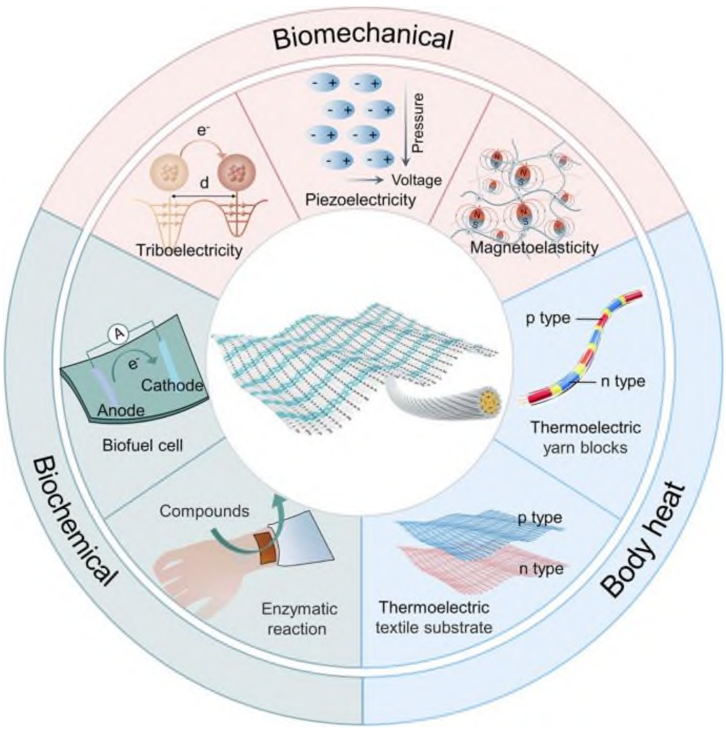
Case study-smart fabric for monitoring biological parameters

Merging electronics with textiles has become an emerging trend since textiles hold magnificent wearing comfort and user-friendliness compared with conventional wearable bioelectronics. Smart textiles can be effectively integrated into our daily wearing to convert on-body biomechanical, biochemical, and body heat energy into electrical signals for long-term, real-time monitoring of physiological states, showing compelling medical and economic benefits. This review summarizes the current progress in self-powered biomonitoring textiles along three pathways: biomechanical, body heat, and biochemical energy conversion. Finally, it also presents promising directions and challenges in the field, as well as insights into future development. This review aims to highlight the frontiers of smart textiles for self-powered biomonitoring, which could contribute to revolutionizing our traditional healthcare into a personalized model.



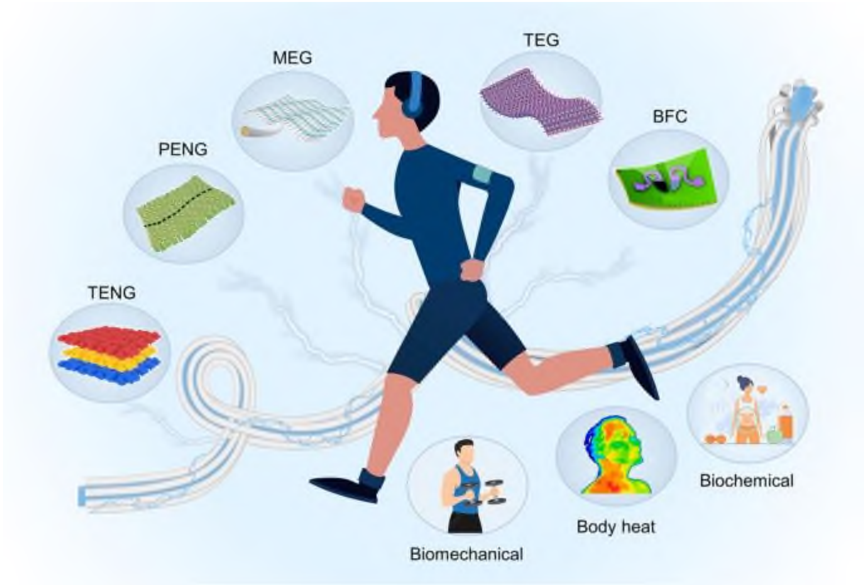
Self-powered biomonitoring textiles via biomechanical, body heat, and biochemical energy conversion are discussed in this work. Platform technologies, including piezoelectric nanogenerators (PENGs), triboelectric nanogenerators (TENGs), and magnetoelastic generators (MEGs) for biomechanical energy conversion, thermoelectric generators (TEGs) for boy heat energy conversion, and biofuel cells (BFCs) for biochemical energy conversion, are systematically introduced and discussed in a textile form. Working in a self-powered manner with greatly improved wearing comfort, the smart biomonitoring textiles pave a compelling road to personalized healthcare.

Highlights

- Self-powered biomonitoring textiles via biomechanical, body heat, and biochemical energy conversion are discussed.
- Platform technologies, including PENG, TENG, MEG, TEG and BFC are systematically introduced.
- Self-powered biomonitoring textiles pave a compelling road to personalized healthcare

Textiles, which have been a part of human civilization for thousands of years, are made from both natural materials such as silk and cotton, and synthetic materials such as polyamide and polyester. These materials can be made into textile bioelectronic devices via scalable weaving, knitting, braid, printing, and electrospinning, showing great wearing comfort and breathability. Conventional fiber fabrication techniques include coating, spinning, and thermal drawing. These various types of fibers can also be arranged into different architectures and structures in textiles endowing them with excellent flexibility, breathability, abrasion resistance, and material integration. An increasing number of platform technologies, including electroluminescent piezoresistive thermoelectric and photovoltaic platforms have been utilized to develop smart healthcare textiles Among them, self-powered biomonitoring textiles that rely on piezoelectric triboelectric magnetoelastic and electrochemical approaches offer unique and compelling features that have attracted significant attention. Self-powered textiles have the capability of sustainably converting the renewable energy from the human body such as biomechanical, body heat, and biochemical energy into electrical signals for healthcare purposes. They not only weaken the dependance of wearable bioelectronics on power supply, but they also provide highly sensitive and real-time information to monitor human physiological states. Additionally, self-powered textiles are also environmentally friendly, simple to manufacture, inexpensive, which can be effectively integrated into daily wear such as clothing, masks, wristbands, and other garments for continuous monitoring.

We will begin by briefly discussing the physiological signals that can be monitored. Then, we will present the progress of self-powered biomonitoring textiles which utilize the on-body renewable energy sources: biomechanical, body heat, and biochemical energy (Fig.). We will illustrate the mechanisms of each of these self-powered textiles and describe how they can monitor various physiological parameters. Finally, we will discuss the challenges within the community of self-powered biomonitoring textiles. This review provides a critical analysis of the current advances in smart biomonitoring textiles and the insights into remaining challenges and future directions.



Platform technologies for self-powered biomonitoring textiles. For self-powered biomechanical sensing, we have systematically introduced PENGs, TENGs and MEGs. The TEGs and BFCs are introduced for self-powered boy temperature and biochemical sensing, respectively. This review provides a critical analysis of the current advances in smart textiles working in the self-powered manner and the insights into remaining challenges and future directions, paving a compelling road to personalized healthcare

ECG Respiration

Wearable light textiles are gaining widespread interest in application for measurement and monitoring of biophysical parameters. Fiber optic sensors, in particular Bragg Grating (FBG) sensors, can be a competitive method for monitoring of respiratory behavior for chest and abdomen regions since the sensors are able to convert physical movement into wavelength shift. This study aims to show the performance of elastic belts with integrated optical fibers during the breathing activities done by two volunteers. Additionally, the work aims to determine how the positions of the volunteers affect the breathing pattern detected by optical fibers. As a reference, commercial mobile application for sensing vibration is used. The obtained results show that the FBGs are able to detect chest and abdomen movements during breathing and consequently reconstruct the breathing pattern. The accuracy of the results varies for two volunteers but remains consistent.

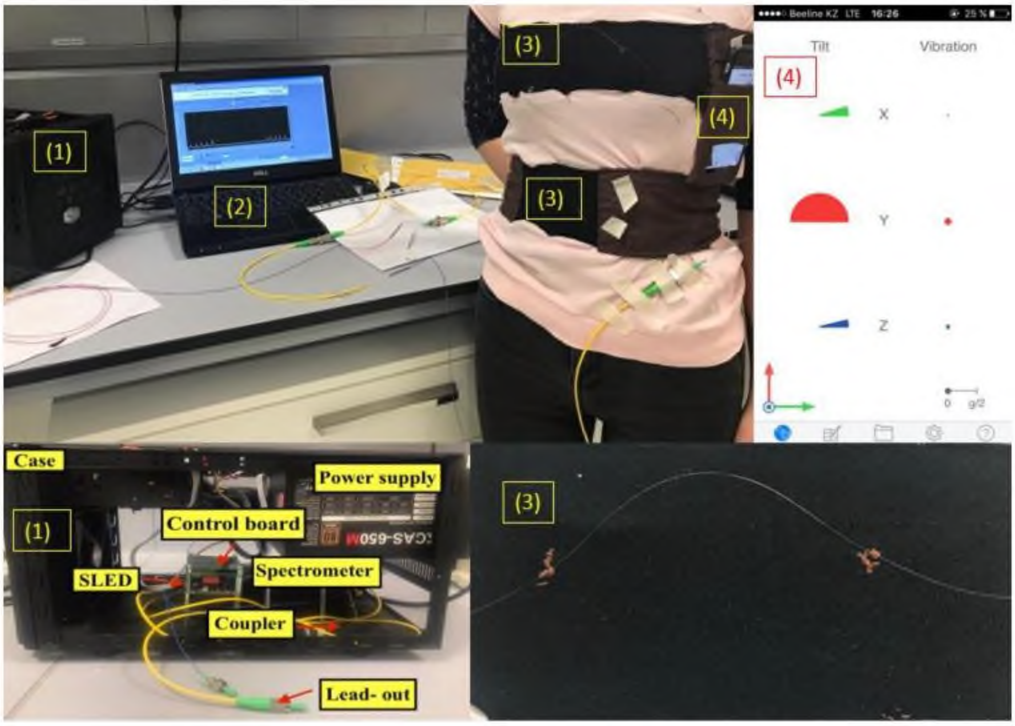
Wireless devices have pushed forward medical science to an advanced level in which people have access to a personalized drug delivery, a remote healthcare including simple diagnostics and data-logging operations outside of hospitals, and a continuous monitoring of biophysical parameters such as blood pressure, body temperature, breathing rate, etc. Low-cost miniature technologies help to prevent sudden infant death syndrome, heart-related diseases and provide minimal invasive continuous monitoring.

For example, Skrzetuska and Wojciechowski studied the ability of T-shirts equipped with a printed respiratory rate sensor to monitor the breathing pattern of two volunteers and the influence of the environmental humidity and temperature on the output of the sensor. The authors have tried several configurations of printed sensor and identified the most optimal shape and size of the sensor. The breathing of volunteers were monitored during physical activities and rest. The sensing technology were able to identify breaths but the external climate conditions were found to have an effect on the accuracy of the results.

Joyashiki and Wada proposed to monitor breathing pattern by a body-conducted sound sensor placed on the neck. The performance of the sensor was compared with two other sensors, namely air-coupled microphone and acceleration sensor. A data analysis technique based on signal processing was developed. The authors came to the conclusion that body-conducted sensor performs better in four different types of the experiments. Schatz et al. studied the application of five different types of depth sensors for breathing rate monitoring and usage of this data for the sleep apnea identification. All of the sensors output were compared with the reference sensor and two of the five sensors have been found appropriate for sleep apnea determination.

The aim of the experiments is to study the feasibility of the FBGs arrays for breathing pattern monitoring application. The breathing pattern is measured at the two locations of the body (abdomen and chest) by two arrays of 5 FBGs.This allows to apply a diversity technique, which is used in communication systems to achieve better accuracy of detection by combining the outputs from several different sensing points. The breathing pattern has been measured in four different positions of the volunteers (sitting, lying, staying or running). Two volunteers have participated in the initial experiments: 23-years old woman, height 165 cm, weight 52 kg and 24-years old man, height 171 cm, weight 72 kg. The volunteers wore T-shirts with two specially designed belts located on the abdomen and chest regions. They have been asked to breath for 23 seconds in different positions: staying, sitting, lying and running. The results of the the strain change detected by FBGs have been compared with the output of a reference sensor, which is a mobile application for acceleration and vibration measurement. The mobile phone with the application has been attached to the upper belt.

The experimental setup, which is illustrated in Figure, consists of the (1) I-MON interrogator connected to (2) PC with evaluation software, (3) T-shirt with two belts each equipped with an array of 5 FBGs, (4) mobile phone with VibSensor application.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