Proceedings of the 5th International Conference on Materials Chemistry and Environmental Engineering
DOI: 10.54254/2755-2721/122/2025.19917

Application of Nanocomposite Pressure Sensors in Health Monitoring

Tiansong Han[1,a,*]

[1]*Dalian Rolay School, Dalian, China*
a. tiansong@fsu.edu.pa
**corresponding author*

Abstract: Nanotechnology has become an essential tool in a wide range of fields due to its unique capabilities and innovative applications. Among these fields, human health has gained significant attention as maintaining and improving health is a top priority in modern society. To contribute to this goal, nanocomposites have been increasingly applied in the development of pressure sensors for health detection. These advanced materials, which combine nanoparticles with other functional materials, offer exceptional properties such as high sensitivity, flexibility, and durability, making them highly suitable for detecting subtle pressure changes in health monitoring applications. This article will provide a comprehensive overview of the role of nanocomposites in pressure sensor technology and their practical applications in health detection, such as monitoring vital signs, detecting early symptoms of diseases, and improving wearable medical devices. By exploring the unique properties of nanocomposites, including their mechanical, electrical, and biocompatible characteristics, the article highlights how these materials enhance the performance and reliability of pressure sensors. The research presented in this paper is expected to offer valuable insights into the potential of nanocomposite-based pressure sensors, further promoting their development and application in health monitoring. Additionally, this work contributes to the broader field of nanotechnology, advancing its use in innovative healthcare solutions and fostering the integration of cutting-edge science in improving human well-being.

Keywords: Nanocomposite, Pressure sensor, Wearable medical devices

1. Introduction

In recent years, nanocomposite pressure sensors have gained increasing attention and gradually found applications in daily life, due to their remarkable potential in various fields, particularly in health monitoring, smart devices, and robotics. A nanocomposite pressure sensor is a type of sensor that combines the advanced properties of nanomaterials with the versatility of composite materials, resulting in devices that exhibit high sensitivity, exceptional precision, and strong repeatability. These sensors are capable of detecting and measuring pressure by converting mechanical deformation into electrical signals, making them highly effective for a wide range of applications [1-3].

Nanocomposite pressure sensors are typically composed of nanomaterials or nanostructures embedded in a flexible or rigid composite matrix. Nanomaterials, such as carbon nanotubes,

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/122/2025.19917

graphene, metal nanoparticles, or conductive polymers, impart unique electrical, mechanical, or optical properties to the composite material. When pressure is applied to the surface of the sensor, the nanomaterials undergo deformation or changes in their electrical properties, such as resistance or capacitance, allowing the sensor to accurately detect and measure the applied force or pressure. This makes nanocomposite pressure sensors highly effective for detecting subtle pressure variations, even at micro or nanoscale levels [4].

The integration of nanomaterials into composite materials has not only enabled significant advancements in pressure sensor technology but has also opened up new possibilities for applications in various fields. For example, in the healthcare industry, nanocomposite pressure sensors are being used in wearable devices to monitor vital signs such as heart rate, respiration, and body movement. They have become valuable tools for early disease detection, rehabilitation monitoring, and personalized health management. Similarly, these sensors are being incorporated into robotics and artificial intelligence systems to enable tactile sensing and improve human-machine interaction. In addition, their flexibility and scalability make them suitable for use in smart textiles, electronic skin, and other emerging technologies.

This article provides an in-depth exploration of the development, research, and applications of nanocomposite pressure sensors, highlighting their role as a key component of nanotechnology. By examining the fundamental principles, material design strategies, and practical applications of these sensors, this work aims to contribute to the advancement of nanotechnology and its integration into everyday life. The insights presented in this article are expected to promote further innovation in nanocomposite pressure sensors, driving their adoption in various industries and enhancing their impact on human well-being and technological progress.

2. Silver/graphene nanocomposite flexible pressure sensor

Flexible pressure sensors are the core components of flexible wearable devices, which have great application potential in health care, sports and fitness, safe production and other fields. Graphene, a two-dimensional material, has high carrier mobility, super-large specific surface area and ultra-high mechanical degree, and is regarded as an excellent sensitive material for the preparation of flexible pressure sensors. However, graphene fragments introduce defects such as grain boundaries or stacking. The preparation of flexible pressure sensors with pure graphene has problems such as low sensitivity, poor stability and narrow response range. Zero-dimensional silver nanoparticles or one-dimensional silver nanowires are used to construct composite materials with graphene, which can effectively cross defects or connect adjacent layers, playing a "bridge" role (Figure 1). Graphene sheets are laid between nanosilver conductive networks, playing a "patch" role [5].

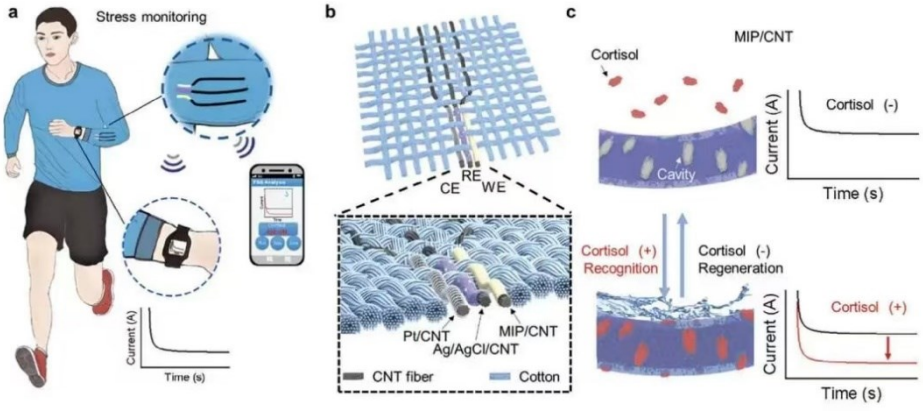


Figure 1: Schematic diagram of wearable fabric sensing system for real-time stress health management [5]

DOI: 10.54254/2755-2721/122/2025.19917

3. Application of electrostatic spinning carbon nanotube substrate composite materials in sensors

At present carbon nanotubes can be used to make capacitors conductive films sensors and touch screen materials. Because of their excellent properties carbon nanotubes are widely used in precise and sensitive materials. As a pure substance composed of carbon elements carbon nanotubes have volume effect surface effect macroscopic quantum tunnel and quantum effect. Adding carbon nanotubes into the sensor can modify the electrode, reduce the overpotential of redox and improve the detection sensitivity. Electrospun carbon nanotubes have the advantages of nanometer scale. Electrospinning makes the sensor structure miniaturized and integrated. 3D stacked nanofibers are used as hazard sensors breathable nano grid sensors and intelligent wearable sensors. Different kinds of atoms can change the electronic structure and adsorption capacity of carbon nanotubes. When the carbon nanotube compounds with different kinds of polymers the response characteristics of the sensor can be changed and the recovery performance and sensitivity of the response can be improved. The high surface area of the carbon nanotube composite provides a large number of gas channels which improves the sensitivity and response speed of sensors. The spiral structure and hollow structure can separate substances to simplify the detection steps. By fixing the protein probe on the carbon nanotubes and using fluorescence irradiation people can quickly detect COVID-19. Technology research and development based on sensor materials and devices is the cornerstone of improving the development of the sensor field. It is proved that the ordered and complex nanofibers produced by electrospinning can provide sufficient biomolecule fixation sites which has become a hot research topic in the sensor field. Carbon nanotubes are compounded with other materials by electrospinning which improves the upper performance limit of sensor materials and broadens the development and application space of the sensor field in the future [6].

4. Self-sufficient human foot pressure monitoring sensor

A composite material with a porous structure of polydimethylsiloxane/multi-walled carbon nanotubes (PDMS/MWCNTs) was prepared, and a self-supply pressure monitoring sensor was designed. The addition of MWCNTs not only improves the dielectric constant of the composite material, but also forms a porous structure by the dissolution of carbon white sugar in water, which can capture more charge, so that the coupling effect improves the frictional electrical properties, thereby increasing the sensitivity. Experiments show that in single-electrode mode, when MWCNTs are 10wt% and the porosity is 62.8%, the self-supply sensor is under a pressure of 110 N, and the open-circuit voltage and short-circuit current are 90 V and 2 μA respectively. The sensor film has the advantages of simple process, wide pressure detection range (0 N~ 125 N), fast response speed (25 ms), good working stability (1,800 cycles) and so on [7].

5. Application of MWCNT interface sensor in thermoplastic composite interface monitoring

Using fibre/master interface phase-filled multi-walled carbon nanotube (MWCNT) technology, in-situ monitoring and repair methods for thermoplastic composite interface damage before and after water immersion are explored. First, the preparation method of MWCNT interface sensor with the best performance was studied, its optimal process parameters were determined, and it was implanted into the fibre/matrisal interface phase; secondly, the sample was soaked in water at different temperatures to study the water absorption behaviour of the interface phase; thirdly, quasi-static In the fibre bundle pull-out experiment under loading conditions, the resistance change of MWCNT is used to monitor the failure process of the interface phase under the pull-out load; finally, electric heat is generated by applying voltage at both ends of the MWCNT in the interface

DOI: 10.54254/2755-2721/122/2025.19917

phase, and the interface damage formed during the pull-out process is repaired by in situ melting. The research results show that the method adopted can obtain a multi-functional thermoplastic composite fibre/mater interface phase that integrates water absorption resistance, in situ monitoring and in situ repair functions [8].

6. Conclusion

As society progresses and people increasingly prioritize their health, the demand for advanced health monitoring technologies continues to rise. Nanotechnology, with its unique capabilities, offers innovative tools to monitor health more accurately, efficiently, and conveniently. This paper explored the role and application of nanocomposite pressure sensors and related materials in the field of health monitoring, focusing on their potential to revolutionize wearable devices, improve sensor performance, and expand applications across diverse fields such as healthcare, fitness, and safety.

The study highlighted several key advancements in nanocomposite pressure sensors. The development of silver/graphene nanocomposites addresses the limitations of pure graphene, such as low sensitivity and poor stability, by leveraging the complementary properties of silver nanoparticles and graphene sheets. Similarly, electrospun carbon nanotube composites enhance the performance of sensors by improving sensitivity, response speed, and adaptability in diverse applications, from hazard detection to COVID-19 testing. Furthermore, self-sufficient sensors based on polydimethylsiloxane (PDMS) and multi-walled carbon nanotubes (MWCNTs) demonstrate improved sensing sensitivity and stability due to their porous structures. Lastly, the integration of MWCNT interface sensors into thermoplastic composites showcases the potential for in-situ monitoring and repair, further broadening the scope of nanotechnology-based sensors.

Looking forward, nanotechnology is expected to become more deeply integrated into daily life, driving the development of smarter, multifunctional, and cost-effective sensor systems. Future research will likely focus on improving the scalability, environmental sustainability, and biocompatibility of nanocomposite sensors to ensure their widespread adoption. These innovations will not only enhance health monitoring capabilities but also contribute to advancements in wearable technology, personalized medicine, and intelligent systems. In conclusion, nanotechnology-based sensors are poised to play a transformative role in healthcare and beyond, offering unparalleled convenience, performance, and adaptability. With continuous research and innovation, they have the potential to redefine the way people interact with technology and improve our quality of life.

References

[1] *Wang, X., Dong, L., Zhang, H., Yu, R., Pan, C., & Wang, Z. L. (2015). Recent progress in electronic skin. Advanced Science, 2(10), 1500169. https://doi.org/10.1002/advs.201500169*

[2] *Yang, J. C., Mun, J., Kwon, S. Y., Park, S., Bao, Z., & Park, S. (2019). Electronic skin: recent progress and future prospects for skin‐attachable devices for health monitoring, robotics, and prosthetics. Advanced Materials, 31(48), 1904765. https://doi.org/10.1002/adma.201904765*

[3] *Wang, M., Luo, Y., Wang, T., Wan, C., Pan, L., Pan, S., He, K., Neo, A., & Chen, X. (2021). Artificial skin perception. Advanced Materials, 33(19), 2003014. https://doi.org/10.1002/adma.202003014*

[4] *Lee, Y., Park, J., Choe, A., Cho, S., Kim, J., & Ko, H. (2020). Mimicking human and biological skins for multifunctional skin electronics. Advanced Functional Materials, 30(20), 1904523. https://doi.org/10.1002/adfm.201904523*

[5] *Shuai, X., Zhu, P., Zeng, W., Hu, Y., Liang, X., Zhang, Y., Sun, R., & Wong, C. P. (2017). Highly sensitive flexible pressure sensor based on silver nanowires-embedded polydimethylsiloxane electrode with microarray structure. ACS Applied Materials & Interfaces, 9(31), 26314-26324. https://doi.org/10.1021/acsami.7b05753*

[6] *Yang, H., Zhang, Y., Liu, Y., & Qin, Z. (2023). Research progress of electrospun carbon nanotube-based composites in sensors. Advanced Textile Technology, 31(2), 1-8.*

DOI: 10.54254/2755-2721/122/2025.19917

[7] *Ren, J., & He, J. (2024). Self-powered human foot pressure monitoring sensor. Ship Electronic Engineering, 44(5), 207-202.*

[8] *He, Y., Liu, Y., Zhao, W., & Liu, S. (2018). Research progress of flexible pressure sensors based on carbon materials. Chemical Industry and Engineering Progress, 37(7), 2664-2671.*