Paper Battery: The Future of batteries

Syed Sibghatullah Quadri [1], Syed Sameer[2], Pathan Jawwad Khan[3], Shaikh Shoeb[4]

1234undergraduate student, Dept. of Electrical Electronics & Power, Jawaharlal Nehru engineering College, Aurangabad, Maharashtra, India

ABSTRACT

Today the biggest problem faced by the electronics industry is the size of the battery as gadgets gets thinner and smaller day by day. But at certain point the battery size and its weight creates an obstacle. To overcome this 'paper battery' present the ultimate solution. The paper battery is literally a conducting paper with a lot of power packed inside it.The the various problems faced by the commonly used batteries and how the paper battery offers the solution to all these problems. A detailed construction of paper battery is explained in this paper. A comparison of SWCNT and MWCNT is also shown in this paper. This paper also contains the possible applications which could change our lives. The safety issues of Li-ion batteries, the limitations of NiCad & NiMH and the drawbacks of lead acid battery are discussed in this paper. The advantage of paper battery over these batteries is also described.

Keyword *:carbon Nano tubes(CNT), single walled carbon Nano tubes(SWCNT), multi walled carbon Nano tubes(MWCNT), and Lithium ion(Li-ion)*

1. INTRODUCTION

There has been a growing demand for thinner and smaller electronic devices. To achieve those demands 'paper battery' offers the best solution. Paper battery is actually a cellulose based 'paper' with CNT deposited on either side of paper. A stack of such papers makes a paper battery. Some batteries use Silver Nano Wires instead of CNT. It is extremely thin, flexible, light weight and stores much power in less space. Recently developed paper battery combines the Li-ion based chemicals to make a combination of Li-ion and paper battery.

Fig.1 Paper Battery

1.1 NECESSITY

There are many reasons to research a battery that is safe, thin, & flexible. Let us study some of the problems of the most commonly used batteries

Li-ion (Lithium ion batteries)

Li-ion battery is the most commonly used battery for smart phones, laptops, digital cameras and all sorts of home appliances.it is basically a rechargeable battery with lithium as a negative electrode. It is known for its low self-discharge, high efficiency. But it is expensive, it has safety issues. The electrolyte needs to be kept pressurized. It also requires an electronic monitoring system to avoid over charging,

overheating, over voltage etc. So, it needs temperature sensor, voltage regulator etc. which increases cost. The electrolyte is highly inflammable, reactive and hazardous.
In September 2016, Samsung recalled 2.5 million galaxies Note 7 because the battery design caused both the electrodes to touch which caused short circuit and they busted into flames. [7,8]

In January, 2013 Boeing 787 Dreamliner of japan airlines caught fire at Boston airport. The batteries were responsible. Luckily, no one got hurt, but had it caught fire while flying the results would have been worst. [9,10]

Today most of the smartphone users have no idea of how dangerous the Li-ion batteries are. Recent studies have recommended to use Li-ion along with CNT to get a better, much safer batteries. [11]

NiCd & NiMH (Nickel cadmium Nickel Metal Hydrate)
These are the most commonly used batteries for Hybrid cars, Satellites, novelties and for Backup power.
The problem of these batteries include that they contain highly toxic metals like Cd(cadmium) they exhibit negative temperature coefficient, this causes charging problems. NiMH produces hydrogen gas which can rupture the cell. The temperature affects the capacity and performance. They have high self-discharge rate. They have been replaced by Li-ion in recent years. But still due to low cost than Li-ion they are used in toys, remote controls &other portable electronics.[12]

Lead acid batteries
These are oldest rechargeable batteries and widely used for large scale applications like power backup, automobiles, submarines, and also in some hybrid vehicles. The problem associated are Sulfation and Stratification of electrolyte, corrosion of plates, toxic nature of lead etc.[13]

After studying the problems associated with the most commonly used batteries we can conclude that paper batteries along some modifications like Li-ion + CNT paper or some other possible combinations can replace the commonly used batteries. And making them much safer, flexible and light weight. If that happens we will be able to power a hybrid vehicle with a newspaper sized paper battery or we can have foldable laptops that can fit in our pocket. The possibilities are endless.

1.2THEME

Paper Battery either CNT based or Li-ion based provides a better solution for energy storage. The electronic gadgets can get even thinner, smaller and flexible. The Li-ion based paper battery can recharged efficiently and is much safer than conventional Li-ion batteries. The CNT based paper battery is bio degradable, ecofriendly and can be cycled many times. They have a wide range of operating temperature. The overall efficiency of the paper battery is high. [14,15]

2.LITERATURE SURVEY

There has been a constant search for super battery. The one's
Which can combine the properties of a capacitor and a battery. A super capacitor can be cycled millions of time, it charges in seconds but at the same time it has high self-discharge and much expensive. A battery might have low self-discharge but need more time charge and doesn't have indefinite recyclability. So, a compromise between battery and capacitor produces the paper battery which have combined properties of both.

The recent developments of the paper batteries utilize CNT as electrode and an integrated design of layer of electrolyte to create thin and flexible battery. [14,15]

Significant works have been carried out independently, notable among which are by Pushparaj et al. [2007] and Yi Cui et al. [2010] in the field of preparing the first prototypes.
Previous designs of flexible energy-storage devices have been based on separated thin-electrode and spacer layers, proving less-than-optimum in performance and handling because of the existence of multiple interfaces between the

layers. Pushparaj et al. demonstrated the fabrication of 'electrode-spacer electrolyte' integrated nanocomposite units to build a variety of thin flexible energy-storage devices. The
robust integrated thin-film structure allows not only good electrochemical performance but also the ability to function over large ranges of mechanical deformation, record temperatures and with a wide
variety of electrolytes. The attempt to integrate the components on to a single unit was revived by Yi Cui et al. with a much simpler and more promising approach. In this paper, they integrated all of the components of a Li-ion battery into a single sheet of paper with a simple lamination process. Although a paper-like membrane has been used as the separator for other energy storage systems including super capacitors, it was the first demonstration of the use of commercial paper in Li-ion batteries, where paper is used as both separator and mechanical support. Another significant attempt to exploit the properties of Paper batteries was made by Dr. Mangilal Agrawal, Louisiana Tech University. Having done much work with biosensors and bio-capacitors, he successfully demonstrated how the relative proportion of CNT and Paper could be used to customize the voltage output of the Paper Battery.

3.Specification of Paper Battery's

3.1 Construction

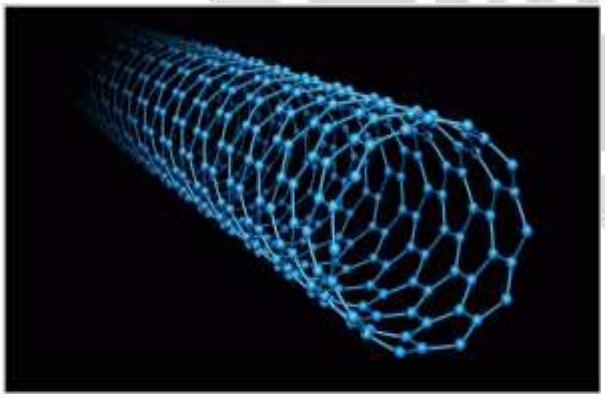
Paper battery combines cellulose based paper with CNT the paper can act both high energy paper battery and super capacitor depending on the design. Cellulose is complex organic substance found in paper and pulp. CNT's are main ingredients of paper battery.

CNT's where discovered by Japanese scientist name Iijima In 1991. [1]
They are now considered as top class subject in academic researches and industrial areas CNT's are allotropes is carbon made of graphite and have be constructed in cylindrical tubes with Nano meter scale in diameter and several millimeters in length. [2,3]

Carbon nanotubes (CNTs) consist exclusively of carbon atoms arranged in a series of condensed benzene rings rolled up into a tubular structure. This novel artificial nanomaterial belongs to the family of fullerenes, the third allotropic form of carbon along with graphite and diamond which are both natural sp2 (planar) and sp3 (cubic) forms, respectively [2, 3, 4].

Based on the number of layers, structures of, CNTs are classified into two types: single-walled carbon nanotubes (SWCNTs) and multi walled carbon nanotubes (MWCNTs)

1.Single Walled **2.Multi Walled**



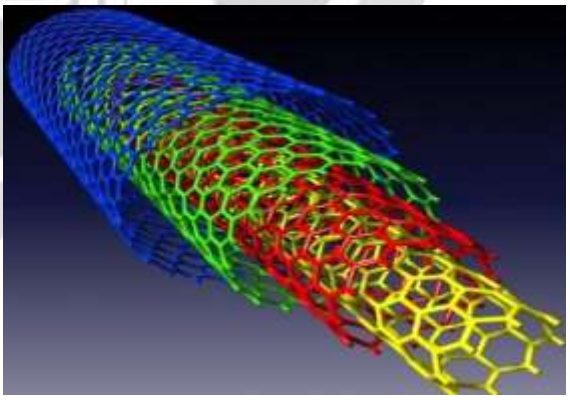
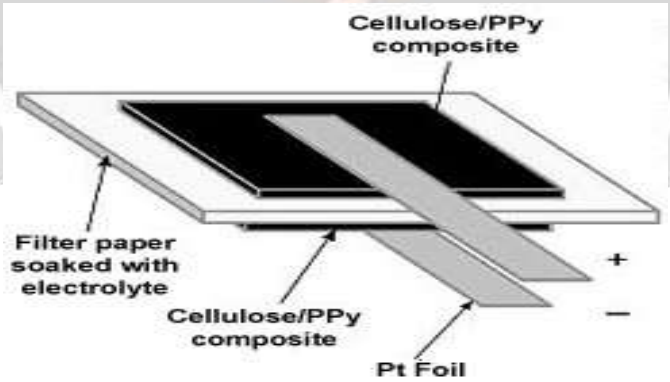


Fig 2.SWCNT **Fig 3.MWCNT**

Single Walled	**Multi Walled**
Single layer of graphene	Multiple layers of graphene
Catalyst is required for synthesis	Can be produce without catalyst
Bulk synthesis is difficult	Bulk synthesis is easy
More Defection during functionalization	Less defection but difficult to improve
Purity is poor	Purity is high
Easy characterization and evaluation	Difficult characterization and evaluation
less accumulation in body	More accumulation body
Easy to twist	Difficult to Twist

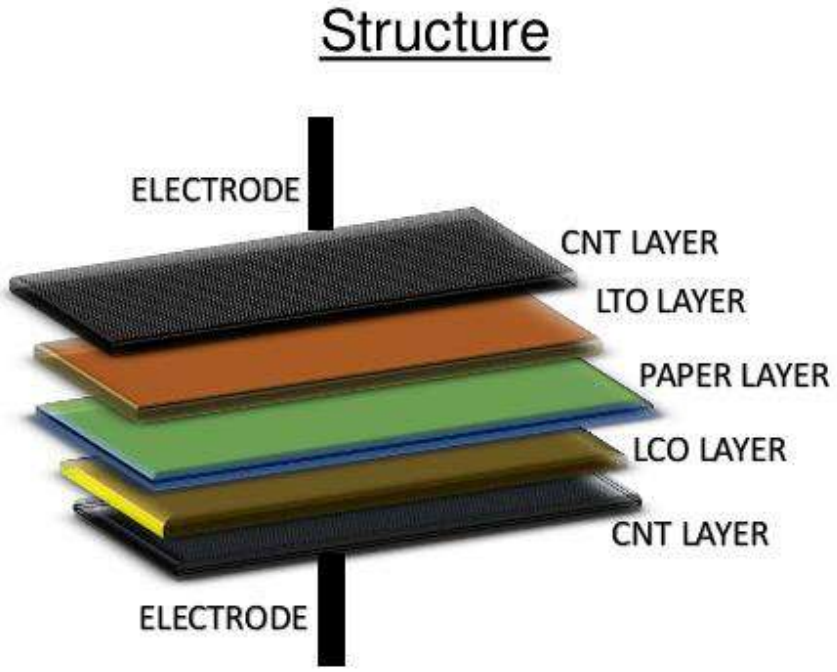
Three main techniques generally used for SWCNTs and MWCNTs production are:
Arc-Discharge method (using arc vaporization of two carbon rods), **Laser Ablation method**(using graphite), and **Chemical Vapor Deposition** (using hydrocarbon sources: CO, methane, ethylene, acetylene). After preparation, CNTs are submitted to purification by acid refluxing, surfactant aided sonication, or air oxidation procedure in order to eliminate impurities such as amorphous carbon, fullerenes, and transition metals introduced as catalysts during the synthesis [3, 5, 6]. Pristine CNTs are now synthesized and marketed by many chemical firms worldwide.

Construction of a Paper Battery



A paper battery construction involves the following components:
•Cathode: Carbon Nanotube(CNT)
•Anode: Lithium Metal (Li+)
•Electrolyte: All electrolytes (including bio Electrolytes like sweat, blood and urine).
•Separator: Paper (Cellulose)

Construction of a paper battery mainly includes these steps:
Step 1: Black carbon ink is applied on a cellulose-based paper.
Step 2: Black Carbon ink is being spread on a paper spread on the paper.
Step 3: A thin lithium film is laminated over the exposed cellulose surface.
Step 4: The cellulose paper is heated at 80_oC for 5 minutes.
Step 5: Next, the film is peeled off from the substrate.
Step 6: The film acts as electrodes of the paper battery. One film is connected to the electrolyte LTO (Li4Ti5012) and another film is pasted to the electrolyte LCO (LiCo02).
Step 7: Next, connect a LED on both the ends of the battery and check its functionality.



3.4 Advantages of paper battery's

- Non-toxic, biodegradable
- • Eco friendly, biocompatible
- • Easy to recycle
- • Durable: shelf life of three years
- • Works during extreme conditions -75°C to 150 °C
- • Rechargeable
- • No leakage of electrolyte
- • No over heating
- • Light weight and flexible
- • Easily mouldable in desired shape
- • Can work as super capacitor
- • More power in less space
- • Customizable output voltage by staking, slicing

3.5 Disadvantages of paper battery's

- Low shear strength can be torn easily
- • CNT production technique is expensive
- • Nano-toxic for CNT manufacturing workers
- • Can cause fibrosis in lungs
- • Aquatic like damaged by CNT

3.6 Possible Application

- RFID tags and other tracking
- Smart Newspapers
- Credit/Debit cards
- Greeting card with audio, light
- Hybrid cards
- Laptops, smartphones etc.
- Aircraft and spacecraft
- Blood and sugar monitoring portable devices
- Toys and novelties
- Calculator and wrist watches
- Wireless mouse, keyboards other computer accessories
- Bluetooth headphones, microphones etc.
- Digital camera
- Printed circuit board(PCB)

4. CONCLUSION

After analysis of paper battery we can conclude that the major component of paper battery is CNT.The CNT manufacturing techniques are inefficient which obviously increases the cost, making the paper battery expensive. If the cost is kept economical the batteries will revolutionize the electronics industry.
The shear strength of paper battery can be increased by adding glass fiber, resins, plastics etc.
Further research is needed in nanotoxicology to make CNT's non hazardous for our health.
The use of lithium as an electrode in paper battery can solve most of the safety issues of Li-ion batteries.
With paper batteries we can predict a whole a new world of possibilities and endless applications which will one day change our daily lives

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BIOGRAPHIES (Not Essential)

	**Syed Sibghatullah Quadri** is an undergraduate student of engineering. He is currently pursuing his graduation in electrical, electronics and power from Jawaharlal Nehru Engineering College(J.N.E.C) Aurangabad,Maharashtra,India E-mail- **ssquadri195@gmail.com**
	**Syed Sameer** is an undergraduate student of engineering. He is currently pursuing his graduation in electrical, electronics and power from Jawaharlal Nehru Engineering College (J.N.E.C) Aurangabad,Maharashtra,India E-mail- **syed_sameer@live.com**
	**Pathan Jawwad Khan** is an undergraduate student of engineering. He is currently pursuing his graduation in electrical, electronics and power from Jawaharlal Nehru Engineering College (J.N.E.C) Aurangabad,Maharashtra,India E-mail-
	**Shaikh Shoeb** is an undergraduate student of engineering. He is currently pursuing his graduation in electrical, electronics and power from Jawaharlal Nehru Engineering College (J.N.E.C) Aurangabad,Maharashtra,India E-mail- **shaikhshb13@gmail.com**