

# Power Paper: Energizing Next Generation Electronics

Mayank Garg<sup>1</sup>, Aakash Sharma<sup>2</sup> and Khushboo<sup>3</sup>

<sup>1,2,3</sup>EEE - Deptt. Northern India Engineering College

E-mail: <sup>1</sup>[niec.mayank@gmail.com](mailto:niec.mayank@gmail.com), <sup>2</sup>[sharma.aakash230@gmail.com](mailto:sharma.aakash230@gmail.com), <sup>3</sup>[kkhushboo\\_2008@yahoo.com](mailto:kkhushboo_2008@yahoo.com)

**Abstract**—This paper gives a deep insight on this comparably satisfying and revolutionary method of energy storage through paper batteries and provides a thorough analysis of the same. Paper, invented more than 2,000 years ago and widely used today in our everyday lives, is shown in this paper as a platform for energy-storage devices by integration with 1D nanomaterials. Studies have revealed that simple paper available with us can be made highly conductive by integrating basic components like:- electrodes, electrolytes, and separators into a single contiguous nanocomposite unit that can serve as building block for a variety of thin mechanically flexible energy storage devices. This can explicitly and evidently be achieved by using simple chemical processes to get conformal layer of single-walled carbon nanotube (CNT) and silver nanowire films on papers or cellulose. On the other side Supercapacitors based on CNT-conductive paper also show excellent performances. Hence this research can achieve two mindboggling outcomes in – A flexible energy storage device and a very high performance supercapacitor. This paper also tells about the various methods of fabrication and construction of Paper Battery and searches for alternative means for mass-production.

**Keywords:** Paper Battery, CNT, Paper, Electrodes, Electrolyte

## 1. INTRODUCTION

In today's world of increasing technology with ever decreasing sizes of the gadgets it has become very important that there should be some research in the fields of battery sizes because these are the major component of any gadget and uses a considerable space with cumulating the weight of the devices. Statistics show that worldwide, there are more than 15 billion batteries in usage. Around 89% of the batteries are common

Household batteries or the alkaline type of batteries. These batteries are prone to create problems. Hence a new technology in face of paper batteries is knocking our lives.

### 1.1 Paper Battery Basics

A Paper Battery is thin, pliable energy storage and production device formed by impregnating carbon nanotubes on a conventional sheet of cellulose-based paper. A paper battery has the capability to perform functions as a battery as well as a supercapacitor, combining two components that are separate

in traditional electronics. The above combination gives the battery steady power production along with bursts of energy.

**Paper Battery = Paper (Cellulose) + Carbon Nanotubes**

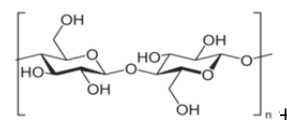
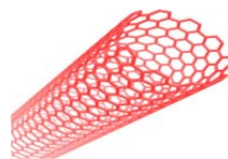


Fig. 1: Carbon Nanotube Fig. 2: Cellulose Structure

Paper batteries can be cut, bent or shaped for various applications without any loss of integrity or efficiency. Cutting one in half, halves its energy production. Stacking them increases power output. Available prototypes of the device are able to produce 2.5 volts of electricity from a sample of size of a postage stamp

## 1.2 Materials And Methods Of Fabrication

The most common materials used till date in fabrication of the prototypes of paper batteries are

- 1.) Carbon NanoTubes(C.N.T.)
- 2.) Cellulose

Properties of Carbon NanoTubes Used In the construction of Paper Battery:-

- The Carbon NanoTubes are flexible and very light weight.
- Carbon NanoTubes offers high tensile strength.
- Carbon NanoTubes are good conductors of electricity.
- Carbon NanoTubes provides low resistance.

Properties of Cellulose Used In the fabrication of Paper Battery:

- It is a bio-compatible and biodegradable material.
- Cellulose has low shear strength.
- It provides high tensile strength.
- It has high porosity and magnificent absorption capacity.
- Cellulose is nontoxic, recyclable and reusable.

### 1.3 Fabrication of Paper Battery

Given below are three ways that are till date found out to construct the paper batteries:

#### 1. First Method:

First fabricate the cathode and anode with Zinc and manganese dioxide respectively. With the help of a standard silk screen printing press, these batteries are printed on to the surface of a paper. After that this printed paper is infused with the carbon nanotubes (electrode). Now let this printed paper to dip into the electrolyte (Ionic liquid solution).

- Cathode – Zinc
- Anode - Manganese dioxide
- Electrode - Carbon nanotubes
- Electrolyte - Ionic liquid solution

#### 1. Second Method:

This method is little complex than the first method. Here silicon is used as the substrate. And the nanotube grows on this substrate. Cellulose is used to fill the gaps in the matrix substrate and also to form a combination with the nanotubes. When the matrix dried, the amalgamated nanotubes and cellulose is striped off. Thus we can create paper sheets having layers of Carbon nanotubes. By combining these two sheets together, we can construct a super capacitor with an ionic solution like urine, sweat or human blood as an electrolyte.

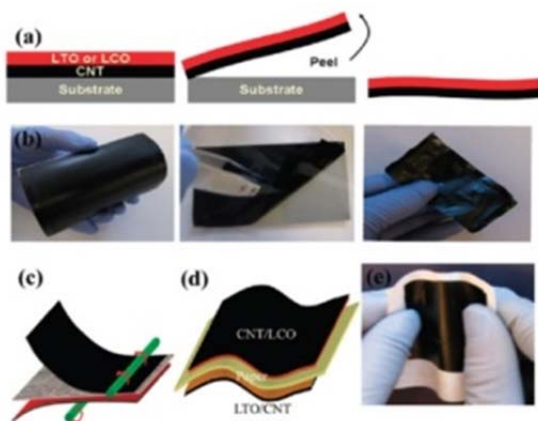


Fig. 3: Fabrication Process

#### 2. Third Method:

This method is comparatively simple and can be fabricate in the laboratory.

- First take a rectangular shaped Xerox paper.
- Now made a coating of ionic solution in to this paper surface.
- Then spread the specially prepared carbon NanoTubes ink over this ionic coated Xerox paper.
- The other side of the Xerox paper is laminated with a thin film or layer of lithium.

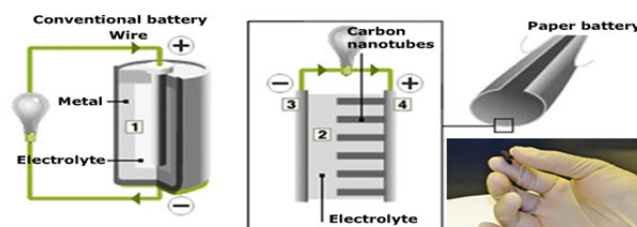
- Aluminum rods are used to transfer current between the 2 electrodes.

### 1.4. Working Principle:

The paper batteries are identical in internal operation as the traditional batteries that generate voltages of about 1.5V.

- Cathode: Carbon NanoTube
- Anode: Lithium metal (Li+)
- Electrolyte: bio electrolytes like urine, blood and sweat. (All electrolytes can be used)
- Separator: Cellulose or Paper

In Paper Batteries, the metal (Lithium) is used as the anode and carbon nanotubes as cathode and also the paper or cellulose is used as the separator. Due to the chemical reaction between the electrolyte and carbon, electrons are generated. Similarly due to the chemical reaction between electrolyte and metal, ions are generated. These generated electrons start flow through the external circuit from cathode to the anode.



## 2. PREVIOUS WORKS ON THE TOPIC

- In the year 2007, Paper Battery was created by a group of students at the Rensselaer Polytechnic Institute in Troy, New York.
- In the year 2009, the team of Yi Cui at STANFORD UNIVERSITY made a prototype, which gave a terminal voltage of 1.5V.

## 3. RESULTS AND DISCUSSION

The Advantages, disadvantages and applications of the Paper Batteries are as Follows: -

#### Advantages:-

- A paper battery can work even if it is folded, cut or rolled up.
- These batteries can be used both as a capacitor and battery.
- These are biodegradable, nontoxic, bio-compatible and economical.
- It is durable, easily recyclable and reusable.

- It is Overheating and Leakage proof.
- Easily Moldable Into different sizes and shapes
- It has customizable output Voltage.

#### Disadvantages:-

- Carbon nanotubes are very expensive.
- Batteries with large enough power are unlikely to be cost effective.
- Should not be inhaled as they can damage the lungs.
- These batteries generate e-wastage

#### Applications



#### 4. OBSTACLES IN ADOPTION OF THIS TECHNOLOGY

Our vision where we expect the paper batteries to prevail over traditional batteries look like as an optimistic thought, with the current technology available with us.

- Lots of research work is required to obtain low cost carbon nanotubes to make the paper batteries more monetarily feasible.
- We still are unable to find the ways to recharge these kinds of batteries, studies show that these can be recharged even by moisture in the air but no concrete evidence are there.
- The prototypes available are very small and produces small amount of power hence for more power we require a larger paper.
- Till now no one has commented on the life of such kind of batteries.

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