

# WHAT ARE THE FLEXIBLE ENERGY STORAGE DEVICES



Why do we need flexible energy storage devices? To achieve complete and independent wearable devices, it is vital to develop flexible energy storage devices. New-generation flexible electronic devices require flexible and reliable power sources with high energy density, long cycle life, excellent rate capability, and compatible electrolytes and separators.



How can flexible energy storage systems advance wearable electronic device development? To advance wearable electronic device development, this review provides a comprehensive review on the research progress in various flexible energy storage systems. This includes novel design and preparation of flexible electrode materials, gel electrolytes, and diaphragms as well as interfacial engineering between different components.



What are flexible energy storage devices (fesds)? Consequently, there is an urgent demand for flexible energy storage devices (FESDs) to cater to the energy storage needs of various forms of flexible products. FESDs can be classified into three categories based on spatial dimension, all of which share the features of excellent electrochemical performance, reliable safety, and superb flexibility.



Are flexible energy-storage devices possible? Consequently, considerable effort has been made in recent years to fulfill the requirements of future flexible energy-storage devices, and much progress has been witnessed. This review describes the most recent advances in flexible energy-storage devices, including flexible lithium-ion batteries and flexible supercapacitors.



Do flexible energy storage devices integrate mechanical and electrochemical performance? However, the existing types of flexible energy storage devices encounter challenges in effectively integrating mechanical and electrochemical performances.

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Can ultraflexible energy harvesters and energy storage devices form flexible power systems? The integration of ultraflexible energy harvesters and energy storage devices to form flexible power systems remains a significant challenge. Here, the authors report a system consisting of organic solar cells and zinc-ion batteries, exhibiting high power output for wearable sensors and gadgets.



Thus, advances in materials and cell designs are needed in flexible/wearable energy storage devices. Some promising batteries, supercapacitors, and micro-energy storage devices have demonstrated quantitative mechanical flexibility at the device level. Parameters including the capacity/capacitance, energy density, cycling stability, and



With the rapid development of wearable electronics, flexible energy storage devices that can power them are quickly emerging. Among multitudinous energy storage technologies, flexible batteries have gained significant attention, benefiting from high energy density and long cycling life. An ideal flexible bat



Inkjet printing is considered to be a promising technology for manufacturing low-cost high-performance flexible energy storage devices because of its material-saving feature and pattern-writing flexibility. Very recently, great efforts have been dedicated to adapting inkjet printing for the production of practical flexible energy storage



Interest in flexible and wearable electronics has surged in the past several years. The development of these electronics critically demands flexible and wearable energy storage devices (ESDs) that possess both high energy and power density and superior flexibility and durability to power various wearable systems. 1 Thus, extensive efforts have been ???

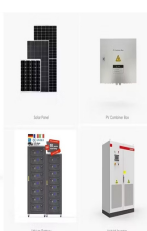
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Research into flexible energy-storage devices with high energy density and superior mechanical performance has aroused considerable interest for the development of flexible electronics. Numerous new materials and strategies have been developed to obtain soft, safe, and high-performance flexible electrodes, which are essential components of



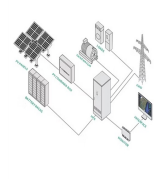
With the rapid advancements in flexible wearable electronics, there is increasing interest in integrated electronic fabric innovations in both academia and industry. However, currently developed plastic board-based batteries remain too rigid and bulky to comfortably accommodate soft wearing surfaces. The integration of fabrics with energy-storage devices ???



Hence, this review is focused on research attempts to shift energy storage materials toward sustainable and flexible components. We would like to introduce recent scientific achievements in the application of noncellulosic polysaccharides for flexible electrochemical energy storage devices as constituents in composite materials for both



Flexible energy storage devices are increasingly capturing worldwide attentions due to their promising potential to be integrated with flexible portable and wearable electronics. The electrochemical performance of the flexible energy storage devices is usually influenced by both the electrode materials and device configurations. The special 2D



Here, the state-of-the-art advances of the hydrogel materials for flexible energy storage devices including supercapacitors and rechargeable batteries are reviewed. In addition, devices with various kinds of functions, such as self-healing, shape memory, and stretchability, are also included to stress the critical role of hydrogel materials.

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With the growing market of wearable devices for smart sensing and personalized healthcare applications, energy storage devices that ensure stable power supply and can be constructed in flexible platforms have attracted tremendous research interests. A variety of active materials and fabrication strategies of flexible energy storage devices have been ???



A series of materials and applications for flexible energy storage devices have been studied in recent years. In this review, the commonly adopted fabrication methods of flexible energy storage devices are introduced. Besides, recent advances in integrating these energy devices into flexible self-powered systems are presented.



Flexible devices, such as flexible electronic devices and flexible energy storage devices, have attracted a significant amount of attention in recent years for their potential applications in modern human lives. The development of flexible devices is moving forward rapidly, as the innovation of methods and manufacturing processes has greatly encouraged ???



This review describes the most recent advances in flexible energy-storage devices, including flexible lithium-ion batteries and flexible supercapacitors, based on carbon materials and a number of composites and flexible micro-supercapacitor. Flexible energy???storage devices are attracting increasing attention as they show unique promising advantages, such ???



In summary, a flexible zinc ion electrochromic energy storage device, integrating electrochromic capabilities, energy storage, and mechanical flexibility, has been successfully developed. By combining a Prussian blue thin film with a self-healing gel electrolyte, the device demonstrates a high discharge voltage of 1.25 V and excellent surface

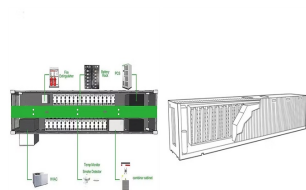
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Within this review, we highlight the design of efficient SOICs and their incorporation into flexible energy generation and storage devices, and address exciting instances that profile the multifunctionality of SOICs such as three-dimensional (3D) ionic channels, excellent thermal stability, dual functionality (hole/ions transportation), one



Energy density (E), also called specific energy, measures the amount of energy that can be stored and released per unit of an energy storage system [34]. The attributes "gravimetric" and "volumetric" can be used when energy density is expressed in watt-hours per kilogram (Wh kg<sup>-1</sup>) and watt-hours per liter (Wh L<sup>-1</sup>), respectively. For flexible energy ???



The development of flexible electronics technology has led to the creation of flexible energy storage devices (FESDs). In recent years, flexible self-supporting cathodes have gained significant attention due to their high energy density, excellent mechanical performance, and strong structural plasticity among various cathode materials.



As the demand for flexible wearable electronic devices increases, the development of light, thin and flexible high-performance energy-storage devices to power them is a research priority. This review highlights the latest research advances in flexible wearable supercapacitors, covering functional classifications such as stretchability, permeability, self ???

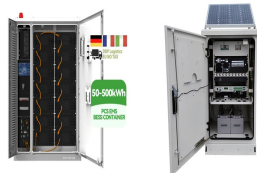


To meet the rapid development of flexible, portable, and wearable electronic devices, extensive efforts have been devoted to develop matchable energy storage and conversion systems as power sources, such as flexible lithium-ion batteries (LIBs), supercapacitors (SCs), solar cells, fuel cells, etc. Particularly, during recent years, exciting works have been done to explore more ???

# WHAT ARE THE FLEXIBLE ENERGY STORAGE DEVICES



Flexible energy storage devices are gaining considerable attentions due to their great potentials in the emerging flexible electronics market, ranging from roll-up displays, bendable mobile phones, conformable health-monitoring skin sensors to implantable medical devices. The development of reliable and flexible electrodes with low cost, high



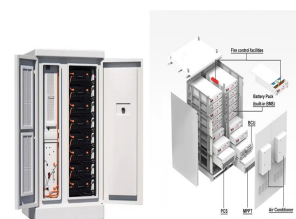
1 INTRODUCTION. Rechargeable batteries have popularized in smart electrical energy storage in view of energy density, power density, cyclability, and technical maturity. 1-5 A great success has been witnessed in the application of lithium-ion (Li-ion) batteries in electrified transportation and portable electronics, and non-lithium battery chemistries emerge as alternatives in special



Flexible energy storage devices typically consist of an electrode, electrolyte, separator membrane, and packaging material. To develop this energy device, each component plays its original functions under various deformation states without any flaws. Thus, several strategies have been reported concerning the effective design of each component



Herein, the state-of-art advances of hydrogel electrolyte materials for flexible energy storage devices are reviewed. In addition, devices with various kinds of functions, such as self-healing, shape memory, and stretchability, are included to stress upon the role of hydrogel materials. Furthermore, the challenges embedded in the current



Among all flexible energy storage devices, supercapacitors and Li-based batteries (e.g., Li-ion, Li-S and Li-O<sub>2</sub> batteries) stand out because of their ease of fabrication, compatibility with other electronic devices and excellent electrochemical performance. 17, 20-24 They are typically composed of two electrodes (cathode and anode), separator



# WHAT ARE THE FLEXIBLE ENERGY STORAGE DEVICES



However, the large-scale application of wearable electronics requires flexible/stretchable energy device(s) as the power source [8, 9]. Up to now, a coplanar or non-coplanar design has been developed for the serpentine structure and applied for energy storage devices with a significantly enhanced stretchability (>100% strain) [25, 31].



The areal density of the 3D NM (3.26 mg. cm<sup>-2</sup>) is superior to the values of the current collectors commonly used in flexible energy storage devices as shown in the comparison Fig. 6 b [96]. This improved areal density is achieved by combining fabrication methods including photolithography and electrodeposition technology.



The booming wearable/portable electronic devices industry has stimulated the progress of supporting flexible energy storage devices. Excellent performance of flexible devices not only requires the component units of each device to maintain the original performance under external forces, but also demands the overall device to be flexible in response to external ???



a Schematic design of a simple flexible wearable device along with the integrated energy harvesting and storage system.b Powe density and power output of flexible OPV cells and modules under



To fulfill flexible energy-storage devices, much effort has been devoted to the design of structures and materials with mechanical characteristics. This review attempts to critically review the state of the art with respect to materials of electrodes and electrolyte, the device structure, and the corresponding fabrication techniques as well as