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Micro Thin Battery

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Abstract: We demonstrated a novel fabrication technique of 3-D biobattery packs by folding or stacking 2-D paper-based biobatteries for their series and/or parallel connections. A stackable, high-performance bacteria-powered battery was developed by folding two functional components (i.e. a conductive hydrophilic reservoir as an anode and a solid electron acceptor as a cathode) integrated into a single sheet of chromatography paper. Upon adding one drop of bacteria-containing liquid on the device, bacterial respiration transferred electrons from the organic liquid to the electrode, providing power to an external load. The various battery folding and/or stacking strategies with different series and/or parallel combinations significantly improved the power and current outputs. This battery manufacturing technique on paper can improve performance, simplify fabrication and connection, and revolutionize mass-production of large-scale flexible paper batteries, enabling the development of new types of powered, paper-based electronics. Traditionally, electronics have been designed around their batteries. In recent years, however, a new battery, known as the paper battery, has been developed that can easily conform to the size and shape of various electronics. The paper battery is becoming increasingly significant as technology tends towards thinner and more paper-like devices. This paper will include a technical discussion of how the paper battery works. It will assess the efficiency and explore the advantages of recent developments in the fabrication of paper batteries. Several applications of the paper battery will then be described, and ethical issues that arise with it will be explored. This paper will illustrate how the paper battery utilizes carbon nanotubes and cellulose in its design to create a flexible battery while maintaining electrical efficiency. Further discussion will detail how the paper battery integrates the components of a typical battery into a cohesive design that is paper thin. The advantages of this design include an increased range of applicability and a simpler, more efficient fabrication process. Applications that will be explored include smart cards, medical devices and solar panels. This description will be followed by a discussion on ethical issues surrounding the paper battery, such as nanotoxicology; since paper batteries use nanotechnology, any health risks must be evaluated, especially for medical applications. However, the paper battery is a promising innovation whose efficient use of space will open up thousands of possibilities for electronic and mechanical design.

Keywords: Paper battery, electronics

I.INTRODUCTION

The field of paper electronics has recently obtained a great deal of attention as a game-changing platform for next-generation applications in healthcare, display, flexible electronics and batteries [1-2]. The most challenging task for those future applications lies in the requirement of the external power supply, so that the paper electronics can work independently and self-sustainably, even in challenging field conditions, where people lack access to a reliable electrical supply [3]. Paper-based bacteria-powered batteries (or microbial fuel cells (MFCs)) have attracted tremendous research interest, as a new type of power source for those paper-based devices [4-5]. The paper-based MFCs have four main advantages over other types of paper-based energy storage devices. First, they are capable of generating electricity from various kinds of organic matter, such as urine, biomass, wastewater, and even commercial beverages. Second, the devices' structures are much simpler than the others. Third, the materials and fabrication methods used are more cost effective. Last, the devices are environmentally friendly, so that they can be cleanly disposed of by incineration. However, despite their vast potential and promise, significant challenges remain in the making of 3-D paper-based MFCs with foldable, batch-fabricable, and scalable solutions for simple and easy-to-use paper-based applications.

A mixture of 1wt% PEDOT:PSS (Sigma-Aldrich), 5wt% dimethyl sulfoxide (DMSO, Sigma-Aldrich) and deionized (DI) water was pipetted into the defined anode reservoir to make it conductive/porous and3-glycidoxypropy-trimethoxysilane was added to improve hydrophilicity (Figure).

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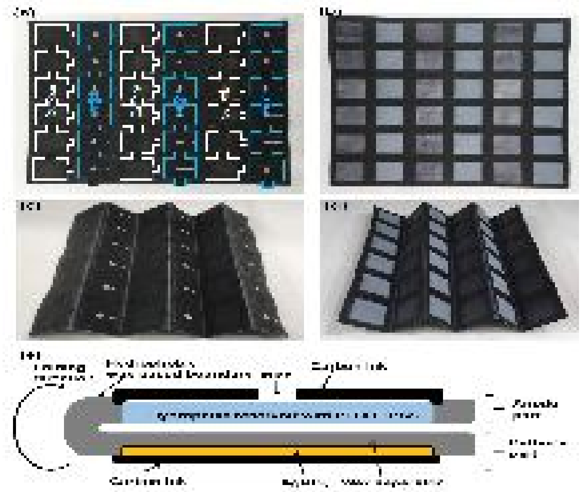

Figure 1: Schematic diagrams for the fabrication process *of the paper-based MFC*

1.4 Anode and conductive anode reservoir

After the reservoir was air-driedin a fume hood, carbon ink was screen printed on the electrode side of the reservoir, and subsequently baked in a ventilated oven.

1.5 Silver-based cathode

The sliver-based cathode was constructed on top of thewax-based proton exchange membrane (PEM) by usingsilver nitrate ink. First, hydrophobic wax was printed on the cathode part of paper and then the wax was penetrated through the paper with heat treatment. A hydrophilic region was defined on the other side of paper as the penetration depth of the wax was controlled by adjustingthe heating time. 50 µL of silver nitrate solution (0.1 M) was dropped to the hydrophilic region to form the cathode (Figure 2).

1.6 Stacking strategies

On the large 2-D single sheet of the filter paper, 18 cells were batch manufactured (Figure 1). Individual cells were pre-connected by the anode and cathode so that every6 cells were connected in parallel. By folding it further (2^{nd} folding), three 6-cell packs connected in parallel were connected in series (*6p* × *3s*). The various device folding and stacking strategies with different series and parallelcombinations can be proposed. One of examples is that *6p*× *3s* battery pack can be readily cut in half to form two *3p*× *3s* battery packs (Figure 3a, 3b, & 3c).

1.7 Inoculum Preparation

Pseudomonas aeruginosa wild-type PAO1 were grown from -80ºC glycerol stock cultures by inoculating20 mL of L-broth (LB) medium with gentle shaking for 24h at 37ºC. The culture was then centrifuged, at 5000 rpm for 5 min to remove the supernatant, and resuspended in fresh L-broth medium. Growth was monitored by

measurement of the optical density at 600 nm (OD600)

The continuously advancing technology of portable electronic devices requires more flexible batteries to power them. Batteries power a wide range of electronic devices including phones, laptop computers and medical devices such as cardiac pacemakers and defibrillators. With the ever increasing demand for efficiency and design, there is a need for ultrathin, safe and flexible energy storage options. A paper battery is a flexible, ultra- thin energy storage and production device formed by combining carbon nanotubes with a conventional sheet of cellulose based paper.

LITERATURE REVIEW:

Paper Battery-A Promising Energy Solution for India

A. Ganguly1 *, S. Sar2

This paper gives a thorough insight on this relatively revolutionizing and satisfying solution of energy storage through Paper Batteries and provides an in-depth analysis of the same. A paper battery is a flexible, ultra-thin energy storage and production device formed by combining carbon nanotubes with a conventional sheet of cellulose-based paper. A paper battery can function both as a high-energy battery and super capacitor , combining two discrete components that are separate in traditional electronics . This combination allows the battery to provide both long-term steady power production as well as bursts of energy. Being Biodegradable, Light-weight and Non-toxic, flexible paper batteries have potential adaptability to power the next generation of electronics, medical devices and hybrid vehicles, allowing for radical new designs and medical technologies. The paper is aimed at understanding & analyzing the properties and characteristics of Paper Batteries; to study its advantages, potential applications, limitations and disadvantages. This paper also aims at highlighting the construction and various methods of production of Paper Battery and look for alternative means of mass-production

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Versatile 3-D Stacking Of 2-D Paper-Based Biobatteries

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We demonstrated a novel fabrication technique of 3-D biobattery packs by folding or stacking 2-D paper-based biobatteries for their series and/or parallel connections. A stackable, high-performance bacteria-powered battery was developed by folding two functional components (i.e. a conductive hydrophilic reservoir as an anode and a solid electron acceptor as a cathode) integrated into a single sheet of chromatography paper.

STRUCTURE OF PAPER BATTERY

Construction of paper batteries

1.A zinc and manganese dioxide based cathode and anode are fabricated from proprietary links. 2. Standard silkscreen printing presses are used to print the batteries onto paper and other substrates. 3. Power Paper batteries are integrated in to production and assembly processes of thin electronic devices. 4. The paper is infused with aligned carbon nano tubes, which gives the device its black color. 5. The tiny carbon filaments or nano tubes substitute for the electrode used in conventional battery. 6. Use an ionic liquid solution as an electrolyte- the two components which conduct electricity. 7. They use the cellulose or paper as a separator- the third essential component of battery

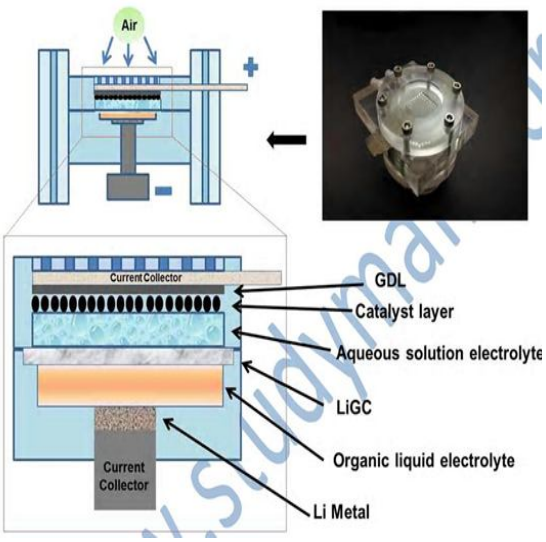

Fig4.1; Structure of paper batteries

WORKING OF PAPER BATTERIES

1. The nano tubes acting as electrodes allow the storage device to conduct electricity. 2. Chemical reaction in battery is occurs between electrolyte and carbon nano tubes. 3. Battery produce electrons through a chemical reaction between electrolyte and metal in the traditional battery. 4. Electrons must flow from the negative to the positive terminal for the chemical reaction to continue. Ionic liquid, essentially a liquid salt, is used as the battery electrolyte. 5. The organic radical materials inside the battery are in an "electrolyte-permeated gel state", which is about halfway between a solid and a liquid. This helps ions to smooth move, reducing resistance, allowing the batteries to charge faster. 6. We can stack one sheet on top of another to boost the power output. It's a single, integrated device. The components are molecularly attached to each other: the carbon nano tube print is embedded in the paper and the electrolyte is soaked in to the paper.

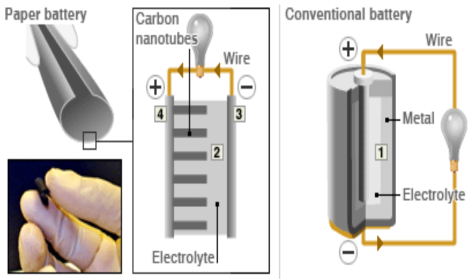

Fig ; **Working Of Paper Battery**

TEST SETUP RESULTS AND DISCUSSION

Electrical potentials between the anodes and cathodes were monitored by a data acquisition system (NI,USB-6212) with a customized LabVIEW interface (Figure 3d). To determine the currents generated by the individual units, external resists (10 kΩ and 1 kΩ) were used to connect the anode and cathode, and the current flow through the resistors was calculated by using Ohm's law Then, polarization and power curves were derived from the voltages generated from stacked MFCs.

6.1Individual MFC units

To determine the performances of the single MFC units, we cut them into individual 18 cells and dropped 60 μL-bacteria inoculum samples on the anode reservoir inlets of individual MFC units (Figure 4a). The liquid infiltrated underneath the carbon-based collector and spread over the conductive anodic reservoir. The hydrophilic, PEDOT:PSS treated conductive anode reservoir rapidly adsorbed the bacteria-containing liquid, which promoted bacterial cell attachment to the conductive paper matrix. Then, bacterial respiration transferred electrons from the organic matter to the anode, from which they flowed through an external load connecting the anode to the cathode. The protons or cations were transferred through the wax-based PEM and were reduced with the solid-state cathode, as well as the electrons, which

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had traveled from the anode. The wax membrane became saturated with the sample liquid and provided an optimal environment.

ADVANTAGES AND DISADVANTAGES

7.1ADVANTAGES

1. Used as both battery and capacitor.
2. It is flexible.
3. It is ultra thin energy storage device.
4. Long lasting.
5. Non toxic.
6. Steady power production.
7. Shaped for different applications.
8. High efficiency.
9. Available in different sizes.
10. Energy efficient.
11. It is light weight.
12. It is more economical.
13. Can be easily disposed.
14. Can be recharged.
15. Generates close to 1.5 Volts of energy.

7.2DISADVANTAGES

- Prone to tearing.
- Nanotubes made from carbon are expensive due to use of procedures like electrolysis and laser ablation.

Should not be inhaled, as they can damage lungs

FUTURE SCOPE

It holds great potential to advance capabilities in portable power design for applications ranging from bioinstrumentation to consumer electronics and even large power systems served by conventional batteries.

The paper like qualities of the material make it especially attractive for energy storage in medically implanted devices (for example, a pacemaker, insulin pump or the implantable radio chip).

CONCLUSION

A paper battery is a paper like device formed by the combination of carbon nanotubes and a conventional sheet of cellulose-based paper which act as a flexible ultra-thin energy storage and energy production device. In addition to using the aqueous and RTIL (Room Temperature Ionic liquids) electrolytes, the device operates with a suite of electrolytes based on bodily fluids. It suggests the possibility of the device being useful as a dry-body implant or for use under special circumstances. In this work, we proposed an origami-inspired fabrication technique for forming 3-D MFC stacks. A solid electron cathode and PEDOT:PSS treated conductive anode reservoir were first applied for the paper-based MFC technique, which revolutionized the MFC fabrication on paper and provided compact and versatile MFC stacking strategies. A maximum power of 31.51μW at 125.53Ma and 44.85μW at 105.89μA were generated from *6p* × *3s* and *6p* × *6s* stack configuration, respectively. The battery stack developed here could greatly reduce fabrication costs, simplify manufacturing processes, and establish an innovative strategy for paper-based MFC stacks

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