject. It covers innovations from the last 10 years, clinical applications, and the integration of sensors into textiles.

In particular, a specialized search engine (Google Scholar) and an academic social network (ResearchGate) provided access to scientific and technical journals dealing with the subject of smart bio-textiles (International Journal of Current Research, Polymer Bulletin, Buletinul Institutului Politehnic din Iași publicat de Universitatea Tehnică Gheorghe Asachi din Iașissrg, Journal of Textile Science and Technology, International Journal of Polymer and Textile Engineering, International Journal of Current Research, Laboratoire de Microbiologie, 8 avenue Rockeffer, 69373 Lyoncedex, Environmental Engineering and Management Journal). A series of keywords was used to conduct this information search. These keywords are:

Functional textiles
Smart textiles
Smart organic textiles
Healthcare sector
Smart animal textiles
Smart plant textiles

2.2. Inclusion Criteria

The research studies included in this meta-analysis are those dealing with or relating to smart bio-textiles in the field of health (bio-based fibers, functional textiles, integration of biometric sensors, applications in health and/or the environment, and additive manufacturing or 3D printing). The studies used are original studies, systematic reviews, scientific conference proceedings, and theses.

2.3. Exclusion Criteria

The works that were excluded from this meta-analysis are articles and theses that discuss non-intelligent artificial or synthetic textiles, non-functional plant-based textiles, and functional textiles that are not in the field of medicine or healthcare.

3. Results and Discussion

A total of 150 studies provided accessible results, but only 25 presented usable numerical data, i.e., those dealing with or relating to smart bio-textiles in the field of health (bio-based fibers, functional textiles, integration of biometric sensors, application to health and/or the environment, and additive manufacturing or 3D printing) (Figure 1).

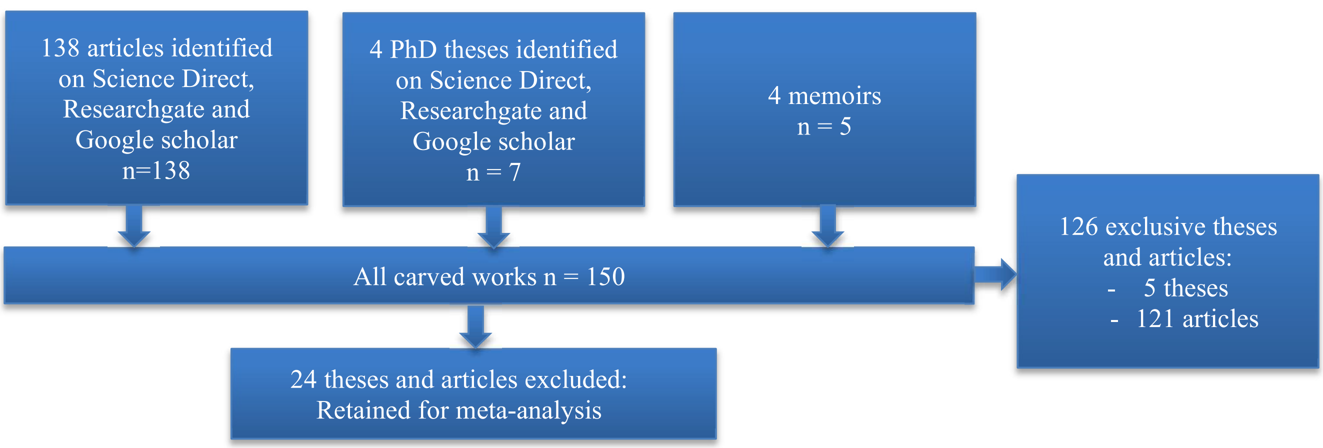

Fig. 1 Flow Chart of articles, theses, dissertations, and patents included in the study

3.1. Integrated Technologies

Smart biomedical textiles are materials capable of monitoring, protecting, or interacting with the human body through the integration of sensors, functional fibers, and communication systems. They pave the way for active thinking, medical monitoring clothing, and flexible implants, but still pose challenges in terms of biocompatibility, reliability, and regulation. Smart bio-textiles combine bio-based fibers (derived from plants, algae, and even zoology) with interactive technologies (sensors, connectivity, self-regulation) to create durable, responsive fabrics that can meet certain physiological, hygienic, and health needs of humans. They mark a convergence between ecology, performance, and digital intelligence. In healthcare, textile innovations are driven by the imperatives of sustainable development, digital intelligence, and advances in materials science. Table 1 summarizes the overall role that sensors play in smart textiles today. In an article, Balkis examines the role of smart textiles in transforming the healthcare environment. He concludes that smart textiles improve patient comfort, safety, and satisfaction. However, he did not evaluate the materials used to manufacture smart textiles [1]. This analysis shows that the use of smart textiles in the medical field is evident despite the cost of manufacturing and the availability of manufacturing materials. The use of biodegradable materials, i.e., sustainable materials that promote the rational use of nature, knowing that there will be a future generation, as recommended by the 1992 Rio de Janeiro Congress in Brazil, remains little known in this sector [9-10]. Table 1 presents the application and role of smart textiles in healthcare.

Table 1. Application and role of smart textiles in healthcare

Application	Function	Impact	References
Bioactive dressings	Controlled release of antibiotics	Reduction of hospital-acquired infections	[1 ,5]
Connected clothing	Integrated sensors for electrocardiogram (ECG)	Home patient monitoring	
Implantable textiles.	Biodegradable sutures	Optimized healing	

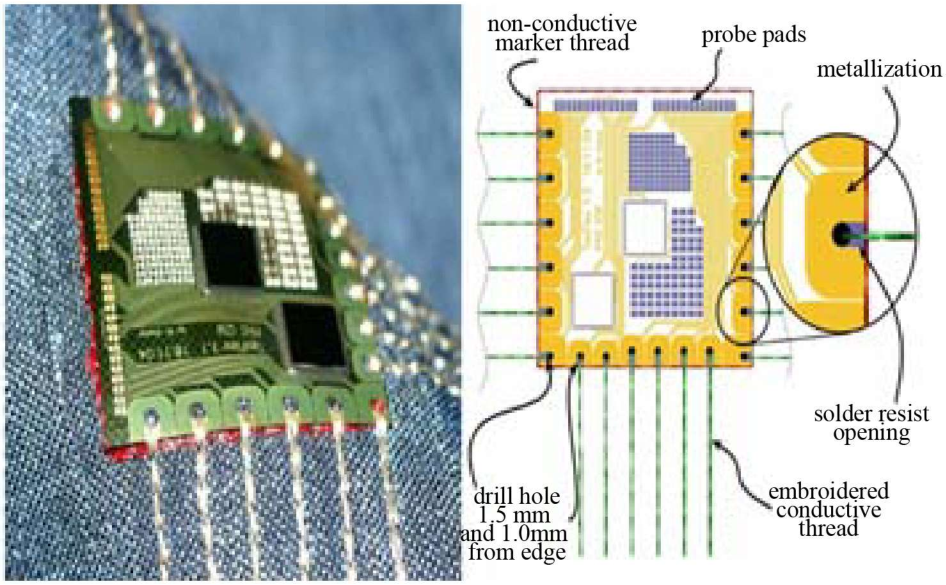

Fig. 2 Functional circuit of smart textile [9]

Table 1 highlights smart textiles in the healthcare sector. It shows several impacts of smart textiles in reducing hospital-acquired infections, monitoring patients at home, wound healing, and even prevention. Figure 2 shows the electronic circuit in the textile. It also shows the importance of electronics and nanotechnology in the textile industry.

With environmental concerns in mind, biodegradable biometric sensors capable of recognizing biological characteristics (fingerprints, irises, heart rate) are incorporated into organic textiles, which are designed using compostable and biodegradable materials, thereby reducing their environmental impact (Figure 2). Textiles with biometric sensors can regulate temperature. This technology is expanding into bio-textiles that monitor heart rate and even diabetes. These biometric sensors are also used in color-changing textiles adapted for health prevention. For example, in the case of diabetics, a red color change indicates hyperglycemia (above 1.26 g/L) or hypoglycemia (below 0.70 g/L), while green indicates normal blood sugar levels between 0.70 g/L and 1.10 g/L.

Table 2. Additive manufacturing applied to biomedical textiles enables the creation of flexible

Scope of Application	Benefits	Limitations or Challenges	References
Physiological monitoring	Continuous, non-invasive measurement, better patient compliance	Complex calibration, interference, and sensor durability	[1,5]
Rehabilitation and mobility	Real-time feedback, movement tracking	Social acceptability, thermal comfort	
Prevention & public health	Early detection (falls, cardiac abnormalities), reduction in hospitalizations	High cost, lack of standards	
Patient experience	Discreet fabric enhances dignity and independence	Need for broad clinical validation	

Additive manufacturing applied to biomedical textiles enables the creation of flexible, customized structures for regenerative medicine, implants, and healthcare devices. It combines biomaterials, hydrogels, and fibers to produce functional fabrics tailored to clinical needs.

3.2. Fibers and Materials

Antimicrobial (antibacterial, antifungal, antiviral) and anti-arthropod textiles are available on the market in all forms of clothing, interior decorations (tablecloths, curtains, bedding), and packaging that we use [10-,13]. Antimicrobial textiles are textiles that inhibit microbes. They are found, for example, in towels, cotton medical bandages, and washable sanitary pads [12]. There are chemical antimicrobial treatments for textiles [13]. by several methods (sol-gel process, microcapsule treatment, bulk polymer treatment, treatment of fibers and fabrics with binders, and simple deposits of chemicals such as silver, copper, and zinc, silver, copper, and zinc salts, silver and copper oxides; zinc sulfide, ceramics and zeolites loaded with metal salts, boron derivatives, halogenated derivatives, Polyhexamethylene oxidants, biguanide (PHMB), quaternary ammonium compounds and derivatives, phenolic derivatives, halogenated diphenyl ethers, nitrated and sulfurized heterocyclic compounds: isothiazolinone, benzothiazole, pyrithione, organic acids, aldehydes, carbamate and arsenic derivatives [12, 14]. Antimicrobial active ingredients can be natural, deposited, primed, dissolved, fused, microencapsulated, grafted (radiochemical), grafted (chemical), [10, 13]. Today, with the advent of sustainable development, biodegradable textiles such as plant-based textiles like cotton, ramie, linen, *Sida rhombifolia,* and animal-based textiles like silk and wool are to be considered over non-biodegradable textiles such as synthetic textiles like polyamide, polyester, and polyacrylic, as well as certain mineral-based textiles such as asbestos [12-18]. The field of textile chemistry is predominant because there are antimicrobial chemical textiles and natural textiles that have acquired antimicrobial properties through synthetic products.

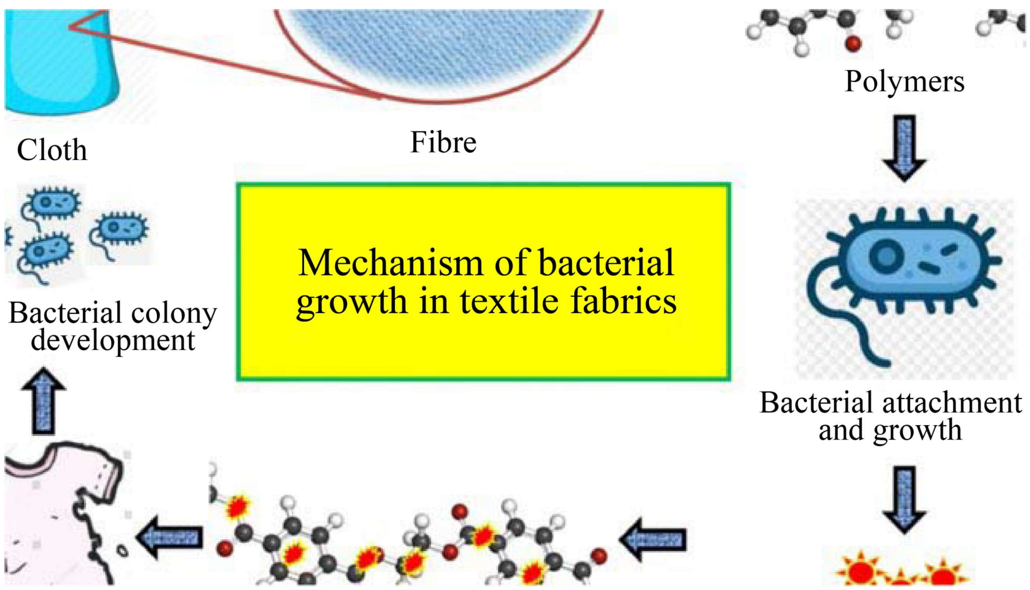

Fig. 3 Protection of fabric polymer from bacterial cell attachment is crucial in avoiding their growth, and the presence of an antibacterial agent in these polymers will inhibit their growth. Antibacterial agent [11]

The textiles used in medicine are nonwovens obtained by melt blowing, wet spinning, or dry spinning, and fabrics (textiles obtained by interweaving warp and weft threads) of natural, synthetic, or artificial origin treated with chemicals. Natural knits impregnated with natural products remain little known in the fight against parasitic arthropods and are still at the laboratory stage for the fight against microbes [19]. Natural textiles that repel arthropods or are treated with natural products are still relatively unknown. However, in today's world, where protecting nature is a priority, natural textiles treated with purely natural products are the focus of global attention. Several anti-arthropod substances have been proposed, namely: Neem, citronella, oil, and aloe vera, which have been tested in textiles on a laboratory scale with convincing results [15]. They must be the subject of clinical studies with a view to contributing to the major environmental challenges posed by climate change, which could be a new source of economic growth. This would limit the production of pyrethroids, which is achieved through an exothermic reaction involving the substitution of hydrogen in alkanes with one or more halogens (chlorine or bromine) or through an addition reaction involving halogens requiring catalysts for alkenes and alkynes in the case of anti-arthropod parasites. Table 3 shows a comparative study between bio-based smart textiles and conventional smart textiles[15-20].

Bio-based smart textiles stand out for their ecological and medical dimensions, seeking to combine technological innovation and sustainability, whereas classic smart textiles are more widespread and diverse, but remain heavily dependent on synthetic materials and pose environmental challenges.

3.3. Three-D Printing in Biomedical Textiles

Additive manufacturing applied to biomedical textiles makes it possible to create flexible, customized, and biocompatible structures, ranging from implants to artificial tissues. It combines polymers, bio-based fibers, and bio-inks to develop customized devices tailored to patients and climatic needs [15, 18].

Fig. 3 Three-D printing or additive manufacturing of a shoe [15]

Additive manufacturing, which is the third industrial revolution after computing, is of paramount importance in textiles because it reduces the loss of manufacturing materials. However, it remains little known in the field of sustainable biomedical textiles. Researchers in this field can focus their thinking on the manufacture of sustainable, bio-based, and biodegradable smart textiles that contribute to human health and well-being.

4. Conclusion

In conclusion, this work analyzes new technologies in the production of green, sustainable, biodegradable, and renewable biomedical smart textiles that are in line with the circular economy and public health. It aims to reduce the environmental impact of the textile industry while promoting local and bio-based resources. This work presents a convergence between textile engineering, electronics, and public health. Their development opens up major prospects for preventive and personalized medicine, but requires efforts in standardization, biocompatibility, and accessibility. The outlook is that consolidating technical performance, ensuring environmental sustainability, guarantees economic competitiveness, and promotes social acceptability. It is a multidisciplinary undertaking in which research, industry, and even culture must move forward together.

Conflicts of Interest

We require that our authors reveal any possible conflict of interest in their submitted manuscripts. If there is no conflict of interest, authors should state that “The author(s) declare that there is no conflict of interest regarding the publication of this paper.”

References

[1] Balkis Ellouze, and Marwa Damak, “*The Use of Smart Textiles in the Healthcare Environment: Towards an Improved User-Patient Experience*,” University of Sfax, pp. 1-10, 2023. [Google Scholar] [Publisher Link]

[2] Guy Némoz, “*Chemistry for Textiles. CLOTHING. Molecules and Macromolecules for Human Comfort and Protection*,” CNRS Chemical Sciences Letter, pp. 56-61, 1999. [Google Scholar] [Publisher Link]

[3] Subbiyan Rajendran, and C. Anand Subhash, *5 - Smart Textiles for Infection Control Management*, Advances in Smart Medical Textiles, Woodhead Publishing Series in Textiles, pp. 93-117, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[4] Elisabeth Frésard, *The Textile Revolution* : *Beyond Imagination*, LEP, pp. 1-144, 2005. [Publisher Link]

[5] Baptiste Garnier, “*Development of NFC-Enabled Textile Structures for Energy and Data Transfer around the Human Body*,” Micro- and Nanotechnologies / Microelectronics, Thesis, University of Lille, pp. 1-77, 2021. [Google Scholar] [Publisher Link]

[6] Quebec Textile Industry Labor Sector Committee, 2015. [Online]. Available: www.csmotextile.qc.ca

[7] Dasong Dai, and Mizi Fan, “Investigation of the Dislocation of Natural Fibres by Fourier-Transform Infrared Spectroscopy,” *Vibrational Spectroscopy*, vol. 55, no. 2, pp. 300-306, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[8] P.K. Adapa et al., “Qualitative and Quantitative Analysis of Lignocellulosic Biomass using Infrared Spectroscopy,” Presented at the CSBE/SCGAB Annual Conference, 2009. [Google Scholar] [Publisher Link]

[9] Patricia Dolez et al., “Analysis of the Potential Application of Smart Textiles in Occupational Health and Safety,” *Scientific reports*, 2018. [Google Scholar] [Publisher Link]

[10] Nsangou Abdouramane et al., “Ecological Anti-Vector Knitwear: Sida Rhombifolia Impregnated with Aloe Vera Gel for Sustainable Control of Insect Vectors,” *International Journal of Engineering Research in Africa*, vol. 78, pp. 29-39, 2026. [CrossRef] [Google Scholar] [Publisher Link]

[11] Swetha Andra et al., “Emerging Nanomaterials for Antibacterial Textile Fabrication,” *Naunyn-Schmiedeberg's Archives of Pharmacology*, vol. 394, pp. 1355-1382, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[12] Nsangou Abdouramane et al., "Analysis of Biosource Antimicrobial Textiles: Review," *Environmental Engineering and Management Journal*, vol. 22, no. 6, pp. 1137-1143, 2023. [CrossRef] [Publisher Link]

[13] Anges Yadouleton et al., "Quality Control of Bifenthrin-Impregnated Curtains for their Use and Dissemination in Benin," *International Journal of Biological and Chemical Sciences*, vol. 12, no. 5, pp. 2044-2052, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[14] I. Arezki, "*Arthropods and Travelers*," Parasitology-Mycology, CHU Avicenne, Université Paris, 2014. [Google Scholar]

[15] Diana Coman, Simona Oancea, and Narcisa Vrînceanu, "Biofunctionalization of Textile Materials by Antimicrobial Treatments: A Critical Overview," *Romanian Biotechnological Letters*, vol. 15, pp. 4913- 4921, 2010. [Google Scholar]

[16] E.C. Directive, Directive 2013/39/EU of the European Parliament and of the Council, Amending Directives 2000/60/EC and 2008/105/EC as Regards Priority Substances in the Field of Water Policy Text with EEA Relevance, 2013. [Online]. Available: https://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:226:0001:0017:EN:PDF

[17] G. Duvallet, Insects and Animal Health: Current Situation and Issues, Pastoralism and Entomofauna, Pastum Special Issue, Lumaret J.P. (Ed.), AFP, pp. 72-82, 2010. [Google Scholar]

[18] Linda A Deanovic et al., "Comparing the Effectiveness of Chronic Water Column Tests with Hyalellaazteca (Order: Amphipoda) and Ceriodaphniadubia (Order: Cladocera) in Detecting Toxicity of Current-Use Insecticides," *Environmental Toxicology and Chemistry*, vol. 32, pp. 707-712, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[19] Nkemaja Dydimus Efeze et al., "Bio-Textiles Against Arthropod Pests: A Review," *Environmental Engineering and Management Journal*, vol. 23, no. 4, pp. 729-734, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[20] O.L. Shanmugasundaram, *Smart and Intelligent Textiles*, *The Indiant Textile Journal*, 2008. [Google Scholar]

[21] Ishan, *What's the Difference between Electronic Textiles (E-Textiles) and Smart Textiles?*, Electronic Textiles & Wearables, 2023. [Online]. Available: https://www.etextilewearables.com/whats-the-difference-between-electronic-textiles-e-textiles-andsmart-textiles

[22] Dilan Canan Çelikel, "Smart E-Textile Materials," *IntechOpen*, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[23] Mahiar Hamedi et al., "Electronic Textiles, Fiber-Embedded Electrolyte-Gated Field-Effect Transistors for e-Textiles," *Advanced Materials*, vol. 21, no. 5, pp. 1-2009. [CrossRef] [Google Scholar] [Publisher Link]

[24] Mahiar Hamedi, Robert Forchheimer, and Olle Inganäs, "Towards Woven Logic from Organic Electronic Fibres," *Nature Materials*, vol. 6, pp. 357-362, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[25] Michael R. Lee et al., "Solar Power Wires Based on Organic Photovoltaic Materials," *Science*, vol. 324 no. 5924 p. 232-235, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[26] Robert R. Mather, "Intelligent Textiles," *Review of Progress in Coloration and Related Topics*, vol. 31, no. 1, pp. 36-41, 2001. [CrossRef] [Google Scholar] [Publisher Link]

[27] T-Shirt OS. [Online]. Available: http://cutecircuit.com/collections/t-shirt-os/

[28] Matthieu Combe, E-Textiles at the Service of your Health, Engineering Techniques, 2018. [Online]. Available: https://www.techniques-ingenieur.fr/actualite/articles/textile-sante-51647/

[29] Smart Clothing for Health, 2014. [Online]. Available: futura-sciences.com

[30] A Connected Swimsuit to Prevent Sunburn, 2015. [Online]. Available: futura-sciences.com

[31] Caroline David, and Camille Beulque, *Futurotextiles: Surprising Textiles, Design & Art*, Stichting Kunstboek, 2012. [Google Scholar] [Publisher Link]

[32] Rosner|Touch|Mp3blue, 2023. [Online]. Available: https://www.cochranelibrary.com/

[33] Philips – Luminous Textiles – Bring Spaces Alive, 2013. [Online]. Available: https://www.signify.com/global/prof

[34] Joanna Berzowska, "Electronic Textiles Wearable Computers, Reactive Fashion and Soft Computation," *Textile*, vol. 3, no. 1, pp. 58-75, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[35] Joshua Ray Windmiller, and Joseph Wang, "Wearable Electrochemical Sensors and Biosensors: A Review," *Electroanalysis*, vol. 25, no. 1, pp. 29-46, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[36] Yang-Li Yang et al., "Thick-Film Textile-Based Amperometric Sensors and Biosensors," *Royal Society of Chemistry*, vol. 135, no. 6, pp. 1230-1234, 2010. [CrossRef] [Google Scholar] [Publisher Link]