

Table of Contents

1. Uncovering isolated resonant responses in antagonistic pure-shear dielectric elastomer actuators.....	2
2. Improved thermoelectric performance in n-type flexible Bi ₂ Se _{3+x} /PVDF composite films.....	3
3. Recent progress in flexible tactile sensor systems: from design to application.....	3
4. Simultaneously enhancing moisture and mechanical stability of flexible perovskite solar cells via a polyimide interfacial layer.....	4
5. Soft materials for wearable supercapacitors.....	5
6. Recent progress in pressure and temperature tactile sensors: principle, classification, integration and outlook.....	5
7. Why is the new journal Soft Science needed?.....	6
8. Sodium nanofluid for efficient oil recovery in heavy oil and oil sand reservoirs.....	7
9. Control of low dimensionality in flexible hybrid inorganic-organic superlattices.....	7
10. Tattoo-like epidermal electronics as skin sensors for human-machine interfaces.....	8
11. Remarkable interfacial dielectric relaxation of physically cross-linked ice hydrogels.....	9
12. Unraveling the main chain effects of fused thiophene conjugated polymers in electrochromism.....	10
13. Design and fabrication of a reconfigurable and flexible frequency selective surface with a buckling dipole via mechanical stretching.....	12
14. Thermoelectric and mechanical performances of ionic liquid-modulated PEDOT:PSS/SWCNT composites at high temperatures.....	13
15. Insights into fluidic endogenous magnetism and magnetic monopoles from a liquid metal droplet machine.....	13
16. Flexible, high-strength, and porous nano-nano composites based on bacterial cellulose for wearable electronics: a review.....	15

1. Uncovering isolated resonant responses in antagonistic pure-shear dielectric elastomer actuators

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Abstract

The dielectric elastomer actuator (DEA) is one type of emerging soft actuator that has the attractive features of large actuation strains, high energy density, and inherent compliance, which is desirable for novel bio-inspired and soft robotic applications. Due to their inherent elasticity, when stimulated by an alternating current voltage with a frequency matching the natural frequency of the DEA system, the DEAs can exhibit resonant responses which maximize the oscillation amplitude. Silicone elastomers are widely utilized for resonant actuation applications for their reduced viscous damping hence better dynamic performance compared to VHB elastomers. However, the low pre-stretch ratios adopted by silicone elastomers could induce loss-of-tension of the membranes in high amplitude oscillations, yet its effects on the dynamic responses of a DEA are not fully understood. By using a numerical dynamic model, this work studies the effects of the loss-of-tension on the frequency response of the antagonistic pure-shear DEAs. A subharmonic frequency response curve isolated from the main response branch is uncovered for the first time in a parametrically forced DEA system, which causes a sudden jump in the oscillation amplitude and serves as a severe threat to the dynamic stability and controllability of the DEA system. By using a global analysis method, the evolution of the isolated response curve against the excitation components and system physical parameters is also investigated numerically.

Keywords: Dielectric elastomer actuators, pure-shear configuration, nonlinear dynamics, isolated response curve, soft oscillator

Research Article

2. Improved thermoelectric performance in n-type flexible $\text{Bi}_2\text{Se}_{3+x}$ /PVDF composite films

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Copy here to cite this article: Zou Q, Shang H, Huang D, Li T, Xie B, Gu H, Ding F. Improved thermoelectric performance in n-type flexible $\text{Bi}_2\text{Se}_{3+x}$ /PVDF composite films. Soft Sci 2021;1:2. <http://dx.doi.org/10.20517/ss.2021.04>

Abstract

Bismuth selenide materials (Bi_2Se_3) have high performance around room temperature, demonstrating potential in thermoelectric applications. Presently, most vacuum preparation techniques used to fabricate the film materials, such as magnetron sputtering and molecular beam epitaxy, usually require complex and expensive equipment. This limits the practical applications of flexible thermoelectric films. Here, we prepared $\text{Bi}_2\text{Se}_{3+x}$ nanoplate/polyvinylidene fluoride composite films with good flexibility using a facile chemical reaction method. Their thermoelectric performance and microstructures were systematically studied. The composite films exhibit a highly preferred orientation along (015). The carrier concentration and mobility were optimized by adding excessive element Se, eventually leading to an improvement in thermoelectric performance. The optimized power factor is $5.2 \mu\text{W}/\text{K}^2\text{m}$ at 300 K. Furthermore, the performance remains stable after 2500 bending cycles at a radius of 1 cm, suggesting promising applications in wearable/portable electronics.

Keywords: Bi_2Se_3 , flexible, thermoelectric films, heterostructure

Review Article

3. Recent progress in flexible tactile sensor systems: from design to application

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Copy here to cite this article: Zhu J, Zhou C, Zhang M. Recent progress in flexible tactile sensor systems: from design to application. Soft Sci 2021;1:3. <http://dx.doi.org/10.20517/ss.2021.02>

Abstract

With the rapid development of artificial intelligence, human-machine interaction, and

healthcare systems, flexible tactile sensors have huge market potentials and research needs, so that both fundamental research and application demonstrations are evolving rapidly to push the potential to reality. In this review, we briefly summarize the recent progress of the flexible tactile sensor system, including the common sensing mechanisms, the important performance evaluation parameters, the device design trend, and the main applications. Moreover, the current device design trend towards flexible tactile sensor systems is discussed, including novel structures for outstanding performance, sensor arrays for large-area information acquisition, multi-mode information acquisition, and integration of tactile sensors with transistors. Various emerging applications enabled with these sensors are also exemplified in this review to show the potentials of the tactile sensors. Finally, we also discuss the technical demands and the future perspectives of flexible tactile sensor systems.

Keywords: Tactile sensor, flexible sensing, sensor system

Research Article

4. Simultaneously enhancing moisture and mechanical stability of flexible perovskite solar cells via a polyimide interfacial layer

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Abstract

Perovskite solar cells (PSCs) have aroused tremendous attention due to the high power conversion efficiency (PCE) and flexibility of the organic-inorganic hybrid perovskite films. However, the commercialization of perovskite solar cells is still impeded due to the instability issue induced by moisture and mechanical stress. Herein, we introduce soluble hydrophobic polyimide (PI) as an interfacial layer on top of the perovskite film to block the infiltration of moisture into the perovskite film. The MAPbI₃-based solar cell with the insertion of PI layer exhibited an impressive stability, maintaining 87% of the initial PCE even after exposing to 50% relative

humidity for 550 h and presenting a decent PCE of 21.22% due to its ability to extract holes and reduce trap-assisted recombination. Moreover, the high tolerance of PI to the mechanical stress gives a more stable flexibility to the PSCs under constant bending.

Keywords: Stability, hydrophobic, charge extraction, perovskite solar cells

Review Article

5. Soft materials for wearable supercapacitors

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Abstract

Along with the rapid progress of wearable and portable electronic devices including electrical sensors, flexible displays, and health monitors, there is an ever-growing demand for wearable power sources. Supercapacitors, as a new kind of energy storage device, have received considerable attention for decades due to their high power density, excellent cycling stability, and easy fabrication. To fulfill the demand of wearable power sources, wearable supercapacitors are also further developed and studied. New electrode materials that play a significant role in determining both the wearability and electrochemical performance of wearable supercapacitors are also extensively explored. Herein, the recent progress on wearable soft electrode/electrolyte materials and the structure design strategies for developing wearable supercapacitors are summarized. Additionally, the existing challenges in current technologies and research are highlighted and discussed with the hope of inspiring future studies.

Keywords: Soft materials, electrodes, electrolytes, structure design, wearable supercapacitors

Review Article

6. Recent progress in pressure and temperature tactile sensors: principle, classification, integration and outlook

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Copy here to cite this article: Yu J, Zhang K, Deng Y. Recent progress in pressure and temperature tactile sensors: principle, classification, integration and outlook. Soft Sci 2021;1:6. <http://dx.doi.org/10.20517/ss.2021.05>

Abstract

Tactile sensors have received increasing research interest owing to the broad applications in areas of health monitoring, artificial intelligence, robotics, and prosthetics. The ability to understand and perceive touch and heat is of importance because it helps people to recognize objects, prevent injury, and provide heat information from grasped objects. However, bimodal tactile sensors often suffer from signal interference and complicated fabrication process. Numerous efforts have been undertaken to develop highly independent sensors based on different transduction principles as well as the device integration techniques. Here, strategies for improvement of main performance parameters such as sensitivity, sensing range, hysteresis, response/recovery time, and stability are discussed. A comprehensive overview of important progress in pressure and temperature tactile sensors in recent years is summarized. According to sensor units and transduction principles, temperature and pressure tactile sensors are categorized into two types: dual-parameter sensors and integrated bimodal sensors. Integration of tactile sensors from the viewpoint of power supply, wireless communication, and signal process circuit is given. Finally, challenges and outlook are provided and presented for pressure and temperature tactile sensors.

Keywords: Tactile sensor, pressure sensor, temperature sensor, dual-parameter sensor, bimodal sensor

Editorial

7. Why is the new journal Soft Science needed?

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

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Research Article

8. Sodium nanofluid for efficient oil recovery in heavy oil and oil sand reservoirs

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

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Abstract

Nanomaterials exhibit unique chemical and physical properties in comparison with their bulk-phase counterparts, attracting significant attention from the oil and gas industry in the hope of solving challenging issues. Current heavy oil extraction methods are costly and have unsatisfactory efficiency, and facing environmental restrictions increasingly. Our recent introduction of sodium (Na) nanofluid provides a promising method for heavy oil extraction since it shows improved oil recovery without burning carbon-containing fuels. Here, we conducted core-flooding tests to further evaluate the effect of this Na nanofluid on recovering oil from different formations, which had not been previously demonstrated, as well as to deepen our understanding of the underlying mechanisms. The Na nanofluid exhibited excellent oil-extraction efficiency for both types of heavy oil tested. The recovery mechanisms were found to be complicated. We also found that post-injection soaking and using the proper solvent to disperse the sodium nanoparticles are important for further boosting oil recovery.

Keywords: Sodium nanoparticles, heavy oil, oil sands, enhanced oil recovery, bitumen

Research Article

9. Control of low dimensionality in flexible hybrid inorganic-organic superlattices

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Abstract

The control of electron and phonon transport by manipulating dimensionality is essential for the performance of advanced electronic materials and devices, such as quantum electronics, thermoelectrics and superconductors, which may also lead to yet undiscovered, emergent electronic or thermal phenomena. In this study, we report a series of hybrid inorganic-organic superlattice structures, in which metallic TiS₂ monolayers are spatially confined between soft and insulating organic molecules of varying thicknesses. By choosing different organic molecules that increase the interlayer distance, the electrons inside the TiS₂ layers gradually become two-dimensional, with increasing density of states, as seen by their effective mass that increases from 5.3 to 8.6 m_0 , where m_0 is the mass of a bare electron. In addition, density functional theory calculations confirm a transition of the electron distribution from bulk to two-dimensional, due to the suppressed interlayer coupling. This result demonstrates that the thermoelectric transport of two-dimensional electrons can be realized in a three-dimensional inorganic-organic superlattice, thus enabling access to the interesting properties of individual two-dimensional materials in the bulk form, which may provide new opportunities in flexible thermoelectrics.

Keywords: TiS₂, inorganic-organic superlattices, two-dimensional electrons, flexible thermoelectrics

Research Article

10. Tattoo-like epidermal electronics as skin sensors for human-machine interfaces

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

Copy here to cite this article: Wong TH, Yiu CK, Zhou J, Song Z, Liu Y, Zhao L, Yao K, Park W, Yoo W, Song E, Xie Z, Yu X. Tattoo-like epidermal electronics as skin sensors for human-machine interfaces. *Soft Sci* 2021;1:10. <http://dx.doi.org/10.20517/ss.2021.09>

Abstract

Flexible electronic skin (e-skin) has been successfully utilized in diverse applications, including prosthesis sensing, body-motion monitoring and human-machine interfaces, due to its excellent mechanical properties and electrical characteristics. However, current e-skins are still relatively thick ($> 10\ \mu\text{m}$) and uncomfortable for long-term usage on the human body. Herein, an ultrathin skin-integrated strain sensor with miniaturized dimensions, based on the piezoresistive effect, with excellent stability and robustness, is introduced. The fractal curve-shaped Au electrode in a serpentine format, which is the dominant component of the strain sensor, is sensitive to ambient strain variations and can turn the mechanical motion into a stable electrical signal output. With the advanced design of metallic electrodes, the device presents good operational stability and excellent mechanical tolerance towards bending, stretching and twisting. The strain sensor allows intimate mounting onto the human epidermal surface for the detection of body motion. By adopting a liquid bandage as an encapsulation layer, the device exhibits an ultrathin thickness ($6.2\ \mu\text{m}$), high sensitivity towards mechanical deformations and capability for the clear detection of motion, such as walking, finger bending and the human pulse rate with identifiable electrical signals. Furthermore, the tattoo-like strain sensor is applied in robotic control by tracing finger bending motion and results in the smooth control of a robotic hand nearly without any detention. This e-skin design exhibits excellent potential for wearable electronics and human-machine interfaces.

Keywords: Skin-integrated electronics, ultrathin, excellent repeatability, fractal design, stretchable electronics

Research Article

11. Remarkable interfacial dielectric relaxation of physically cross-linked ice hydrogels

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

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Abstract

In the conventional scenario, it is believed that hydrogels typically consist of two-phase coexisting structures based on polymer structural networks filled with water droplets and that the polymer-water interfacial layer may not be a substantial component in determining their structure and functionality. Unfortunately, it is challenging to unveil the properties of the interfacial layer, if any, owing to the multiphase nature and structural complexity of hydrogels. In this work, the morphology and microstructures of the well-known non-covalent bonding dominant polyacrylonitrile-based hydrogels are characterized and it is confirmed that the as-prepared hydrogels do consist of polymer networks and filled water droplets. The dielectric relaxation behavior in the ice hydrogel state with different water/ice contents is investigated in detail by means of dielectric relaxation spectroscopy, in order to avoid the electrode polarization effect, which is non-negligible in liquid hydrogels, particularly in the low-frequency range. The dielectric relaxation spectroscopy data demonstrate the remarkable dielectric response contributed from the polymer-ice interfacial layer, which likely accommodates a high density of polar molecules/dipoles. The temperature-dependent dielectric relaxation behavior of the ice hydrogels with different water contents is discussed and the thermal activation energy for the interfacial polar structure may be likely extracted from the dielectric loss peak data. It is found that this energy is approximately consistent with the typical bonding energy of non-covalent bonding dominant hydrogels. This study represents a substantial step towards understanding the interfacial coupling in hydrogels, an issue that has not yet been thoroughly considered.

Keywords: Ice hydrogels, dielectric relaxation, polar molecules, interfacial layer

Research Article

12. Unraveling the main chain effects of fused thiophene conjugated polymers in

electrochromism

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Copy here to cite this article: Lin K, Liang H, Zheng Y, Hu R, Chen H, Wu Z, Zhang X, Xie H, Wang Y, Jiang Q, Lu B. Unraveling the main chain effects of fused thiophene conjugated polymers in electrochromism. *Soft Sci* 2021;1:12. <http://dx.doi.org/10.20517/ss.2021.15>

Abstract

The influence of increasing fused thiophene rings for the corresponding conjugated polymers [polythiophene (PT), poly(thieno[3,2-b]thiophene) (PTT) and poly(dithieno[3,2-b:2',3'-d]thiophene) (PDTT)] on their photophysical and electrochemical properties, morphology and electrochromic performance are investigated in detail in this study. PDTT is the easiest of the three polymers to prepare and has the lowest onset oxidation potential of 1.17 V because of its increased donor ability, lower than those of PTT (1.41 V) and PT (1.82 V). PDTT also exhibits the best electrochemical and thermal stability because of its extended conjugated skeleton. The PT, PTT and PDTT polymers present poor, good and moderate electrochromic properties, respectively, with increasing fused thiophene rings. PTT displays the highest ΔT of 35% in 700 nm, the fastest response time of 1.0 s and the maximum colouration efficiency (CE) of $94 \text{ cm}^2 \text{ C}^{-1}$, which is attributed to its enhanced morphology, since the PTT film is conducive to the promotion of ions to dope and dedope. Flexible electrochromic devices are fabricated and PTT exhibits the highest ΔT (60% in 480 nm and 16% in 660 nm), as well as excellent stability with less than a 5% ΔT reduction after successive cycling of 1000 s. All these findings indicate that the precise regulation of the fused thiophene is crucial in achieving high performance in electrochromism, which provides insight for the design of electrochromic conjugated polymers and flexible electrochromic devices.

Keywords: Fused thiophene rings, main chain effect, electrochemistry, electrochromism, flexible electrochromic devices

13. Design and fabrication of a reconfigurable and flexible frequency selective surface with a buckling dipole via mechanical stretching

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

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Abstract

Frequency selective surfaces (FSSs) with reconfigurable resonant frequency show significant potential for engineering applications. In this study, we propose a flexible FSS with a buckling dipole prepared by releasing the substrate pre-strain to buckle the locally adhered two-dimensional precursors, which can withstand large mechanical tensile deformation and change their resonant frequency during deformation. When the FSS is subjected to uniaxial tensile deformation, the capacitive effect between the adjacent buckled metal unit cells is significantly reduced due to the increase in the gap between the unit cells and period. This significant change in the equivalent circuit parameters due to the geometry change is highly beneficial for actively tuning the resonant frequency of the FSS. Electromagnetic (EM) experiments and simulations and equivalent circuit calculations are used to explore the EM tuning mechanism of the FSS and consistent conclusions are obtained. The results show that the FSS exhibits band-stop EM wave transmission characteristics with a resonant frequency of 6.1 GHz in the unstretched state and 21% uniaxial stretching strain can introduce a ~1.1 GHz increase in the resonant frequency. The corresponding parameter analysis shows that when the gap of the buckling dipoles in the width direction is reduced, the change in the resonant frequency caused by uniaxial stretching can be significantly increased, even to 2.5 GHz, which may help the FSS adapt to complex practical applications by tailoring the geometry of the buckling dipole.

Keywords: Frequency selective surfaces, flexible, reconfigurable, mechanical stretching, three-dimensional assembly

Research Article

14. Thermoelectric and mechanical performances of ionic liquid-modulated PEDOT:PSS/SWCNT composites at high temperatures

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Abstract

Significant progress has been achieved for flexible polymer thermoelectric (TE) composites in the last decade due to their potential application in wearable devices and sensors. In sharp contrast to the exceptional increase in TE studies at room temperature, the mechanical performance of polymer TE composites has received relatively less attention despite the significance of the application of TE composites in high-temperature environments. The TE and mechanical performances of flexible poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate)/single-walled carbon nanotube (PEDOT:PSS/SWCNT) composite films with an ionic liquid (IL) (referred to as “PEDOT:PSS/SWCNT-IL”) at high temperatures are studied in the present work. The fabricated composite films show increasing TE performance with increasing temperature and SWCNT content. The maximum value of the power factor reaches $301.35 \mu\text{Wm}^{-1} \text{K}^{-2}$ at 470 K for the PEDOT:PSS/SWCNT-IL composite. Furthermore, the addition of the IL improves the elongation at break of the composites compared to the IL-free composites. This work promotes the advancement of flexible polymer TE composites and widens their potential applications at different temperature ranges.

Keywords: Thermoelectrics, composite films, ionic liquids, mechanical performance

Research Article

15. Insights into fluidic endogenous magnetism and magnetic monopoles from a liquid metal droplet machine

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

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Abstract

Magnetism and magnetic monopoles are among the most classical issues in physics. Conventional magnets are generally composed of rigid materials and may face challenges in extreme situations. Here, as an alternative to rigid magnets, we propose, for the first time, the generation of fluidic endogenous magnetism and construct a magnetic monopole through tuning with a liquid metal machine. Based on theoretical interpretation and conceptual experimental observations, we illustrate that when liquid metals, such as gallium alloy, in a solution rotate under electrical actuation, they form an endogenous magnetic field inside. This explains the phenomenon where two such discrete metal droplets can easily fuse together, indicating their reciprocal attraction via the N and S poles. Furthermore, we reveal that a self-fueled liquid metal motor also runs as an endogenous fluidic magnet owing to the electromagnetic homology. When aluminum is added to liquid gallium in solution, it forms a spin motor and dynamically variable charge distribution that produces endogenous magnetism inside. This explains the common phenomena where reflective collision and attractive fusion between running liquid metal motors occur, which are partially caused by the dynamic adjustment of their N and S polarities, respectively. On this basis, more experimental approaches capable of generating dynamic electrical fields also work for the same target. Finally, we propose that such a fluidic endogenous magnet could lead to a magnetic monopole and four technical routes to realize this are suggested. The first involves matching the interior flow of liquid metal machines. The second is the superposition between an external electric effect and the magnetic field. The third route involves composite construction between magnetic particles and a liquid metal spin motor. Finally, chemical methods, such as via galvanic cell reactions, are proposed. Overall, the present theory and identified experimental evidence illustrate the role of a liquid metal machine as a fluidic endogenous magnet and highlight promising methods for the realization of magnetic monopoles. A group of

unconventional magnetoelectric devices and applications could therefore be possible in the near future.

Keywords: Fluidic magnet, magnetic monopoles, spin liquid metal, endogenous magnetism, droplet machine, self-fueled motor

Research Article

16. Flexible, high-strength, and porous nano-nano composites based on bacterial cellulose for wearable electronics: a review

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

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Abstract

Portable flexible electronics based on petroleum-based polymers have stepped onto the stage of modern technology. Increasing environmental problems facilitate emerging technologies based on cellulose because of its abundant sources and the nature of CO₂ consumption and biodegradability. Bacterial cellulose (BC) stands out among all cellulose materials because of its unique features, including the abundant hydrogen bonds, small diameter, three-dimensional nano-networked structures, high purity and crystallinity, and the degree of polymerization. The adequate properties impart BC and its nano-nano composites with superior balance among ductility, strength, and porosity, which are crucial for wearables. The principles of this balance, the fabrication of the nano-nano composites, and the wearable electronic applications based on BC are discussed in detail in this review.

Keywords: bacterial cellulose, strength, porosity, flexibility, nano-nano structure