8 学生发表的高质量代表性论文

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序号	论文题目	期刊名称	发表时间	分区
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1 A lightweight visual mamba network for image recognition under resource-limited environments

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A lightweight visual mamba network for image recognition under resource-limited environments

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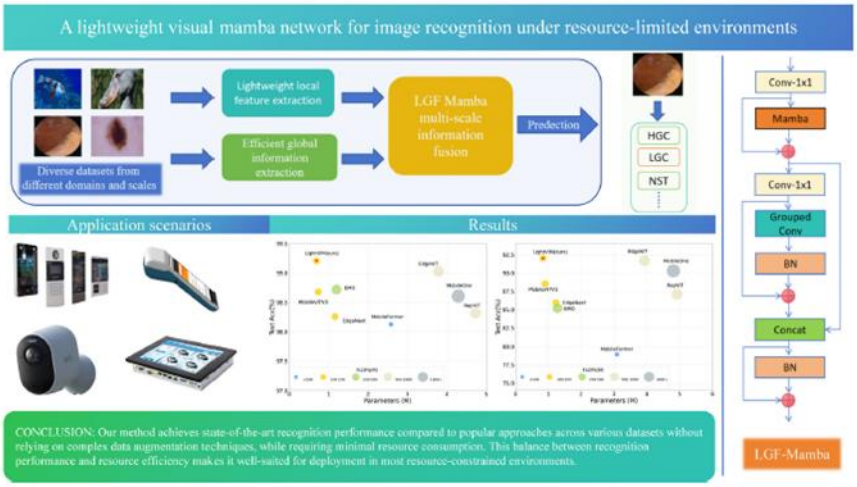
GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Lightweight
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ABSTRACT

The Vision Transformers (ViTs) models show great potential in recognition due to their excellent self-attention mechanisms. However, they often need more computational complexity, making achieving high performance in resource-constrained environments challenging. This paper proposes a lightweight visual model

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2 LMSFF: Lightweight multi-scale feature fusion network for image recognition under resource-constrained environments

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LMSFF: Lightweight multi-scale feature fusion network for image recognition under resource-constrained environments

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ARTICLE INFO

Keywords:
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Image recognition

ABSTRACT

In many resource-constrained environments, recognition tasks often require efficient and fast execution. Currently, many methods designed for this field adopt a combination of convolutional operations and Vision Transformers (ViTs) to achieve comprehensive feature representation while maintaining efficient performance. However, these methods still have higher parameter counts or floating point operations (FLOPs), making it difficult to adapt more resource-constrained environments. Therefore, a lightweight Multi-Scale Feature Fusion Network (LMSFF) is proposed to address this issue. The proposed method mainly consists of three modules: lightweight local processing (LLP) modules, local–global fusion modules (LGFM), and lightweight information fusion (LIF) modules. The LLP modules, considering the issue of computational redundancy, propose a branch structure that effectively reduces parameter consumption while maintaining high performance. To capture more comprehensive contextual information, the LGFM fuses local and global features, thus enhancing the comprehensive representation of image features. The LIF extracts crucial features through pooling operations at different scales while preserving lightweight characteristics. Additionally, to enhance the model's generalization, a new weighted loss function is introduced, which alleviates the long-tail distribution issue in real-world scenarios and improves recognition performance for rare categories. Experimental results demonstrate that LMSFF achieves better balance between recognition accuracy and resource consumption compared with other state-of-the-art lightweight hybrid models.

1. Introduction

In recent years, the increasing demand for mobile applications, characterized by limited storage and computing resources, has posed challenges for the development of efficient and accurate lighting recognition methods (Ige & Mohd Noor, 2023). Early lightweight models have already achieved success in various domains, such as high-performance computing, demonstrating the potential of resource-efficient designs (Allen et al., 2003; He, Zhang, & Sun, 2017; Liu et al., 2017). In many real-world scenarios with constrained resources, there is a desire for recognition processes to be both accurate and fast, such as in robotics, unmanned vehicles, embedded devices, and mobile devices (Raja Sekaran, Han, & Yin, 2023). However, due to hardware limitations, deploying large-scale and computationally expensive models in these scenarios is not feasible (Haque, Arefin, Shihavuddin, & Hasan, 2021). Therefore, the development of lightweight image recognition methods with simple and efficient structures, which can be well-deployed in real-world resource-constrained environments, becomes crucial. For example, in autonomous drones, lightweight recognition methods are essential for ensuring real-time object detection and navigation while minimizing power consumption. Similarly, in wearable health monitoring devices, these methods enable continuous monitoring and rapid processing of visual data without significantly draining the battery. In smart home devices, lightweight models facilitate efficient processing of visual inputs for tasks like security monitoring and gesture recognition, even in devices with limited computational power. Additionally, these optimized lightweight methods can be effectively

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3 Enhancing small satellite image resolution via shrinking rearranged mechanism and multiscale reparameterized attention

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Research paper

Enhancing small satellite image resolution via shrinking rearranged mechanism and multiscale reparameterized attention☆

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ARTICLE INFO

Keywords:
Image super-resolution
Small satellite
Shrinking & rearranged
Multiscale attention
Reparameterization

ABSTRACT

Small satellites, weighing under 1,000 kg, are increasingly used in defense, civil, and commercial sectors due to their cost-effectiveness and portability. However, their imaging resolution is limited by the size and cost of their apertures. Existing super-resolution (SR) algorithms struggle to reconstruct large-area surface information and fine local textures, and often require high computing power, making them unsuitable for small satellites. This study proposes a lightweight super-resolution network, MSRN (Multiscale Shrinking Rearranged Attention Network), engineered for deployment on small satellites. Specifically, MSRN employs a shrinking window-partition strategy to extract different ranges of feature priors and capture local high-frequency details. It also uses a channel rearranged mechanism to expand the receptive field and extract global context information. Additionally, a multiscale reparameterized attention group is designed to efficiently extract features and contours of objects at various scales, enhancing channel information representation. The use of reparameterization technology simplifies the model and enables fast response and processing of small satellite image data. Multiple comparisons on several popular public remote sensing datasets demonstrate that MSRN outperforms mainstream methods in terms of resource occupancy and reconstruction performance, and exhibits strong robustness and generalization across different scenarios.

1. Introduction

The growing importance of remote sensing imagery in a diverse array of applications, including environmental monitoring (Wasehun et al., 2024), resource surveys (Liu et al., 2023), urban planning (Yu et al., 2024; Darem et al., 2023) and weather prediction (Mohite et al., 2023), has led to an increased demand for high resolution images. Blurry, artifact-ridden images may lead to misinterpretation of remote sensing information, potentially resulting in unnecessary planning errors and even serious national security issues. Traditionally, the cost of optical telescopes on satellites is roughly proportional to the square of the aperture size (Constantinou et al., 2024), which means that to double the resolution of imaging hardware, it requires nearly four times the cost. Moreover, large-aperture telescopes need to be mounted on large satellites, which are bulky and heavy, making them difficult to assemble and launch. In recent years, the emergence of high-capacity microelectronic devices has enabled the manufacture of small satellites (weighing less than 1000 kg) in the aerospace industry, particularly in Low Earth Orbit (LEO) (Sweeting, 2018). Compared to large satellites, such small satellites are cheaper to manufacture, take less time to assemble, and are easier to integrate and launch with rockets due to small size and available fairing capacity (Constantinou et al., 2024). Meanwhile, they are harder to target by adversaries,

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4 Enhancement of the wheat straw pretreatment in pulping: The microbial intelligent response

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Short communication

Enhancement of the wheat straw pretreatment in pulping: The microbial intelligent response

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Keywords:
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Intelligent regulatory mechanism
Lignocellulose
Pulping of wheat straw
Cuticle

ABSTRACT

In this study, *Bacillus licheniformis* (BL) was employed for the pretreatment of wheat straw, utilizing an intelligent regulatory mechanism to modulate the secretion of various enzymes. As a result, the cuticle and sclerenchyma within the lignocellulosic array were gradually degraded. Following a 36 h treatment period, the cellulose content in the pulp reached 77.18 %, whereas the lignin and hemicellulose contents continued to decrease. Additionally, the pulp brightness increased by 66.3 % after 48 h of treatment, and the tensile and tear indexes increased by 25.2 % and 61.5 %, respectively. Furthermore, we elucidated how BL intelligently regulated the surface characteristics of wheat stalks to highlight its advantages over direct enzyme treatments. These findings demonstrate the feasibility of using bacteria for wheat straw pretreatment in the papermaking process.

1. Introduction

In the current global context of advancing low-carbon economy and sustainable development, the papermaking industry is hindered by a significant shortage of wood resources, which limit its advancement (Zhang et al., 2019). Biomass is a renewable resource with diverse applications in various sectors, such as energy production, medicine, food, and cosmetics (Popp et al., 2021; Sen et al., 2022; Sonu et al., 2023). Biomass is progressively replacing wood as a primary raw material for paper production (Espinosa et al., 2015). The northern regions of China have abundant wheatgrass resources that can be used as alternatives to forest resources and mitigate environmental impacts. Wheatgrass fibers have a fine structure that closely resembles that of wood fibers, making them highly promising for papermaking (Hyväkkö et al., 2019).

Lignocellulose, the predominant biological macromolecule in plants, is the major component of plant cell walls, and it has remarkable mechanical strength and stability (Zhong et al., 2019). In wheatgrass, the intermolecular hydrogen and glycosidic bonds between fibers in straws help to form a distinctive lignocellulosic structure with hierarchical and directional arrangement. This structure gives wheatgrass considerable mechanical strength and stability. However, the effective and environmentally friendly removal of lignin from straw remains a major challenge in straw-pulp paper production. Chemical pulping is currently the most widely used method in developing countries. The cuticle, as a protective layer of non-wood raw materials, hinders the efficiency of chemical reagents and enzymes penetrating to the fiber tissue. To address this issue, it is essential to conduct a pretreatment operation prior to the cooking stage to decompose the cuticle and disrupt the lignocellulosic structure (Bian et al., 2019). The pretreatment process, which involves physical, chemical, and biological methods, have the potential to improve pulping efficiency, reduce the amount of required chemical reagents, and minimize energy consumption during the cooking stage (Allan et al., 2023; Priyadarshinee et al., 2016).

In recent years, there has been an increasing emphasis on the adoption of biological methods in the pretreatment of straw to promote environmental sustainability. A promising approach involves the use of enzyme-producing bacteria for straw pretreatment. Current research on microbial lignin degradation primarily focuses on white-rot fungi, which decompose lignocellulosic materials through the secretion of two enzyme systems: an oxidative lignin degradation system that targets the

5 Cellulose fiber drainage improvement via citric acid crosslinking

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Cellulose fiber drainage improvement via citric acid crosslinking

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ARTICLE INFO

Keywords:
Wheat straw
Citric acid
Cellulose
Drainage

ABSTRACT

Wheat straw, as a non-wood fiber waste, is available worldwide and can be used in cellulosic matrix production, promoting the application of sustainable materials. However, poor fiber properties and water drainage are the primary obstacles to its utilization. In this study, wheat straw pulp fibers were chemically crosslinked by citric acid (CA) in an environmentally friendly process. X-ray photoelectron spectroscopy and Fourier transform infrared spectra confirmed that the chemical treatment introduced carboxylic groups to cellulose fibers. Meanwhile, X-ray diffraction patterns showed that the crystallinity of cellulose was reduced. The average fiber length and water retention value of the pulp decreased with increasing CA dosage under the conditions of 3 mL/g CA_4 (4 wt% CA), and the drainage performance of the cellulose pulp improved by 21 %. Also, the crosslinking of fibers contributed to the mechanical properties of the cellulosic matrix, increasing the dry and wet strength by 21 % and 282 %, respectively. These results demonstrated that citric acid could be a sustainable method for improving the properties of wheat straw fibers, thereby promoting its application in fabricating sustainable materials.

1. Introduction

Non-wood waste is considered an effective alternative to wood in producing cellulose derivatives in countries with limited forest resources [1,2]. Wheat straw is a rich renewable raw material [3,4] and has become one of the primary resources of the paper industry in developing countries [5]. Wheat straw has a unique hierarchical anisotropic structure [6]. It is rich in cellulose, with a large fiber length-to-diameter ratio. The high degree of alignment and complex hierarchical structure of cellulose fibers make wheat straw an excellent potential for various novel sustainable material generation, e.g., anisotropic, light-transmitting, and biodegradable films [7,8].

In recent years, wheat straw-based pulping strategies have developed rapidly. Chemi-mechanical pulping technology is the primary technology for wheat straw pulping [9,10], which can be used to produce cellulose nanofiber and cellulose bio-composites, addressing the urgent call for sustainable material production [11,12]. However, some challenges are still associated with the chemo-mechanical pulping of straw. Wheat straws are different from wood fibers due to their chemical composition, biological structure, and fiber morphology [13]. Specifically, the wheat straw fibers have a large aspect ratio, and their fiber wall cavity ratio is large. Due to the thin epidermal cells of wheat straw, the primary wall is brittle and easy to break [14,15]. These features enable fine particle production during the pulping process, which increases the resistance of water to flow through the pulp suspension, thus affecting the drainage of the generated pulp while limiting its practical applications [16–18].

In the past few years, numerous studies have been conducted on improving cellulosic pulp drainage and paper properties [19–21]. Cationic polyacrylamides (CPAM), polydimethyl diallylammonium chloride (PDADMAC), and cationic starch are the most commonly used additives for pulp drainage improvement [22–25]. These cationic polyelectrolytes interact with the fibers and other additives for their more efficient flocculation, thereby increasing the drainage properties of the pulp [26]. These additives are often petroleum-based inefficient polymers that are difficult to biodegrade and thus not attractive for sustainable material development.

Thanks to the abundant hydroxyl groups on the surface of cellulose fibers, advanced functionality can be imparted to cellulose [27]. For example, Wang et al. successfully synthesized a novel graft copolymer via reacting cellulose and polyisoprene, which improved the

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6 Recent advances in transdermal insulin delivery technology: A review

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Review

Recent advances in transdermal insulin delivery technology: A review

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ARTICLE INFO

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Microneedles
Needle-free injectors

ABSTRACT

Transdermal drug delivery refers to the administration of drugs through the skin, after which the drugs can directly act on or circulate through the body to the target organs or cells and avoid the first-pass metabolism in the liver and kidneys experienced by oral drugs, reducing the risk of drug poisoning. From the initial singular approach to transdermal drug delivery, there has been a shift toward combining multiple methods to enhance drug permeation efficiency and address the limitations of individual approaches. Technological advancements have also improved the accuracy of drug delivery. Optimizing insulin itself also enables its long-term release via needle-free injectors.

In this review, the diverse transdermal delivery methods employed in insulin therapy and their respective advantages and limitations are discussed. By considering factors such as the principles of transdermal penetration, drug delivery efficiency, research progress, synergistic innovations among different methods, patient compliance, skin damage, and posttreatment skin recovery, a comprehensive evaluation is presented, along with prospects for potential novel combinatorial approaches. Furthermore, as insulin is a macromolecular drug, insights gained from its transdermal delivery may also serve as a valuable reference for the use of other macromolecular drugs for treatment.

1. Introduction

Insulin, the primary medication for treating diabetes, was discovered by Banting and Best in 1922 [1]. As insulin is a macromolecular drug [2], it is most commonly injected subcutaneously with needles for diabetes treatment. However, this approach not only causes pain [3] and carries a risk of skin infection [4] but also leads to long-term subcutaneous tissue fibrosis after prolonged use [5]. The primary concept behind transdermal drug delivery is that a therapeutic can be administered through the stratum corneum via a route that is particularly suitable for hydrophilic molecules and large macromolecules such as proteins and RNA, which penetrate the skin and enter the systemic circulation. The major obstacle in transdermal drug delivery technology lies in the stratum corneum (SC) of the skin [6]. As shown in Fig. 1-1, the SC, the outermost layer of the epidermis, has a thickness of approximately 10–20 μm and is composed of keratinized cells embedded in a highly organized lipid bilayer. Below the stratum corneum is the living epidermis with a thickness ranging from 50 to 100 μm that is densely packed with corneocytes and covered by an aqueous extracellular matrix. The junction of the stratum corneum and the outer viable epidermal layer is called the epidermis. Beneath the epidermis lies the dermis, which is 1–2 mm thick and contains a dense capillary network interconnected with the systemic circulation, serving as the first drug absorption point. Collagen fibers are embedded in the extracellular matrix solution, aiding in anchoring sweat glands, blood vessels, nerves, and hair follicles in the transdermal drug delivery system. Insulin must pass through the stratum corneum, followed by the epidermis and the topmost layer of the dermis to reach the capillary bed below the dermo-epidermal junction, where it is absorbed and enters the systemic circulation. Subcutaneous tissue is the deepest layer of the skin and consists of vascularized, loose areolar connective tissue and adipose tissue [7]. Typically, the skin passively transports small drug molecules. However, when the integrity of the stratum corneum (SC) is compromised, large macromolecules can be delivered either locally or systemically to target

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7 Effect of ultrasound assisted xylanase pretreatment on the soluble substances of poplar wood and its model construction

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RESEARCH

Effect of ultrasound-assisted xylanase pretreatment on the soluble substances of *poplar* wood and its model construction

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Abstract
Cellulose, hemicellulose, and lignin molecules in *poplar* wood are interwoven to form a dense network-like structure, which prevents their degradation into oligomers for the preparation of biomass-based materials and chemicals. Therefore, it is necessary to use a pretreatment process to decompose the complex matrix. In this study, ultrasound-assisted xylanase treatment was used for *poplar* wood pretreatment. The effects of different parameters, such as enzyme treatment time, enzyme dosage, and ultrasound time on soluble substances and the surface of the cell wall were systematically investigated. The optimal conditions for the degradation of hemicellulose and lignin in *poplar* wood were a treatment time of 60 min and a xylanase dosage of 25 U/g. Ultrasound-assisted xylanase treatment improved the efficiency of removing hemicellulose. The contents of glucose, xylose, and lignin were increased by 34.73%, 32.01%, and 59.65%, respectively, with the ultrasound-assisted xylanase treatment. In addition, a least-squares model was constructed to describe the dissolution behavior of component, which is helpful to guide the subsequent conversion and utilization of *poplar* wood biomass.

Keywords *Poplar* wood · Xylanase · Ultrasonication · Least squares method · Ultrasound-assisted xylanase treatment

1 Introduction

Poplar is a fast-growing tree species with strong adaptability and short growth cycle. The main components of *poplar* wood are cellulose, hemicellulose, and lignin. Cellulose is the most highly abundant of the three main components of *poplar* wood and is the most important component required in the pulp and paper process [1–8]. The content of hemicellulose in *poplar* wood is second only to cellulose, and the highest content of hemicellulose is xylan, which is dominated by 4-O-methylglucuronide xylan. Lignin fills the space between cellulose and hemicellulose, playing a role in protection and support [9]. The minor components of *poplar* wood include extractives, starch, inorganic substances, and plant gums. Cellulose, hemicellulose, and lignin are linked through ether bonds, phenyl glycosidic bonds, and other chemical bonds, intertwined with each other to form a complex matrix [10–13]. This structure is highly recalcitrant to enzyme and microbial degradation and is the main obstacle to the conversion of lignocellulosic biomass into biomass-based materials and chemicals. Thus, it is necessary to develop efficient pretreatment processes to decompose the complex structures.

Currently, the main pretreatment methods for lignocellulosic biomass are physical, chemical, physic-chemical, and biological approaches, etc. [14]. Among them, physical methods such as mechanical grinding, ultrasonic, microwave, and high-energy radiation are energy-intensive [15]. Chemical methods that usually involve acid [16], alkali, organic solvents, and ionic liquid are facing the challenges, such as corrosion and solvent recycling [17]. Physic-chemical methods, such as ammonia steam explosion and hydrothermal pretreatment, usually require high reaction temperatures and pressures [18]. Biological methods refer to employing microorganisms or enzymes to degrade biomass feedstocks to improve the efficiency of component utilization [19]. It is a green pretreatment technology with low energy consumption, high catalytic specificity, and low environmental pollution [20].

For the pulp and paper industry, enzyme pretreatment can not only reduce the amount of chemicals but also improved

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8 Recent Advances in 2- Keto- L- gulonic Acid Production Using MixedCulture Fermentation and Future Prospects

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Recent Advances in 2-Keto-L-gulonic Acid Production Using Mixed-Culture Fermentation and Future Prospects

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ABSTRACT: Vitamin C, also known as ascorbic acid, is an essential vitamin that cannot be synthesized by the human body and must be acquired through our diet. At present, the precursor of vitamin C, 2-keto-L-gulonic acid (2-KGA), is typically produced via a two-step fermentation process utilizing three bacterial strains. The second step of this traditional two-step fermentation method involves mixed-culture fermentation employing 2-KGA-producing bacteria (*Ketogulonicigenium vulgare*) along with associated bacteria. Because *K. vulgare* has defects in various metabolic pathways, associated bacteria are needed to provide key substances to promote *K. vulgare* growth and 2-KGA production. Unlike previous reviews where the main focus was the interaction between associated bacteria and *K. vulgare*, this Review presents the latest scientific research from the perspective of the metabolic pathways associated with 2-KGA production by *K. vulgare* and the mechanism underlying the interaction between *K. vulgare* and the associated bacteria. In addition, the dehydrogenases that are responsible for 2-KGA production, the 2-KGA synthesis pathway, strategies for simplifying 2-KGA production via a one-step fermentation route, and, finally, future prospects and research goals in vitamin C production are also presented.

KEYWORDS: *vitamin C, 2-keto-L-gulonic acid, Ketogulonicigenium vulgare, dehydrogenase, mixed-culture fermentation*

1. INTRODUCTION

Vitamin C, also known as ascorbic acid, is an acidic polyhydroxy compound that is widely distributed in the animal and plant kingdoms. The human body lacks the ability to synthesize vitamin C and depends on ingested food as a source of the vitamin; therefore, vitamin C supplements are chiefly used for treatment of diseases caused by vitamin C deficiency.[1] In addition to its antioxidant qualities, vitamin C is essential for human collagen formation, the scavenging of reactive oxygen species (ROS),[2] the prevention of hair loss,[3] and the bolstering of the immune system. However, the chemical stability of vitamin C is poor; photothermal factors, oxidants, and heavy-metal ions accelerate its degradation and decrease its physiological activity, thereby limiting its application.

In recent years, improvements in the standard of living and growing health awareness have increased the daily intake of vitamin C and demand for vitamin C-related products,[4] thereby resulting in the rapid growth of the global vitamin C market. Initially, because of insufficient understanding regarding the structure and properties of vitamin C and limitations on production conditions, the commercial production of vitamin C mainly involves extraction from lemons, carrots, peppers, and other plants. In 1933, the Swiss scientist Tadeusz Reichstein developed a chemical process for the industrial manufacture of vitamin C; however, this method is cumbersome, labor-intensive, and expensive and causes environmental pollution.[5] In the 1970s, scientists from China vitamin C precursor, using three bacterial strains, followed by its chemical conversion to vitamin C. However, the disadvantages of the two-step fermentation process include a lengthy fermentation cycle and the requirement for two fermentation and sterilization steps. Recent research has focused on simplifying the production of vitamin C by transforming the two-step fermentation into a one-step process using either a single or mixed-culture system. This Review summarizes the key enzymes and their mechanism of action in bacterial strains employed for 2-KGA production, as well as the latest research on the process.

2. CONVENTIONAL PROCESS OF 2-KGA PRODUCTION

The conventional process of vitamin C production is based on the "Reichstein method" and the two-step fermentation process involving three bacterial strains.

2.1. Reichstein Method. The Reichstein method involves the chemical catalysis of the substrate glucose to D-sorbitol, followed by fermentation to produce L-sorbose using *Acetobacteraceae* spp., in turn followed by a five-step reaction

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9 Amorphous nanosphere self-supporting electrode based on filter paper for efficient water splitting

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Amorphous nanosphere self-supporting electrode based on filter paper for efficient water splitting

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ABSTRACT

Given its superior structure, the abundance of surface functional groups, and low cost, cotton fiber filtration paper can be used as the support for hydrogen evolution reaction (HER) and oxygen evolution reaction catalysts (OER) instead of copper foam (CF), nickel foam (NF), or carbon cloth (CC). Herein, the chemical plating method was used to create thin self-supporting electrodes based on cotton fiber filtration paper (FP). The Co-Ni-P amorphous nanospheres can be uniformly dispersed on the self-supporting FP due to its porous structure and oxygen functional groups. The Co-Ni-P/FP electrode has an overpotential as low as 125 mV for HER and 320 mV for OER at the current density of 10 mA cm^{-2}. Additionally, according to density functional theory (DFT) calculations, the Co atom added to the Ni-P nanosphere can lead to considerably more charge accumulation around the Co and Ni active sites, which greatly encourages the HER and OER processes. The novel porous support, FP, provides a fresh way the preparation of self-supporting electrodes.

1. Introduction

With its high energy density, lightweight, and environmental kindness, hydrogen is predicted to replace conventional fossil fuels as a source of energy [1–4]. In recent years, one of the most effective and environmentally friendly energy methods for producing hydrogen has been electrocatalytic water splitting [5–7]. Electrocatalytic water splitting includes cathodic HER and anodic OER [8]. The HER, among them, is essential for generating hydrogen with a high degree of purity [9,10]. Although platinum (Pt) and ruthenium (Ru) oxides are the most effective electrocatalysts for water electrolysis according to Volcano plots because of its suitable Gibbs free energy for H* and *OOH adsorption and desorption, the commercial implementation of electrocatalytic water splitting is severely constrained by the prohibitively high cost of noble metal catalysts [11–13]. Therefore, it is essential to seek out catalysts with low costs and great efficiency.

The majority of research focus has been on the creation of low-cost, high-efficiency electrocatalysts has garnered the majority of research attention; however, a variety of other factors, such as the optimization of the catalyst support, also affect the performance in practical applications. The performance of the electrocatalyst will be compromised by mass transfer and reduced conductivity when electrodes are created using the conventional approach, which comprises combing the powder catalyst with a binder to make a slurry and coating the electrode. Although the problem caused by the binder can be resolved by employing CF [14], NF [15], or CC [16] as the support for in situ growth of catalysts, doing so introduces additional Ni and Cu elements and is thus only appropriate for the synthesis of specific catalyst materials. When using CC as the support for in-situ growth catalysts, in contrast, there are no element residues, but the high cost has complicated commercialization [17–25]. However, compared with the aforementioned supports, the FP supports have surface functional groups that facilitate the diffusion and deposition of elements and refrain from introducing impurity elements. Therefore, FP can be thought of as the potential electrocatalyst support due to its abundance of surface functional groups, low cost, renewable nature, and material suitability.

Besides, the researchers found that the amorphous catalysts outperformed crystalline catalysts in the process of water electrolysis since higher intrinsic activity and more active sites result from the disordered structure [26–28]. Tang et al. prepared amorphous Ni-Fe-P-B catalysts

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10 A compound enzyme with synergistic interaction to treat cotton stalk chemi?mechanical pulp to improve the properties of wastepaper pulp

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ORIGINAL RESEARCH

A compound enzyme with synergistic interaction to treat cotton stalk chemi-mechanical pulp to improve the properties of wastepaper pulp

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Abstract In this work, a compound enzyme treated cotton stalk chemi-mechanical pulp (CE-CSCMP) that could improve the properties of wastepaper pulp was investigated. Firstly, according to whether the enzymes (cellulase, xylanase, pectinase and lipase) could promote the mechanical properties of cotton stalk chemi-mechanical pulp (CSCMP) paper, xylanase, pectinase and lipase were selected to prepare compound enzyme. Afterwards, the underlying mechanism of enzymatic treatment of CSCMP was elucidated through the loss of cellulose, hemicellulose and lignin. Single enzymes, such as xylanase, pectinase or lipase, could only directly act on one substrate when treating CSCMP, while non-enzymatic substrates could impede the hydrolysis of the substrate. Therefore, the exposure area of cellulose was small, and the improvement of CSCMP paper strength was limited. It is found that there was a synergistic interaction between the three components in the compound enzyme, leading to a higher hydrolysis efficiency compared to that of single enzyme. Consequently, the area available for hydrogen bonding on the fiber surface was greatly increased, and CE-CSCMP obtained the best paper properties. Finally, CSCMP were furnished with wastepaper pulp, which resulted obvious improvement of the tensile strength, tear strength and ring compressive strength of wastepaper pulp. In conclusion, CE-CSCMP was a high-yield pulp of non-wood raw materials with better performance and could be used to improve wastepaper pulp.

Keywords Cotton stalk · Enzyme treatment · Chemi-mechanical pulp · Wastepaper pulp

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Introduction

As a major by-product of cotton, cotton stalk is mainly used for composting, fuel and raising livestock, while another part is directly burned or discarded in the field (Kaur et al. 2012; Singh et al. 2017). The value of cotton stalk as a biomass resource is not fully utilized. Cotton stalks have received extensive attention due to their fiber morphology, similar to wood fibers. Mixing cotton stalk fibers with cement can increase the strength of concrete and reduce the thermal conductivity (Liu et al. 2022). The physical strength and thermal stability of cotton stalk fiber/polyvinyl

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11 Thermoplastic collagen fiber films improved by bacterial cellulose withhigh barrier properties

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Thermoplastic collagen fiber films improved by bacterial cellulose with high barrier properties

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ABSTRACT

Irradiated bacterial cellulose (mBC) was used to enhance the properties of collagen fiber (CF)-based food packaging films to gradually replace plastic packaging materials. The structural differences between bacterial cellulose (BC) and irradiated bacterial cellulose (mBC) were analyzed, and the heat sealing properties, mechanical properties and barrier properties of CF-mBC composite films were investigated and analyzed. FTIR and XPS results showed that CF and mBC mainly have hydrogen bonding and amide bond formation. The addition of mBC improved the thermal stability of the CF film and increased the heat seal performance, optical properties and mechanical properties from 1 N/15 mm to 8.53 N/15 mm, 82.45 % to 85.02 % and 44.54 MPa to 58.56 MPa, respectively. In addition, the good barrier property of this composite film makes it achieve grade 12 oil-proof under − 9 ℃ to 100 ℃ oil temperature. Therefore, mBC reinforced CF film has a broad application prospect in the food packaging field.

1. Introduction

As food packaging materials are related to human health and environmental pollution issues, plastic food packaging is gradually replaced by bio-based food packaging materials (Asgher et al., 2020; Sangroniz et al., 2019). Bio-based packaging materials have received widespread attention by their greenness, good biocompatibility, and degradability (Stark and Matuana, 2021).

Among the various bio-based polymers, polysaccharide-based, lipid-based, and protein-based materials have good film-forming properties, making them environmentally degradable packaging materials (Abral et al., 2021; Atta et al., 2022; Bandyopadhyay et al., 2021). In the food packaging sector, these films are required to be loaded with certain food desiccants (to extend shelf life) and food ingredients (to facilitate direct handling) to form small bags (Bandyopadhyay et al., 2018; Ilhan et al., 2021). As a food material, the packaging needs, and the storage and transportation process, film packaging materials must have good performance and muscular sealing strength to avoid food release in the bag caused by external conditions (Ciannamea et al., 2018; Ilhan et al., 2021). In heat sealing, two films at a specific temperature and pressure, the polymer film surface heating melting, the internal molecular chain active movement, intertwined action. After cooling, the two polymer films internally combine and recrystallize with hydrogen and covalent bonds to produce a sealed joint (Cortes-Morales et al., 2021; Huang et al., 2023; Prateepchanachai et al., 2019).

In previous reports, protein-based films have certain heat sealing properties (Cortes-Morales et al., 2021; Islam et al., 2023). Among them, collagen fibers (CF), mostly from animal dermal tissue, are natural biopolymers formed by the polymerization of collagen into collagenous protofibrils (Xu et al., 2020b). With good degradability, biocompatibility, and film-forming properties, collagen fibers are well used in biological and pharmaceutical, bioengineering and food industries (Jing et al., 2022a; Xu et al., 2020c). In particular, collagen fiber films are widely developed and used in food packaging. Nevertheless, CF films' poor mechanical properties, barrier properties, and heat seal strength have reduced their application in the food industry. Blending other biopolymers with collagen fibers is the most common method to improve the performance of collagen fiber films (Cao et al., 2020; Xu

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12 Bifunctional collagen fiber/carbon quantum dot fluorescent adsorbent for efficient adsorption and detection of Pb2+

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Bifunctional collagen fiber/carbon quantum dot fluorescent adsorbent for efficient adsorption and detection of Pb^{2+}

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HIGHLIGHTS

- The fluorescent adsorbent had dual functions of adsorption and detection.
- The reusability of adsorbent was improved by carboxylation modification.
- The incorporation of Carbon dots improved the adsorption capacity.
- Real-time fluorescence changes can be used to reflect the adsorption process.

GRAPHICAL ABSTRACT

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ABSTRACT

In this work, fluorescent adsorbents that can efficiently detect and remove Pb^{2+} were developed by integrating the designed amino-modified carbon quantum dots and carboxyl-modified collagen. The adsorption properties of the fluorescent adsorbent were further optimized and analyzed using a series of response surface experiments. The maximum adsorption concentration for Pb^{2+} was 183 mg.g^{-1}. The adsorption isotherms fit well with the Langmuir model, and the adsorption kinetics fit with the pseudo-second-order model. The emission intensity of the fluorescent adsorbent gradually decreased with the increase of the concentration of Pb^{2+}, and had a good linear correlation. In addition, the mechanism of detection and removal of Pb^{2+} by fluorescent adsorbents was further demonstrated. The novel three-dimensional structured fluorescent aerogel can be used as a promising adsorbent with good adsorption concentration and sensing ability for Pb^{2+}, which shows great prospects in wastewater.

1. Introduction

Pollution of wastewater by toxic heavy metal ions is a worldwide environmental issue that has attracted much attention (Ali, 2010; Carolin et al., 2017; Kumar and Chawla, 2014). Heavy metal ions are not biodegraded and tend to accumulate in organisms and eventually enter the food chain (Akpor and Muchie, 2010; Giani et al., 2021; Zhang and Wang, 2020). Lead (Pb) is an important pollutant in wastewater mainly from untreated municipal waste, over-fertilized soil and deposition of industrial waste gas (Cheng and Hu, 2010; Khan et al., 2021). It has been reported that countries around the world have released about 800,000 tons of Pb^{2+} into water and soil annually over the past few decades. Undegradable Pb^{2+} in water will not only harm the ecosystem but also seriously threaten human health and safety through human contact and the amplification effect of the food chain. (Chibowska et al., 2016; Kim et al., 2014; Metryka et al., 2018). Therefore, it is of great significance to develop a technology for rapid and efficient detection and removal of Pb^{2+} in wastewater.

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13 High wet-strength, durable composite film with nacre-like structure for moisture-driven actuators

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High wet-strength, durable composite film with nacre-like structure for moisture-driven actuators

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ABSTRACT

As an emerging two-dimensional nanomaterial, $Ti_3C_2T_X$ MXene exhibits promising applications in the fields of energy, electromagnetic shielding, sensors and actuators. However, the structural instability and vulnerability to oxidation of MXene limit its application in moisture self-driven actuator. In this work, a composite film of moisture actuator with a lamellar structure inspired by pearl was reported. The composite film consists of tannic acid-modified Mxene and bacterial cellulose (BC). The synergistic interaction between TA and MXene imparts MXene with toughness and oxidation resistance, whereas the introduction of high wet/dry strength BC imparts the composite film with high tensile strength (243.5 MPa for dry strength and 173.4 MPa for wet strength) and high fracture strain (7.4 %). In addition, the actuator is highly moisture sensitive with fast response (2.48 s) and high cycling stability (more than 100 cycles). The results provide a strategy for the development of moisture-driven soft actuators, and reveal the great promise of this moisture actuator for applications in soft bionic robots and flexible arms, solving the current shortcomings of poor durability and low strength of MXene-based actuators, establishing the foundation for a wider application of moisture actuator devices.

1. Introduction

The emergence of robotics has significantly promoted the development of the intelligent sensing field, which has been widely used in domestic [1], industrial [2], medical [3] and military fields [4]. With the rapid development of technology, researchers have observed the opening and closing mechanism of the leaves in flytrap [5,6] and *Mimosa pudica* [7,8], and investigated that chameleons can periodically change their skin structure as a response to the environment [9]. All these phenomena provide researchers with inspiration to design bionic intelligent actuators. Flexible actuation systems are capable of converting energy from external stimuli (e.g., light [10], electricity [11], magnetism [12], temperature [13,14], humidity [15–17]) into mechanical power, which has been widely used in actuators, robots [18], artificial muscles [19] and active carrier [20,21]. Among them, flexible actuators driven by humidity gradients are eco-friendly and recyclable. Moreover, water molecules are abundantly existing in the environment and considered as a promising approach for energy conversion.

Recently, various materials have been used to build smart actuators, such as 2D carbon-based materials [22,23], hydrogels [24–26], liquid crystal elastomers [27], polymers [28], etc. Among them, 2D carbon-based materials exhibit favorable machinability which make them one of the most commonly used materials for actuators. For example, the typical 2D nanomaterial graphene oxide (GO) has been widely used for the development of moisture actuators due to its abundant oxygen functional groups [29–31]. Mu et al. [32] reported a graphene monolayer paper with a gradient-reduced graphene oxide/graphene oxide (rGO/GO) structure with reversible deformation capability. Jing et al. [33] reported a film actuator composed of 2D GO and 1D single-walled carbon nanotubes (SWCNT). Among them, these reports attempt to endow the structure with both electrical conductivity and hydrophilicity by adding another material (e.g., rGO and SWCNT).

MXene, known as a group of transition metal carbides or nitride analogs, is a novel two-dimensional material, typified by $Ti_2C_3T_x$ [34–36]. The selective etching of the MAX phase by HCl/LiF [37] generates abundant active terminal groups such as -F and –OH, endowing MXene with hydrophilicity and maintaining its high electrical conductivity, rich interfacial properties, as well as favorable processability. Smart materials based on MXene are considered as potential candidates for the fabrication of moisture gradient actuators. For example, Xiao et al. [13] demonstrated a flexible actuator based on gradient paraffin-filled MXene films with good response time (0.3 s). Tang et al. [38]

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14 Light-colored lignin extraction by ultrafiltration membrane fractionation for lignin nanoparticles preparation as UV- blocking sunscreen

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Light-colored lignin extraction by ultrafiltration membrane fractionation for lignin nanoparticles preparation as UV-blocking sunscreen

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ABSTRACT

A wide range of applications are available for kraft lignin (KL). However, the dark color and wide size distribution of KL make it challenging to use in cosmetics and nanoparticle preparation. In this study, we fractionated KL from a paper-making enterprise using ultrafiltration membrane fractionation, and obtained four kinds of lignin with different molecular weights, namely ultrafiltration lignin (UL). Following that, lignin nanoparticles (ULNPs) were formed by self-assembly from four types of UL. Analyzing the UL and ULNP properties, the low molecular weight lignin, such as ULA, exhibited good antioxidant properties (89.47 %, 5 mg/mL), high brightness (ISO% = 7.55), high L^* value (L^* = 72.3) and low polydispersity index (PDI = 1.41). The ULNP showed a narrow size distribution (0.8–1.4 m) and high dispersibility in sunscreen. When ULNP was added to sunscreen with 5 % load, its sun protection factor (SPF) value increased from 14.93 to 63.74. Therefore, this study offered an effective way for the comprehensive utilization of pulping waste KL.

1. Introduction

The rising consumption of traditional fossil fuels, along with growing worries about environmental contamination, has attracted attention in the high-value utilization biomass resources [1–7]. Lignin is an aromatic polymer that is often regarded as the most abundant renewable source of aromatic hydrocarbons. Lignin possesses anti-UV, anti-bacterial, and anti-oxidant qualities, and it is also natural, renewable, biodegradable, and non-toxic, giving lignin and its derivatives a high potential commercial value [8–11]. Furthermore, lignin is rich in benzene rings and ketone structures [12,13], making it an excellent choice for UV protection applications [14–16]. On the basis of this, lignin was investigated as a sunscreen ingredient and was shown to be effective at blocking Ultraviolet radiation [17,18]. Kraft lignin (KL) is primarily obtained from the sulfate pulping process's black liquid [19]. Commercial application of KL in sunscreen is problematic due to its wide range of molecular weight, complicated structure, dark color, and poor dispersibility [20–22], it is essential to bleach KL to an acceptable color. On the other hand, the biocompatibility, amphiphilicity, and conjugated structure of lignin nanoparticles (LNPs), make LNPs are one of the most valuable lignin-based products for natural anti-UV sunscreen [23–25]. However, LNPs from KL are typically characterized by a wide size distribution in which some particles are even 1–2 orders of magnitude larger than others. Therefore, reducing the color of lignin, narrowing its molecular weight range, and preparing LNPs with a uniform size are essential.

Traditional chemical bleaching is unsuitable for lignin color reduction since it intends to destroy the lignin structure as much as possible [26,27]. The UV absorbability of degraded lignin after bleaching is difficult to maintain, hence it cannot be employed as a sunscreen component. Lignin fractionation is a traditional method to reduce its color and narrow its molecular weight range by aggregating the lignin with specific molecular weight or chemical characteristics with a certain way [28,29]. Zhang and co-workers whitened the color of lignin via solvent fractionation and subsequent acetylation to resolve this problem. The color of lignin was whitened by 313.5 % with a two-step treatment method. This method is beneficial, and a successful preparation of a light-colored lignin-based sunscreen with good UV absorbability was accomplished. But as we know the organic solvent fractionation of lignin destroys the structure of lignin itself, and the

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15 Bacterial cellulose/MWCNT coatings for highly sensitiveand flexible paper-based humidity sensors

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ORIGINAL RESEARCH

Bacterial cellulose/MWCNT coatings for highly sensitive and flexible paper-based humidity sensors

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Abstract As a human-computer interaction technology for the Internet of Things (IoT), non-contact humidity sensors have been widely explored. However, traditional humidity sensors have become a bottleneck in the development of flexible electronics owing to their complex processes and non-degradability. Here, bacterial cellulose (BC) and MWCNT were sequentially coated on paper to construct a durable and highly sensitive bacterial cellulose/MWCNT humidity sensor (BCNT). The BC endows the paper substrate with dense structure and significantly reduces the consumption of active materials (6.7 times reduction). Further, the well-dispersed CNT coating forms an interlocking structure with the BC nano-network, which results in a high mechanical strength (66.3 MPa). The maximum response of BCNT02 can be up to 94.5% ($-\Delta I/I_0$) under 98% RH, and the response and recovery times were 150 and 297 s, respectively. Moreover, the high humidity sensitivity of the BCNT make it an excellent choice for research and development of humidity sensors for respiration detection, non-contact switching and humidity localization.

Keywords MWCNT · Bacterial cellulose · Paper-based · Humidity sensor · Respiration monitoring · Non-contact

Hongliang Ma and Zhuqing Liu have contributed equally to this paper.

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Introduction

In recent years, flexible electronics with sensitive response to environmental changes are playing a crucial role in smart electronics (Jiang et al. 2020; Xu et al. 2020; Yang et al. 2021), robotics (Steffens et al. 2013; Wang et al. 2020b) and medical technology (Jin et al. 2020; Kaspar et al. 2021). The emergence of artificial intelligence has significantly promoted the development of the sensors field (Chung et al. 2019; Ghosh et al. 2020; Meng et al. 2020). Based on the quantitative measurements, sensors can be classified into strain (Ma et al. 2020; Tang et al. 2020; Yong et al. 2020), humidity (Cho et al. 2020; Ghosh et al. 2020; Lu et al. 2020), temperature (Meng et al. 2020), pressure (Xiong et al. 2020; Zhong et al. 2021), and gas (Dai et al. 2020; Wang et al. 2016). Humidity is a pervasive source of environmental stimuli free of time and seasonal restrictions. Besides, as a common

16 Simple preparation of environmentally friendly superhydrophobic paper with durability and anti-bacterial property

Simple preparation of environmentally friendly superhydrophobic paper with durability and anti-bacterial property

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17 Bacterial cellulose-based dual chemical reaction coupled hydrogel thermocells for efficient heat harvesting

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Bacterial cellulose-based dual chemical reaction coupled hydrogel thermocells for efficient heat harvesting

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ABSTRACT

Reasonable and efficient utilization of low-grade thermal energy in nature is the choice for sustainable energy development. We demonstrate a bacterial cellulose (BC) hydrogel thermocell (TEC) based on BC electrolyte combined with carbon fiber paper and copper composite electrode sheets. The large specific surface area of carbon fiber paper provides a large number of active sites for thermoelectric ions, which drives the redox reaction inside the electrolyte and stimulates the chemical reaction between the electrolyte and the electrode. The combination of the two chemical reactions significantly improves the thermoelectric performance of the thermocell. The thermopower of the BC-TEC reaches 5.9 $mV{\cdot}K^{-1}$ at a temperature difference of 50 K. The TEC consisting of 6-units in series produces an open-circuit voltage of about 2 V and a peak power of 535 μW. The TEC shows new potential and prospects in ambient thermoelectric energy conversion by rationally designing the power generation principle.

1. Introduction

The ubiquitous low-grade waste heat (geothermal, sunlight, industrial pipelines, human bodies, etc.) stimulates the need for efficient use of waste heat to convert it into valuable energy (T. Li et al., 2019). Thermoelectric power generation devices based on the thermopower or Seebeck coefficient have attracted much attention from researchers (Chen et al., 2021; H. Li et al., 2021; Liu, Wang, et al., 2021). In particular, thermocells (TECs, $-mV{\cdot}K^{-1}$) with orders of magnitude higher thermopower compared to thermoelectric generators (TEGs, $-\mu V{\cdot}K^{-1}$)(Han et al., 2020; H. Li et al., 2022; Y. Liu et al., 2020).

Conventional TECs based on ionic conductors generate electricity through ion transfer or redox reactions under the action of temperature differences. When the TEC rebalances the redox reaction through ion diffusion, electricity can be continuously generated based on a thermoelectric mechanism (Lei et al., 2021). The simple structure and low production cost of TECs make it ideal for waste heat collection. For example, Pu et al. (2020) prepared a TEC with thermopower of −1.2 $mV{\cdot}K^{-1}$ using polyacrylamide (PAAm)-$K_{3/4}Fe(CN)_6$ as the hydrogel electrolyte and titanium plates and titanium meshes as electrodes. Zhou et al.(Yang et al., 2016) combined PVA-$FeCl_{2/3}$ hydrogel electrolyte with Au/Gr electrode sheet to obtain a TEC with thermopower of 1.02 $mV{\cdot}K^{-1}$. Studies have shown that porous carbon materials are ideal electrode materials because of their high specific surface area, which can increase the electrochemically active sites and help improve the thermoelectric performance of TECs (Hu et al., 2010; Ma et al., 2015; Wang et al., 2019). Kim and Kang (2019) prepared TEC with $Fe(ClO_4)_{2/3}$ as electrolyte and non-woven polyacrylonitrile-based carbon fiber sheet as electrode sheet, which thermopower reached 1.7 $mV{\cdot}K^{-1}$. In addition, Kang et al.(Lee et al., 2021) used $Fe(ClO_4)_{2/3}$ as the electrolyte and Pt mesh/single-walled carbon nanotubes (SWCNT)/Platinum nanoparticles (PtNP) as the composite electrode sheet to prepare TEC with thermopower of 1.72 $mV{\cdot}K^{-1}$. Although the performance of TECs has been improved by introducing carbon materials, the development of TECs with higher thermoelectric efficiency in combination with porous carbon fiber materials is more in line with the current concept of sustainable energy development and is more conducive to the efficient use of waste heat to meet the energy demand.

Bacterial cellulose (BC), as natural polymer compounds cultured by *Acetobacter xylinum* and available in large quantities through industrial production, have the advantages of abundant sources, low cost, biodegradability, and high liquid loading capacity. In our previous work, we

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18 High-performance hybrid supercapacitors based on hierarchical NiC204/Ni(OH)2 nanospheres and biomass-derived carbon

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Full Length Article

High-performance hybrid supercapacitors based on hierarchical $NiC_2O_4/Ni(OH)_2$ nanospheres and biomass-derived carbon

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ABSTRACT

The high-performance hybrid supercapacitor (HSC) with high power capability and stable cyclability is intensively pursued as a next-generation energy storage device. Here, a kind of hierarchical $NiC_2O_4/Ni(OH)_2$ nanospheres, consisting of subunits of NiC_2O_4 nanorods and $Ni(OH)_2$ nanospheres, are synthesized via a two-step hydrothermal method. The hierarchical $NiC_2O_4/Ni(OH)_2$ nanosphere positive electrode, benefiting from the synergistic effect of unique hierarchical structure and built-in electric fields, significantly boosting electron transmission capability and accelerating the ion/electron transfer rate, delivers an excellent specific capacity of 668 C g^{-1} at 1 A g^{-1}. In addition, the porous biomass-derived carbon (PBC) with the honeycomb structure from pine petals as the negative electrode shows a remarkable electrochemical performance, exhibiting a specific capacitance of 249.7 F g^{-1} at 1 A g^{-1}. As such, an assembled HSC of $NiC_2O_4/Ni(OH)_2$||PBC based on hierarchical $NiC_2O_4/Ni(OH)_2$ nanospheres positive electrode and PBC negative electrode display a conspicuous energy density of 31.07 Wh kg^{-1}, and a power density of 833.47 W kg^{-1} at a maximum potential window of 1.7 V. This innovative hierarchical engineering of double nickel-based composites with bio-carbon provides an advanced enlightenment for high-performance HSCs.

1. Introduction

The exhaustion of fossil fuels together with environmental concerns have pushed the ever-increasing demand for a sustainable energy paradigm [1,2]. However, new and renewable clean energy such as solar, wind, hydropower, and geothermal energy are affected by natural changes such as terrain, weather, and day-night alternation, resulting in unstable energy output, which limits its application in storage systems needing sustainable energy supply [3]. Therefore, it is necessary to develop high-efficiency energy storage devices with an uninterruptible power supply [4]. The current electrochemical energy storage systems are mainly batteries and supercapacitors, which can realize electrical energy storage through the mutual conversion of chemical energy and electrical energy [5,6]. Among them, lithium-ion batteries are widely used in rechargeable energy storage devices, due to the features of high energy density and long lifespan [7,8]. However, the drawbacks of the high cost, low power density, and safety risks limit the development of lithium-ion batteries [1,9,10]. On the contrary, supercapacitors with great power density, excellent cycling stability, and rate capability are regarded as one of the most potential energy storage devices in the future [11,12]. Currently, supercapacitors have been used in small electronic devices such as instrumentation, PDAs and smart watches, as well as large-scale devices such as electric vehicles, marine and land fans, and solar street lights [13].

The high-performance supercapacitor is highly dependent on the design and optimization of novel electrode material. The nickel-based transition metal materials have received attention as electrode materials for battery-type supercapacitors, storing charges through strong redox reactions [14,15]. Among them, the NiC_2O_4 and $Ni(OH)_2$ have revealed good potential due to their abundant valence states, high

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19 Strong Bacterial Cellulose-Based Films with Natural Laminar Alignment for Highly Sensitive Humidity Sensors

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Strong Bacterial Cellulose-Based Films with Natural Laminar Alignment for Highly Sensitive Humidity Sensors

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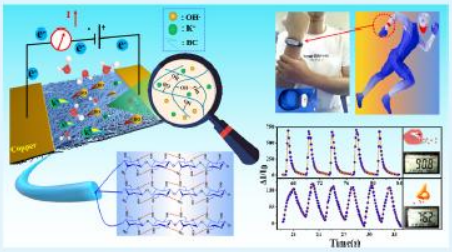
ABSTRACT: Humidity sensors have been widely used for humidity monitoring in industry and agriculture fields. However, the rigid structure, nondegradability, and large dimension of traditional humidity sensors significantly restrict their applications in wearable fields. In this study, a flexible, strong, and eco-friendly bacterial cellulose-based humidity sensor (BPS) was fabricated using a two-step method, involving solvent evaporation-induced self-assembly and electrolyte permeation. Rapid evaporation of organic solvent induces the formation of nanopores of the bacterial cellulose (BC) surface and promotes structural densification. Furthermore, the successful embedding of potassium hydroxide into the sophisticated network of BC effectively enhanced the sensing performance of BPS. The BPS exhibits an excellent humidity sensing response of more than 10^3 within the relative humidity ranging from 36.4 to 93% and strong (66.4 MPa) and high flexibility properties owing to the ultrafine fiber network and abundant hydrophilic functional groups of BC. Besides being strong and thin, BPS is also highly flexible, biodegradable, and humidity-sensitive, making it a potential candidate in wearable electronics, human health monitoring, and noncontact switching.



KEYWORDS: *bacterial cellulose, humidity sensor, biodegradable, strong, respiration monitoring*

1. INTRODUCTION

In recent years, the potential applications of flexible electronics in the fields of energy storage,[1−3] human health monitoring,[4−6] and personal thermal management[7−9] have attracted much attention, simultaneously influencing the lifestyles of human beings. The emergence of the Internet of Things (IoT) has also expanded the demand for sensor applications in daily life.[10−13] Smart sensors can be divided into pressure,[14,15] strain,[16−19] temperature,[20,21] gas,[22,23] and humidity[24−26] based on their basic sensing functions. Among them, humidity sensors as a humidity detection tool can convey the comfort of the living environment and reflect human health information in real time. Furthermore, noncontact control utilizing the changing humidity field in the environment can significantly reduce equipment wear and tear and bacterial cross-contamination.[27] However, the stiffness and large thickness of rigid ceramic or metal oxide-based humidity sensors[28,29] tremendously limit their wide applications. Thus, reasonable material selection and structural design are highly desirable to enhance the flexibility and extensive use of the device in the smart wearable field. Typically, flexible and transparent insulating polymer substrates combined with conductive active materials are considered to be the ideal substrates for the design and scalable fabrication of cost-effective humidity sensors.[30] A variety of polymers have been developed to fabricate flexible humidity sensor platforms, such as polyethylene terephthalate (PET),[31−33] polyimide (PI),[34] and polyethylene (PE).[35] Despite the impressive advances, most of the above materials pose tremendous pressure on the environment owing to the undegradable substrates. Hence, it is highly imperative to develop an environmentally effective strategy to fabricate multifunctional humidity sensors with satisfactory flexibility and high performance.

Cellulose, the most abundant organic material on earth, is considered to be an ideal scaffold for the fabrication of humidity sensors and wearable devices due to high biocompatibility, biodegradability, and abundant hydrophilic groups that inherently exist on its surface.[36,37] In recent years, with the pursuance of material strength and structural refinement, many studies have been dedicated to the fabrication of nanocellulose for humidity sensors. Currently, nanocellulose-based humidity sensors are mainly concentrated on films,[38−40] gels,[41] and nanocellulose-filled composites.[42]

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20 Alkylation modification for lignin color reduction and molecular weight adjustment

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Alkylation modification for lignin color reduction and molecular weight adjustment

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ABSTRACT

The application of industrial kraft lignin is limited by its low molecular weight, dark color, and low solubility. In this work, an efficient crosslinking reaction with N,N-Dimethylformamide (DMF) and 1,6-dibromohexane was proposed for adjusting the molecular weight and color of lignin. The chemical structure of alkylation lignin was systematically investigated by gel permeation chromatography (GPC), ultraviolet spectroscopy, Fourier transform infrared (FT-IR) spectroscopy, and 2D heteronuclear single quantum correlation nuclear magnetic resonance (HSQC NMR) spectra. After the alkylation modification, the molecular weights of the lignin were increased to 1643%. The resinol (β-β), β-aryl ether (β-O-4), and phenylcoumaran (β-5) linkages were still the main types of the linkages. The formation of β-β linkage would be inhibited at high temperatures. The color reduction of lignin can be attributed to the low content of chromophores and low packing density. This alkylation lignin will be a new and general approach for developing molecular weight-controlled and light-colored lignins, which can find more applications in cosmetics, packing, and other fields.

1. Introduction

Lignin, one of the three major components of lignocellulosic biomass [1-6], is the largest natural source of aromatic compounds accounts for 15-40 wt% in wood [7-9], only 2% of lignin is used to produce high value-added products [10-15]. The conversion of lignin into chemicals is an effective way to promote the sustainable development of the paper industry [16-19]. The dispersant is one of the important applications of lignosulfonate and sulfonated alkali lignin. The traditional naphthalene and phenol dispersants were produced from fossil fuel, which provides more than 95% of the organic chemicals for human beings and lead to a series of defects including high toxicity, high cost, and high energy consumption [20,21].

Lignin-based dye dispersants have higher economic benefits, energy conservation, and high-temperature stability. However, the low molecular weight, dark color, and low solubility are still hinder the wide application of lignin-based dye dispersants. The lignin with low molecular weight has not only a darker color but also a higher activity which can destroy the structures of dye molecules. There are many strategies to control the molecular weight of lignin, such as ultrafiltration [22], gradient precipitation [16,23,24], organic solvent multistage separation [25,26], enzyme induced free radical coupling [27,28], and gel-assisted filtration [29,30], etc. Among them, chemical crosslinking could be the most common and efficient method to enhance molecular weight [31,32]. However, the cross-linking reactions mainly take place on the hydroxyl groups of lignin [33] and reduce the reactivities of obtained lignins. Besides, the high molecular weight lignin has low solubility and poor dispersibility. Therefore, it is quite necessary to develop an effective method for controlling the molecular weight and color of lignin.

In this study, 1,6-dibromohexane, which has low toxicity and high reactivity, was used to crosslinke the lignin *via* a typical nucleophilic substitution reaction. N,N-Dimethylformamide (DMF) and K_2CO_3 were selected as the solvent and acid binding reagent, respectively. As an aprotic polar solvent, DMF is hard to give the characteristics of protons, so it is rarely solvated for negative ions. Nucleophiles can generally not

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