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Research article

1. Enhanced electromechanical conversion via in situ grown CsPbBr₃ nanoparticle/poly(vinylidene fluoride) fiber composites for physiological signal monitoring

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Sun X, Zhang F, Zhang L, Liu G, Wang Y, Wang Y, Deng Y. Enhanced electromechanical conversion via in situ grown CsPbBr₃ nanoparticle/poly(vinylidene fluoride) fiber composites for physiological signal monitoring. Soft Sci 2022;2:1. <http://dx.doi.org/10.20517/ss.2021.21>

Abstract

Mechanical energy conversion based on the piezoelectric principle has received significant attention due to its promising applications in sustainable power supply systems and sensor technology. Ferroelectric poly(vinylidene fluoride) (PVDF) combines the advantages of both good electromechanical coupling and easy processability, yet its low piezoelectric coefficient limits its output performance and it thus cannot meet the increasing requirements for power generation and sensing. Here, inorganic metal halide perovskite CsPbBr₃ (CPB) nanoparticles are incorporated into PVDF fibers via an electrospinning technique, where an *in situ* crystallization and growth process of the CPB nanoparticles is established. Both the CPB nanoparticles and PVDF fibers are poled by the electric field during the electrospinning process, which promotes the formation of the polar phase of PVDF and distortion of the CPB lattice, resulting in greatly enhanced piezoelectric performance for the CPB/PVDF composites. The output performance under the external force of a flexible generator developed from electrospun CPB/PVDF films is significantly enhanced compared with the neat PVDF film, with an 8.4 times higher maximum open circuit voltage value. Furthermore, the measurements on the microscopic piezoelectric responses unambiguously reveal that the increased polar phase mainly contributes to the enhanced electromechanical coupling. The functions of the CPB/PVDF films as physiological signal monitoring sensors are determined and they demonstrate their

potential applications as flexible piezoelectric generators and electronics for wearable health monitoring.

Keywords: Electromechanical conversion, PVDF fibers, inorganic metal halide perovskite, physiological signal monitoring

Review Article

2. A brief review of mechanical designs for additive manufactured soft materials

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Abstract

Additive manufacturing is an arising technology for soft materials and structures with improved complexity and functionality and has gradually become widespread in various fields, including soft robotics, flexible electronics and biomedical devices. Along with the development of material systems and fabrication techniques, mechanical design principles for additive manufactured soft materials have been greatly developed and evolved in recent years and some unique issues that are distinct from conventional manufacturing techniques have emerged. In this short review, we mainly focus on additive manufactured soft materials that are in significant need of mechanical models/simulations to provide design guidelines; therefore, topics such as soft robotics and electronics are not considered here. We first discuss the mechanical design methods for controlling shape distortions and interfacial strength, as they are directly related to the quality and reliability of additive manufactured soft materials. Design principles and manufacturing strategies for bioinspired composites, which represent a large part of current research on additive manufactured soft materials, are then summarized integrally with regards to three aspects. In addition, basic mechanical considerations for additive manufactured four-dimensional shape-changing structures are explained, together with a review of the recent theories and numerical approaches. Finally, suggestions and perspectives are given for future

developments in soft material additive manufacturing.

Keywords: Additive manufacturing, soft materials and structures, mechanical design

Perspective

3. Biomedical DNA hydrogels

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Abstract

Due to considerable progress in DNA nanotechnology, DNA is gaining significant attention as a programmable building block for the next generation of soft biomaterials. DNA has been used as either a single component to form all-DNA hydrogels or a crosslinker or functional entity to form hybrid DNA hydrogels through physical interactions or chemical reactions. The formed hydrogels exhibit adequate biocompatibility, convenient programmability, tunable multifunctionality and the capability of precise molecular recognition, making them an irreplaceable polymeric platform for interfacing with biology. Responsive DNA hydrogels that are prepared through the hybridization of DNA sticky ends, the formation of i-motifs, enzymatic ligation and enzymatic polymerization are commonly reported nowadays and can undergo disassembly induced by various triggers, including alterations in ionic strength, pH, temperature and biomolecules. These hydrogels are envisioned for applications in drug delivery and biosensing. This perspective assesses the most recent and important developments in this emerging class of biomedically useful DNA hydrogels.

Keywords: DNA polymers, DNA hydrogels, drug delivery, biosensing

Research Article

4. Fabrication method and performance of a light-responsive hydrogel microvalve in a microfluidic chip

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Abstract

Microfluidic technology has potential advantages in the complex manipulation of microfluidics on small-sized chips. However, it is difficult to integrate microvalves with complex flow channel structures, and this has limited the miniaturization of microfluidic systems and their portable applications. Light-responsive hydrogel (LRH) materials can rapidly change their volume under laser irradiation and can be used to prepare flexible microvalves to realize the integrated control of microfluidics. A simple fabrication method for an LRH microvalve on a microfluidic chip is proposed. The microspheres, as control elements of the microvalve based on an LRH modified with Laponite RD nanoclay and ferriferrous oxide (Fe_3O_4) nanoparticles, are prepared through a T-shaped flow channel. The microvalve is assembled on the microfluidic chip with a normally closed circulation channel. The open/close performance of the microvalve is represented by the color change of the photonic crystal material. The results show that the LRH microspheres shrink and the flow channel opens after laser irradiation for 2 s. After stopping the laser at 18 s, the valve core swells and the flow channel closes.

Keywords: Microvalve, responsive hydrogel, microfluidic chip, photonic crystals

Review Article

5. Crosslinked organosulfur-based self-assembled monolayers: formation and applications

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Copy here to cite this article: Yu T, Marquez MD, Tran HV, Lee TR. Crosslinked organosulfur-based self-assembled monolayers: formation and applications. Soft Sci 2022;2:5. <http://dx.doi.org/10.20517/ss.2022.04>

Abstract

Self-assembled monolayers (SAMs) have found use in diverse applications that range

from corrosion prevention to biosensing. However, for all of these applications, stability remains a key challenge for the utilization of SAMs. Over the last decade, intermolecular crosslinking as a method to enhance the thermal and chemical stability of SAMs has attracted increased attention from scientists and engineers. As such, this review introduces a variety of crosslinked SAMs: (1) aromatic thiol-based SAMs; (2) olefinic- and acetylenic-based alkanethiols; (3) other aliphatic alkanethiols; (4) silane-based alkanethiols; (5) boronic acid-based alkanethiols; and (6) crosslinked SAMs realized by hydrogen bonding. By offering insight into the structure-application relationships of the aforementioned SAMs, this review seeks to inspire researchers toward the development of new classes of SAMs with enhanced stabilities and working lifetimes.

Keywords: Self-assembled monolayers (SAMs), crosslinking, nanocoatings, stabilities, nanostructures

Review Article

6. A brief review of miniature flexible and soft tactile sensors for interventional catheter applications

[Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Interventional surgery has the advantages of small skin incisions, minimal blood loss, low postoperative infection and short recovery times, and thus has gradually become the preferred surgical approach over traditional open surgeries. Even though significant achievements have been made towards clinical applications, limitations still exist, among which the loss of the natural tactile perception of surgeons due to their indirect touch along the long catheter to the intervening human tissue is the crucial one. In recent years, researchers have dedicated great efforts to the development of advanced medical catheters with smart tactile perception ability, with

considerable progress having been made. In this regard, we review the most recent developments of state-of-the-art miniature flexible and soft tactile sensors that are able to be integrated in the tip or on the side wall of medical catheters. We particularly focus on the sensing mechanisms, design requirements, device configuration and sensing performance of different types of sensors, as well as their application demonstration in synthetic anatomical models and in vivo animal experiments. After reviewing the representative research work, the challenges that still exist are summarized and the prospects toward future development are proposed.

Keywords: Flexible and soft electronics, tactile sensors, pressure sensors, miniature sensors, interventional catheter, minimally invasive surgery

Perspective

7. PEDOT:PSS-based intrinsically soft and stretchable bioelectronics

[Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Intrinsically soft and stretchable bioelectronics exhibit tissue-like mechanical behavior that enables the seamless integration of electronic devices with the human body to achieve high-quality biosignal recording and high-efficacy neural modulation. The conducting polymer poly(3,4-ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS) shows significant promise in this field because of its high conductivity, excellent biocompatibility and commercial availability. However, pristine PEDOT:PSS is brittle and rigid and thus cannot be used in soft and stretchable electronics. More effort is therefore required to engineer PEDOT:PSS into a stretchable conductor that meets the demands of bioelectronics. In this perspective, we review the recent progress and propose the possible future directions of PEDOT:PSS-based bioelectronics.

Keywords

PEDOT:PSS, bioelectronics, stretchability, electrical conductivity

Research Article

8. Biocompatible composite thin-film wearable piezoelectric pressure sensor for monitoring of physiological and muscle motions

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Kim NI, Lee JM, Moradnia M, Chen J, Pouladi S, Yarali M, Kim JY, Kwon MK, Lee TR, Ryou JH. Biocompatible composite thin-film wearable piezoelectric pressure sensor for monitoring of physiological and muscle motions. *Soft Sci* 2022;2:8.

<http://dx.doi.org/10.20517/ss.2022.06>

Abstract

Whereas piezoelectric pressure sensors (PPSs) have been applied in the monitoring of human body movement and physiological parameters, they show inherent limitations in wearable applications, including toxicity, degradation, and brittleness. In this study, we develop safe, stable, and mechanically flexible composite thin films consisting of polyvinylidene fluoride (PVDF), BaTiO₃ nanoparticles (BTO-NPs), and textured aluminum nitride (AlN) thin film for the demonstration of wearable PPS with enhanced output performance and biocompatibility. The PPS made of BTO-NP-embedded-PVDF and AlN film on Cu foil is attached to different parts of human body to measure different output voltages depending on the physiological and physical stimulus. The simple bending (from breathing, chewing, and swallowing), joint motions (at wrist, elbow, and finger), and low- (from eyeball movement) and high-pressure applications (by squat, lunge, and walking) are measured. Our PVDF+BTO-NP/AlN-PPS (PBA-PPS) device has the potential for personal safety, healthcare, and activity monitoring applications with easy wearability.

Keywords

Wearable electronics, BaTiO₃-embedded PVDF, BaTiO₃/PVDF/AlN flexible piezoelectric pressure sensor, sputtered AlN thin films, human motion monitoring

9. Wearable electronics for skin wound monitoring and healing

[Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Wound healing is one of the most complex processes in the human body, supported by many cellular events that are tightly coordinated to repair the wound efficiently. Slow-healing wounds or chronic wounds have potentially life-threatening consequences. Traditional wound dressings come in direct contact with the wound to help it heal and avoid further complications. However, traditional wound dressings have some limitations. These dressings do not provide real-time information on wound conditions, missing the best time for adjusting treatment. Moreover, the current diagnosis of wounds is relatively subjective. Wearable electronics have become a unique platform to potentially monitor wound conditions in a continuous manner accurately and even to serve as accelerated healing vehicles. In this review, we briefly discuss the wound status with some objective parameters and biomarkers influencing wound healing, followed by the presentation of various novel wearable devices used for monitoring wounds and accelerating wound healing. We further summarize the associated device working principles. This review concludes by highlighting some major challenges in wearable devices toward wound healing that need to be addressed by the research community.

Keywords

Wearable electronics, sensors, wound monitoring, wound healing

10. Polyelectrolyte-based conductive hydrogels: from theory to applications

[Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Fan X, Chen Z, Sun H, Zeng S, Liu R, Tian Y. Polyelectrolyte-based conductive hydrogels: from theory to applications. Soft Sci 2022;2:10. <http://dx.doi.org/10.20517/ss.2022.09>

Abstract

With the continuous development of soft conductive materials, polyelectrolyte-based conductive hydrogels have gradually become a major research hotspot because of their strong application potential. This review first considers the basic conductive theory of hydrogels, which can be divided into the hydrogel structure and zwitterionic enhancing conductivity theories. We then classify polyelectrolyte-based conductive hydrogels into different types, including double, ionic-hydrogen bond, hydrogen bond, and physically crosslinked networks. Furthermore, the mechanical, electrical, and self-healing properties and fatigue and temperature interference resistance of polyelectrolyte-based conductive hydrogels are described in detail. We then discuss their versatile applications in strain sensors, solid-state supercapacitors, visual displays, wound dressings, and drug delivery. Finally, we offer perspectives on future research trends for polyelectrolyte-based conductive hydrogels.

Keywords

Polyelectrolytes, hydrogels, flexible sensors, hydrogel sensors

Review Article

11. A systematic review of fused deposition modeling process parameters

[Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Ahmad NFN, Wong YH, Ghazali NNN. A systematic review of fused deposition modeling process parameters. Soft Sci 2022;2:11. <http://dx.doi.org/10.20517/ss.2022.08>

Abstract

Fused deposition modeling (FDM) is an additive manufacturing technique with significant advantages, including cost effectiveness, applicability for a wide range of materials, user-friendliness and small equipment features. However, its poor resolution represents a hindrance for functional parts for commercial production. In

this review, the key process parameters are presented with their factors and effects on the characteristics of FDM-printed polymeric products. Hence, better insights into the relationship between key parameters and three main printing characteristics, namely, surface roughness, mechanical strength and dimensional accuracy, in existing FDM research are provided. A conclusion that addresses the challenges and future research directions in this area is also presented.

Keywords

Additive manufacturing, fused deposition modeling, process parameters, polymers, characteristics

Review Article

12. Advances in second-generation high-temperature superconducting tapes and their applications in high-field magnets

[Full-Text](#) [PDF](#) [RIS](#)

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Wang K, Dong H, Huang D, Shang H, Xie B, Zou Q, Zhang L, Feng C, Gu H, Ding F. Advances in second-generation high-temperature superconducting tapes and their applications in high-field magnets. *Soft Sci* 2022;2:12.

<http://dx.doi.org/10.20517/ss.2022.10>

Abstract

Second-generation high-temperature superconducting (2G-HTS) tapes based on REBa₂Cu₃O_{7-x} (REBCO, RE: rare earth) materials enable the energy-efficient and high-power-density delivery of electricity, thereby promoting the development of clean energy generation, conversion, transmission, and storage. To overcome the weak grain-boundary connection and poor mechanical properties of these superconductors, a thin-film technology for epitaxy and biaxial textures based on flexible substrates has been developed. In recent years, high-quality 2G-HTS tapes have been produced at the kilometer scale and used in superconducting demonstration projects. This review first summarizes the development of HTS materials and briefly expounds the properties of REBCO superconducting materials. Subsequently, the structural

characteristics, preparation methods, and current research progress of 2G-HTS tapes are given. In addition, the applications of REBCO tapes in constructing high-field magnets are also briefly reviewed.

Keywords

2G-HTS tapes, REBCO, flux pinning, high-field magnets

Research Article

13. Reliable metal alloy contact for $\text{Mg}_{3+\delta}\text{Bi}_{1.5}\text{Sb}_{0.5}$ thermoelectric devices

[Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Proper contacts between thermoelectric (TE) materials and electrodes are critical for TE power generation or refrigeration. The Bi-rich n-type Zintl material $\text{Mg}_{3+\delta}\text{Bi}_{2-x}\text{Sb}_x$ exhibits very good TE performance near room temperature, which makes $\text{Mg}_{3+\delta}\text{Bi}_{2-x}\text{Sb}_x$ -based compounds highly promising candidates to replace the $\text{Bi}_2\text{Te}_{3-y}\text{Sb}_y$ alloys, but ideal contacts that can match their TE performance have not yet been well studied. Here we investigate different metal (Ni and Fe) and metal alloy (NiFe, NiCr, NiCrFe, and stainless steel) contacts on n-type $\text{Mg}_{3+\delta}\text{Bi}_{1.5}\text{Sb}_{0.5}$. It is first shown that the low Schottky barrier and narrow depletion region resulting from the band degeneracy and high carrier concentration of a heavily doped TE material are beneficial for the formation of a low-resistivity ohmic contact with a metal or a metal alloy. Most fully optimized TE materials can take advantage of this. Second, it is found that the NiFe/ $\text{Mg}_{3+\delta}\text{Bi}_{1.5}\text{Sb}_{0.5}$ contact exhibits excellent thermal stability and the lowest ohmic contact resistivity among those studied after aging for over 2100 h, which is attributed to the formation of metallic NiMgBi between the NiFe and $\text{Mg}_{3+\delta}\text{Bi}_{1.5}\text{Sb}_{0.5}$ layers. As a buffer phase, NiMgBi can effectively prevent elemental diffusion without negatively affecting the electron transport. Benefiting from such low contact resistance, a $\text{Mg}_{3+\delta}\text{Bi}_{1.5}\text{Sb}_{0.5}/\text{Bi}_{0.4}\text{Sb}_{1.6}\text{Te}_3$ uncouple exhibits competitive

conversion efficiency, 6% with a 150 K temperature difference and a hot-side temperature of 448 K.

Keywords

Thermoelectric power generator, ohmic contact, $\text{Mg}_{3+\delta}\text{Bi}_{1.5}\text{Sb}_{0.5}$, NiFe alloy, energy conversion

Research Article

14. A hierarchical design for thermoelectric hybrid materials: Bi_2Te_3 particles covered by partial Au skins enhance thermoelectric performance in sticky thermoelectric materials

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Copy here to cite this article: Satoh N, Otsuka M, Kawakita J, Mori T. A hierarchical design for thermoelectric hybrid materials: Bi_2Te_3 particles covered by partial Au skins enhance thermoelectric performance in sticky thermoelectric materials. *Soft Sci* 2022;2:15. <http://dx.doi.org/10.20517/ss.2022.15>

Abstract

Sticky thermoelectric (TE) materials have been inversely designed to enable the mass production of flexible TE sheets through lamination or roll-to-roll processes without using electrically conductive adhesives. They have also been demonstrated as inorganic/organic hybrid materials consisting of TE inorganic particles and low-volatilizable organic solvents to exhibit Seebeck coefficients based on the TE particles and low thermal conductivities based on the organic matrix. To achieve energy harvesting of 250 μW for driving various electric devices using voltage boosters, herein, we employ p- and n-type Bi_2Te_3 particles due to their high Seebeck coefficients, and cover the Bi_2Te_3 bodies with Au skins because the interfacial electrical resistance depends on the electrical resistance of opposing substances at the interface. After controlling the plating amount to cover the Bi_2Te_3 particles with Au skins, we achieve a TE power generation two orders of magnitude greater than the previous study, i.e., 255 μW on a hot plate of 110 $^{\circ}\text{C}$ with a 6×6 module. Overall, with input from other organic devices, like organic light-emitting diodes and

dye-sensitized solar cells, this study presents a hierarchical design for TE hybrid materials that suppresses the thermal conduction by hybridizing TE particles with the organic matrix at the microscale. This reduces the electrical resistance by modifying the interfaces of the TE particles at the nanoscale and optimizes the Seebeck coefficient of TE particles at the atomic scale. To compete with solid-state TE modules with regards to power generation capacity, the hierarchical design towards a possible further two orders of magnitude improvement is also discussed.

Keywords

Hybrid materials, Bi₂Te₃ particles, particle plating, hierarchical design, organic light-emitting diodes, dye-sensitized solar cells

Research Article

15. A template-stripped carbon nanofiber/poly(styrene-butadiene-styrene) compound for high-sensitivity pressure and strain sensing

[Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article:

Xiong Y, Lin Z, Zhao Z, Xu Y, Wan Y, Zhu P, Hu Y, Sun R. A template-stripped carbon nanofiber/poly(styrene-butadiene-styrene) compound for high-sensitivity pressure and strain sensing. Soft Sci 2022;2:14. <http://dx.doi.org/10.20517/ss.2022.12>

Abstract

Materials selection and microstructural design of the sensing part of flexible pressure sensors are of great significance in improving their performance. However, achieving synergy between the sensing material and the microstructure of the flexible sensors remains a challenge. Herein, compressible and stretchable sensors based on a carbon nanofiber/poly(styrene-butadiene-styrene) (CNF/SBS) compound are demonstrated with a template-stripped method for detecting various human motions, including pulses, finger bending and pressure distributions. Benefiting from the adjustable fingerprint microstructure and mass fraction of CNFs, the as-designed flexible pressure sensor dramatically achieves a high sensitivity of 769.2 kPa⁻¹, a low detection limit of 5 Pa and high reliability of over 1000 cycles. Moreover, the flexible

sensor based on CNF/SBS can be stretched due to the outstanding tensile properties of SBS. The enhanced stretchable sensor remarkably possesses a high gauge factor of 105.6 with a stretch range of 0%-300% and up to 600% elongation. Importantly, the proposed pressure and tension strain sensors are investigated to monitor vigorous human motion, revealing their tremendous potential for applications in flexible compressible and stretchable wearable electronics.

Keywords

Pressure sensors, stretchable sensors, high sensitivity, tactile application

Research Article

16. Citric acid-based degradable polyester elastomers coated with silver nanowires for sustainable soft sensors

[Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article:

Wang Z, Zhou H, Zheng B, Gao Y, Zhang H, Jin X, Zhang G, Ma A. Citric acid-based degradable polyester elastomers coated with silver nanowires for sustainable soft sensors. *Soft Sci* 2022;2:16. <http://dx.doi.org/10.20517/ss.2022.14>

Abstract

Although soft electronic materials are of significant importance for flexible electronic devices, most of them are derived from commercial polymer elastomers, such as polydimethylsiloxane, polyurethane and Ecoflex. In this work, citric acid-based degradable polyester elastomers are prepared by a melt polycondensation process, utilizing citric acid, 1,8-octanediol and poly(ethylene glycol) (PEG) as monomers. Furthermore, poly(1,8-octanediol citrate acid) (POC)-PEG/silver nanowire (AgNW) conductive polyester elastomers (CPEs) are prepared by introducing a AgNW layer on the surface of the POC-PEG films. Scanning electron microscopy images reveal that the thickness of the AgNW layer is on the scale of several micrometers and the AgNWs form a continuous conductive network. Upon mechanical stimuli, POC-PEG exhibits recoverable deformation and induces variation in the AgNW conductive network, resulting in a conversion of strain to detectable resistance. When tensile

strain is applied, the POC-PEG/AgNW CPEs achieve a gauge factor of 231.6, a response range of 0%-50%, a low response time of 35 ms and high stability. Moreover, the POC-10PEG/AgNW CPE also responds to bending deformation with a gauge factor of 3667.5, a response range of 0%-8.4%, a low response time of 62 ms and high stability. On the basis of strain sensitivity, wireless sensors are further assembled by integrating the POC-PEG/AgNW CPEs into a Bluetooth signal transmission system. Various human motions and physiological activities are successfully monitored using the wireless sensors. The results demonstrate that degradable citric acid-based polyester elastomers/AgNW CPEs are promising materials for next-generation sustainable and flexible electronic devices.

Keywords

Polyester elastomers, citric acid, AgNWs, strain sensitivity, degradable

Review Article

17. Recent advances in flexible and soft gel-based pressure sensors

[Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Sun G , Wang P , Jiang Y , Sun H , Meng C , Guo S . Recent advances in flexible and soft gel-based pressure sensors. *Soft Sci* 2022;2:17. <http://dx.doi.org/10.20517/ss.2022.16>

Abstract

Gels, as typical flexible and soft materials, possess the intrinsic merits of transparent bionic structures, superior mechanical properties and excellent elasticity and viscosity. Recently, gel-based materials have attracted significant attention as a result of their broad and promising applications in biomedical, energy storage, light emission, actuator, military and aerospace devices, especially the intelligent sensing for human-related applications. Among the various flexible and soft pressure sensors, gel-based ones have been gradually studied as an emerging hot research topic. This review focuses on the latest findings in the rapidly developing field of gel-based pressure sensors. Firstly, the classification and properties of the three types of gels and

their corresponding fabrication methods are introduced. Secondly, the four basic working principles of pressure sensors are summarized with a comparison of their advantages and disadvantages, followed by an introduction to the construction of pressure sensors based on gel structures. Thirdly, the latest representative research on the three types of gel-based materials towards various wearable sensing applications, including electronic skin, human motion capture, healthcare and rehabilitation, physiological activity monitoring and human-machine interactions, is comprehensively reviewed. Finally, a summary of the remaining challenges and an outline of the development trend for this field are presented.

Keywords

Hydrogels, ionogels, aerogels, soft materials, pressure sensors, wearable electronics

Research Article

18. Direct fabrication of high-performance multi-response e-skin based on a graphene nanosheet film

[Full-Text](#) [PDF](#) [RIS](#)

Abstract

With the increasing popularity of wearable devices, lightweight electronic skin (e-skin) has attracted significant attention. However, current fabrication technologies make it difficult to directly fabricate sensing materials on flexible substrates at low temperatures. Hence, we propose a flexible graphene nanosheet-embedded carbon (F-GNEC) film, which is directly grown on a flexible substrate using an electron cyclotron resonance low-temperature sputtering system. The direct batch manufacturing of e-skin is obtained by the unique plasma generation mode of electron cyclotron resonance and the polariton energy transfer mode between the plasma and substrate surface. The F-GNEC film contains a large number of graphene nanosheets grown vertically and the graphene edges can serve as electron capture centers, thereby

enabling the multi-response properties. We achieve a high gauge factor of 14,699 under a tensile strain of $\varepsilon = 0.5\%$ and the changing rate of the resistance reaches to 113.2% when the e-skin is bent to 120° . Furthermore, the e-skin achieves a photocurrent of $1.2 \mu\text{A}$ under 532 nm laser illumination. The F-GNEC film exhibits a sensitive temperature response and achieves a coefficient of $-0.58\%/^\circ\text{C}$ in a wide temperature range (30-100 $^\circ\text{C}$). The directly fabricated F-GNEC film-based e-skin is stable and firm and exhibits multi-response detection capabilities, which enable its potential application in virtual reality technology and flexible robots.

Keywords

Electronic skin, direct fabrication, graphene-embedded carbon film, multi-response detection