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### A Critical Review of Materials and Manufacturing Techniques in Wearable

#### Textiles

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#### Abstract

This comprehensive review of wearable textiles addresses the pivotal role of materials and manufacturing techniques in shaping the field. It explores the significance of these factors, contrasting natural and synthetic materials, and delving into conductive and smart materials with their applications and challenges. Sustainable materials and environmental considerations are examined, along with the potential of biomaterials in wearables. Manufacturing techniques, including traditional processes like weaving, knitting, and spinning, as well as emerging methods such as 3D printing and nanotechnology, are discussed. The integration of electronics and sensors, sustainable manufacturing practices, and their challenges are highlighted. The interplay between materials and manufacturing is analyzed, showcasing successful combinations. The review also acknowledges challenges like material durability, scalability, compatibility, and environmental concerns. It explores future trends, emerging materials, manufacturing technologies, and applications across healthcare, sports, fashion, consumer wearables, and industrial sectors. This review concludes by summarizing key insights, emphasizing the importance of research and development for the future of wearable textiles.

## **1. Introduction**

Wearable textiles stand at the nexus of fashion, technology, and functionality, showcasing transformative potential. The integration of cutting-edge materials and manufacturing techniques has become instrumental in shaping the landscape of wearable textiles, yielding innovations with implications across various sectors. Research (Smith et al., 2023; Wang et al. 2022) has delved into advanced materials, including conductive polymers and shape-memory alloys, highlighting their role in enhancing flexibility, durability, and conductivity in wearable textiles. Simultaneously, manufacturing techniques, such as additive manufacturing and 3D printing, have witnessed significant advancements, contributing to the creation of intricate and customized textile structures (Xiang et al., 2020). These advancements not only influence aesthetics but also substantially impact functionality and performance.

Materials serve as the foundational elements of wearable textiles, and their selection is pivotal. The purpose of this review article is to present a comprehensive overview of wearable textiles, emphasizing the role of materials and manufacturing techniques. Drawing from recent research publications, the review aims to elucidate key advancements, challenges, and future directions in the field.

Structured logically, this article will commence with an exploration of the background and context of wearable textiles. Significantly, it will delve into the crucial role of materials and manufacturing techniques, shedding light on their individual and collective impacts on the field.

## **2. Materials in Wearable Textiles**

The choice between natural and synthetic materials in wearable textiles plays a pivotal role in determining their performance and ecological footprint. Natural materials, such as cotton and wool, offer breathability and comfort, while synthetic counterparts like polyester provide durability and moisture-wicking properties (Jones et al., 2020). However, the environmental impact of synthetic materials, particularly in terms of microplastic pollution, raises concerns (Smith et al., 2023). On the other hand, natural materials may face challenges related to resource-intensive cultivation practices (Wang et al. 2022).

Advancements in wearable technology have ushered in a new era of conductive and smart materials, expanding the functionality of textiles. Research (Jones et al., 2020) highlights the applications of conductive materials, such as conductive polymers and metal-infused fabrics, in creating flexible and responsive garments. The integration of smart materials, including shape-memory alloys and responsive polymers, enables garments to adapt to environmental conditions or user preferences (Biswas et al. 2021).

As sustainability becomes a central concern in the textile industry, the demand for environmentally friendly materials has grown. Recent research (Provin et al. 2021) explores sustainable alternatives, including recycled fibers, organic cotton, and biodegradable polymers, highlighting their potential to mitigate the environmental impact of wearable textiles. Innovations in biomaterials have opened new frontiers in wearable textiles, with potential applications ranging from healthcare to responsive clothing. Studies (Ganewatta et al., 2021) showcase the use of biomimetic materials, such as spider silk-inspired fibers and bacterial cellulose, in creating functional and biocompatible textiles.

### **3. Manufacturing Techniques for Wearable Textiles**

The foundation of wearable textiles lies in traditional manufacturing processes such as weaving, knitting, and spinning, which have evolved over centuries. These techniques, while time-tested, continue to play a crucial role in the production of textiles with diverse textures and patterns (Chur, 2005).

The advent of technology has ushered in new possibilities for manufacturing wearable textiles, with 3D printing and additive manufacturing at the forefront. Recent studies (Jones et al., 2020) highlight how these methods allow for precise and customizable textile structures, opening avenues for intricate designs and personalized garments. Additionally, nanotechnology has found application in textile production, enabling the development of fabrics with enhanced properties such as water repellency and UV resistance.

The seamless integration of electronics and sensors into textiles represents a paradigm shift in wearable technology. Research (Smith et al., 2023) showcases breakthroughs in incorporating flexible circuits, sensors, and other electronic components directly into fabrics. However, challenges such as maintaining flexibility, washability, and durability remain significant (Wang et al. 2022).

Sustainability considerations are increasingly shaping manufacturing practices in the textile industry. Recent research (Wang et al. 2022) explores sustainable manufacturing alternatives, emphasizing reduced waste and energy-efficient techniques. From recycled materials to environmentally friendly dyeing processes, the push for sustainable practices is reshaping the way wearable textiles are produced.

#### **4. Materials and Manufacturing**

The synergy between materials and manufacturing processes is a critical determinant of the performance and characteristics of wearable textiles. Research (Chatterjee and Gosh, 2020) underscores the importance of selecting materials tailored to specific manufacturing techniques, such as 3D printing or weaving. For instance, the compatibility of conductive polymers with additive manufacturing has been explored to create flexible and electronically functional textiles (Ismar et al., 2020).

The manufacturing techniques employed exert a profound influence on the properties of materials used in wearable textiles. Studies (Liu et al., 2021) showcase how 3D printing and additive manufacturing can alter the structural composition of materials, leading to enhanced flexibility or strength. Similarly, the integration of electronics into textiles necessitates materials with specific conductive and insulating properties (Heo et al., 2018).

Examining successful material-manufacturing combinations in wearable textiles through case studies offers tangible insights into effective strategies and innovative solutions. For example, the use of nanotechnology in combination with traditional weaving techniques has yielded textiles with enhanced functionality, such as self-cleaning properties (Shah et al., 2022).

#### **5. Challenges and Limitations**

Despite the rapid progress in wearable textiles, material limitations remain a critical aspect influencing the performance and acceptance of these innovations. Durability and comfort are key concerns, as highlighted in recent studies (Islam et al., 2020). While the integration of conductive and smart materials has enabled novel functionalities, issues related to the longevity and comfort of these materials persist. Wearable textiles must strike a delicate balance between functionality and user

experience, and addressing these material limitations is imperative for widespread adoption.

The scalability and cost-effectiveness of manufacturing processes pose significant challenges in the realm of wearable textiles. Research (Kong et al., 2019) underscores the need for scalable manufacturing methods that can cater to mass production while maintaining the integrity of design and functionality. Additionally, cost-effectiveness is crucial for ensuring accessibility to a broader consumer base. As wearable technology advances, finding manufacturing solutions that balance scalability and cost remains an ongoing challenge.

The seamless integration of various components, such as electronics and sensors, into textile structures presents notable challenges. Recent research (Wu et al., 2016) highlights issues related to compatibility and integration, emphasizing the need for standardized interfaces and manufacturing processes. Achieving a harmonious blend between electronic elements and textile materials while preserving flexibility and washability is an intricate task.

As the textile industry strives for sustainability, wearable textiles face environmental concerns that demand attention. Research (Kholer, 2008) addresses the environmental impact of materials and manufacturing processes, emphasizing the need for eco-friendly alternatives. Issues such as the carbon footprint of production and the end-of-life disposal of smart textiles contribute to the environmental discourse.

## **6. Future Directions and Innovation**

The future of wearable textiles is poised for transformation with the emergence of innovative materials. Research (Wu et al., 2021) introduces the prospect of materials like graphene and carbon nanotubes, showcasing their potential to revolutionize the field by offering enhanced conductivity, flexibility, and strength. Additionally, the exploration of biofabricated materials, inspired by natural processes, opens new avenues for sustainable and biocompatible textile solutions (Pedde et al., 2017).

The trajectory of wearable textiles is closely intertwined with cutting-edge manufacturing technologies that continue to evolve. The integration of artificial intelligence and automation into manufacturing processes holds promise for increased efficiency and precision (Lu et al. 2020).

Sustainability remains at the forefront of the textile industry, and wearable textiles are no exception. The growing trends in sustainable approaches, including the

use of recycled materials, environmentally friendly dyeing processes, and circular design principles. The incorporation of eco-friendly practices into every stage of the textile lifecycle is becoming a key focus, addressing environmental concerns associated with production, use, and disposal (Rotimi et al., 2021).

## **7. Applications and Industries**

Wearable textiles have significantly impacted the healthcare and medical sectors, offering innovative solutions for monitoring, diagnosis, and treatment. Recent studies (Paradiso et al., 2005) demonstrate the integration of wearable sensors into textiles for continuous health monitoring, enabling real-time data collection for conditions such as heart rate, temperature, and respiratory patterns. Smart textiles, equipped with biosensors, can facilitate early detection of medical issues and enhance patient care. The potential of wearable textiles extends to the development of smart garments for rehabilitation and assistive devices, showcasing their transformative role in improving healthcare outcomes (Chen et al. 2021).

The sports and fitness industry has embraced wearable textiles as a means to enhance performance, monitor athletes' well-being, and provide personalized training insights (Shen et al. 2023). Recent advancements (Sheshadri et al., 2019) showcase the integration of smart fabrics and sensors into athletic wear to track metrics such as biomechanics, muscle activity, and hydration levels. Wearable textiles in sports not only offer real-time performance feedback but also contribute to injury prevention and recovery.

Wearable textiles have seamlessly merged with the fashion industry, giving rise to a new era of consumer wearables that blend style and functionality (Guler et al. 2016). Recent research (Kubicek et al., 2020) emphasizes the integration of smart fabrics and electronic components into fashion garments, enabling functionalities such as interactive displays, climate adaptability, and even emotion sensing. This fusion of technology and fashion not only enhances the aesthetics of clothing but also introduces novel consumer experiences.

The industrial and military sectors have embraced wearable textiles for enhanced safety, communication, and performance (Casselman et al., 2017). Recent studies (Basodan., 2021) showcase the use of smart textiles in industrial settings for monitoring workers' health, detecting hazardous conditions, and improving overall workplace safety. In the military, wearable textiles contribute to the development of

smart uniforms with integrated sensors and communication systems, enhancing situational awareness and soldier performance.

## 8. Conclusion

The exploration of wearable textiles has revealed a dynamic landscape at the intersection of materials, manufacturing, and diverse applications. Key findings highlight the pivotal role of advanced materials such as graphene and carbon nanotubes in revolutionizing the field, offering enhanced conductivity and sustainability. The interplay between materials and manufacturing techniques, encompassing 3D printing and smart fabric integration, underscores the intricate synergy shaping the evolution of wearable textiles. Applications span across healthcare, sports, fashion, and industrial sectors, showcasing the versatility and transformative potential of these innovations. Looking ahead, the implications for the future of wearable textiles are profound, with promises of personalized healthcare, advanced athletic performance monitoring, stylish consumer wearables, and improved safety in industrial and military contexts. As we stand on the cusp of a new era in textile technology, this review calls for continued research and development to address existing challenges, such as material limitations and manufacturing scalability, and to explore untapped possibilities in emerging materials and technologies. The pursuit of sustainable, functional, and aesthetically pleasing wearable textiles is poised to redefine how we interact with and benefit from clothing in the years to come.

## References

1. Smith, M., Cacucciolo, V., & Shea, H. (2023). Fiber pumps for wearable fluidic systems. *Science*, 379(6639), 1327-1332.
2. Wang, C., Zhang, W., Xu, X., Su, J., Shi, J., Amin, M. A., ... & Yamauchi, Y. (2022). Multifunctional wearable thermal management textile fabricated by one-step sputtering. *Nano Today*, 45, 101526.
3. Xiang, D., Zhang, X., Harkin-Jones, E., Zhu, W., Zhou, Z., Shen, Y., ... & Wang, P. (2020). Synergistic effects of hybrid conductive nanofillers on the performance of 3D printed highly elastic strain sensors. *Composites Part A: Applied Science and Manufacturing*, 129, 105730.
4. Jones, L., Nabil, S., McLeod, A., & Girouard, A. (2020, February). Wearable Bits: scaffolding creativity with a prototyping toolkit for wearable e-textiles.

In Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction (pp. 165-177).

5. Biswas, M. C., Chakraborty, S., Bhattacharjee, A., & Mohammed, Z. (2021). 4D printing of shape memory materials for textiles: Mechanism, mathematical modeling, and challenges. *Advanced Functional Materials*, 31(19), 2100257.

6. Provin, A. P., de Aguiar Dutra, A. R., Machado, M. M., & Cubas, A. L. V. (2021). New materials for clothing: Rethinking possibilities through a sustainability approach-A review. *Journal of Cleaner Production*, 282, 124444.

7. Ganewatta, M. S., Wang, Z., & Tang, C. (2021). Chemical syntheses of bioinspired and biomimetic polymers toward biobased materials. *Nature Reviews Chemistry*, 5(11), 753-772.

8. Chur, C. L. (2005). *The Raquette River quilters: A case study of cultural biases and contemporary quilting production from a feminist perspective*. State University of New York at Buffalo.

9. Chatterjee, K., & Ghosh, T. K. (2020). 3D printing of textiles: potential roadmap to printing with fibers. *Advanced Materials*, 32(4), 1902086.

10. Ismar, E., Kurşun Bahadır, S., Kalaoglu, F., & Koncar, V. (2020). Futuristic clothes: electronic textiles and wearable technologies. *Global Challenges*, 4(7), 1900092.

11. Liu, G., Zhang, X., Chen, X., He, Y., Cheng, L., Huo, M., ... & Lu, J. (2021). Additive manufacturing of structural materials. *Materials Science and Engineering: R: Reports*, 145, 100596.

12. Heo, J. S., Eom, J., Kim, Y. H., & Park, S. K. (2018). Recent progress of textile-based wearable electronics: a comprehensive review of materials, devices, and applications. *Small*, 14(3), 1703034.

13. Shah, M. A., Pirzada, B. M., Price, G., Shibiru, A. L., & Qurashi, A. (2022). Applications of nanotechnology in smart textile industry: A critical review. *Journal of Advanced Research*, 38, 55-75.

14. Islam, G. N., Ali, A., & Collie, S. (2020). Textile sensors for wearable applications: A comprehensive review. *Cellulose*, 27, 6103-6131.

15. Kong, X. T., Luo, H., Huang, G. Q., & Yang, X. (2019). Industrial wearable system: the human-centric empowering technology in Industry 4.0. *Journal of Intelligent Manufacturing*, 30, 2853-2869.



16. Wu, H., Huang, Y., Xu, F., Duan, Y., & Yin, Z. (2016). Energy harvesters for wearable and stretchable electronics: from flexibility to stretchability. *Advanced materials*, 28(45), 9881-9919.
17. Köhler, A. R. (2008). End-of-life implications of electronic textiles. *Assessment of a Converging Technology, IEEE Theses*.
18. Wu, Y., Zhao, X., Shang, Y., Chang, S., Dai, L., & Cao, A. (2021). Application-driven carbon nanotube functional materials. *ACS nano*, 15(5), 7946-7974.
19. Pedde, R. D., Mirani, B., Navaei, A., Styan, T., Wong, S., Mehrali, M., ... & Akbari, M. (2017). Emerging biofabrication strategies for engineering complex tissue constructs. *Advanced Materials*, 29(19), 1606061.
20. Lu, Y., Xu, X., & Wang, L. (2020). Smart manufacturing process and system automation—a critical review of the standards and envisioned scenarios. *Journal of Manufacturing Systems*, 56, 312-325.
21. Rotimi, E. O. O., Topple, C., & Hopkins, J. (2021). Towards a conceptual framework of sustainable practices of post-consumer textile waste at garment end of lifecycle: A systematic literature review approach. *Sustainability*, 13(5), 2965.
22. Paradiso, R., Loriga, G., & Taccini, N. (2005). A wearable health care system based on knitted integrated sensors. *IEEE transactions on Information Technology in biomedicine*, 9(3), 337-344.
23. Chen, Guorui, Xiao Xiao, Xun Zhao, Trinny Tat, Michael Bick, and Jun Chen. "Electronic textiles for wearable point-of-care systems." *Chemical Reviews* 122, no. 3 (2021): 3259-3291.
24. Shen, D., Tao, X., Koncar, V., & Wang, J. (2023). A Review of Intelligent Garment System for Bioelectric Monitoring During Long-Lasting Intensive Sports. *IEEE Access*.
25. Seshadri, D. R., Li, R. T., Voos, J. E., Rowbottom, J. R., Alfes, C. M., Zorman, C. A., & Drummond, C. K. (2019). Wearable sensors for monitoring the physiological and biochemical profile of the athlete. *NPJ digital medicine*, 2(1), 72.
26. Guler, S. D., Gannon, M., & Sicchio, K. (2016). *Crafting wearables: Blending technology with fashion*. Apress.
27. Kubicek, J., Fiedorova, K., Vilimek, D., Cerny, M., Penhaker, M., Janura, M., & Rosicky, J. (2020). Recent trends, construction, and applications of smart

textiles and clothing for monitoring of health activity: A comprehensive multidisciplinary review. *IEEE Reviews in Biomedical Engineering*, 15, 36-60.

28. Casselman, J., Onopa, N., & Khansa, L. (2017). Wearable healthcare: Lessons from the past and a peek into the future. *Telematics and Informatics*, 34(7), 1011-1023.

29. Basodan, R. A., Park, B., & Chung, H. J. (2021). Smart personal protective equipment (PPE): Current PPE needs, opportunities for nanotechnology and e-textiles. *Flexible and Printed Electronics*, 6(4), 043004.

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