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Paper Battery : A Biodegradable Resource for Future Generation

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Abstract: This paper presents a complete insight on this revolutionising and satisfying solution for energy storage through biodegradable and also analyse in solving the problem from unbiodegradable energy resources. After the use of unbiodegradable energy resources, a lot of pollution is caused which is contaminating the environment. It is a flexible, ultra-thin device for energy storage and production.It is composed of carbon nanotubes along with sheet of cellulose-based paper. It can be used both as a high-energy battery and super capacitor. By these two types of functioning, it allows the battery to provide both long-term steady power production as well as a lot of energy as power backup regarding capacitors. Being Biodegradable, Light-weight and Non-toxic, flexible paper batteries have potential capability to adapt as a power source for the next generation. Paper battery has the potential to be used in electronics, medical devices and hybrid vehicles(Transformers) and medical technologies. The paper is aimed at understanding & analysing the properties and characteristics of Paper Batteries for the upcoming world; to study its advantages over unbiodegradable energy resources, limitations and disadvantages. This paper also aims at highlighting the construction and since it is the biodegradable and efficient source to replace other sources so finding various methods of mass production of Paper Battery

I INTRODUCTION

A paper battery is a flexible energy storage device consists of carbon nanotubes with a conventional sheet of cellulose. A paper battery can be used as high-energy battery and super capacitor, combination of two discrete quantities.

Paper Battery=
Paper (Cellulose) + Carbon Nanotubes

Cellulose which is a complex organic substance found in pulp.It is not digestible by humans. A Carbon NanoTubes (CNT) is a very tiny cylinder formed from a single sheet of carbon.these carbon atoms are rolled to form cylinder.Their conductivity is better than best semiconductor and strength is more than steel[1].

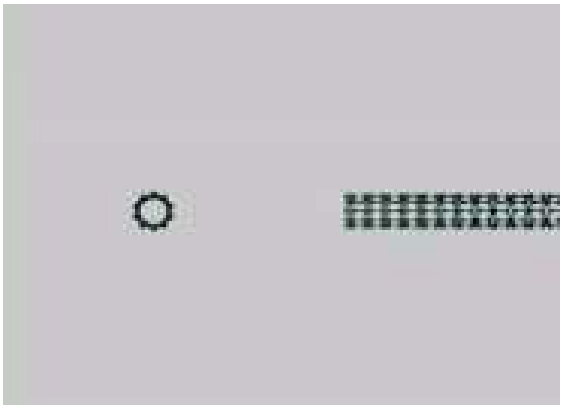

Figure 1:STRUCTURE OF CARBON NANO TUBES

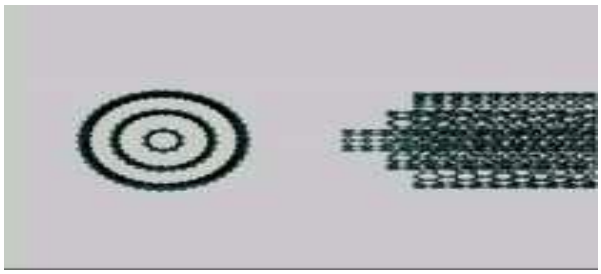

Figure 2: STRUCTURE OF CNT

1.1 Properties of Paper Batteries

The properties of Paper Batteries are mainly dependent on the properties of cellulose as well as CNT"s

Cellulose:

- High Tensile strength; Low Shear Strength
- Biodegradable
- Biocompatible
- Excellent Porosity & Absorption Capacity
- Easily Reusable and Recyclable
- Non –Toxic

Carbon Nanotubes:

- Width to Length ratio: 1:107
- Tensile strength is more than Steel.
- Lower Mass density.
- Much Lighter and Flexible.
- Higher Electrical Conductivity and Lower Resistivity
- Attaching the Paper and CNT layers multiplies the Output Voltage; Detaching the Paper and CNT layers divides the Output Voltage.

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• Thickness is between 0.5-0.7mm.
• Operating temperature range varies from:75°C to +150°C.
• Does not contain heavy metals like Hg,Pb etc
•Mechanical damage does not lead to over heating and no shipment issue caused by leakage.

1.2 Need

The main problem we are facing with present Electro-Chemical batteries is:

Limited Life Time Primary batteries irreversibly transform chemical energy to electrical energy but after using for some time they are just a unbiodegradable waste. Secondary batteries can be easily recharged; i.e. they can have their chemical reactions reversed by supplying electrical energy to the cell, restoring their original composition. There is also one major problem with Rechargeable batteries is that these are still costlier than Primary Batteries

Leakage In these batteries, a main issue is that as time passes these batteries storage starts declining If leakage occurs,through accident or any how, the chemicals released may be dangerous.The active chemical leakage can then damage the equipment in which the batteries were inserted.

Environmental Concerns The widespread use of batteries has created many environmental problems, such as toxic metal pollution. Metals such as Cadmium, Mercury, Lead, Lithium and Zinc have been identified as highly toxic metals.Batteries may be harmful or fatal if swallowed by young children While in the digestive tract the battery's electrical discharge can burn the body cells and tissues and can be serious enough to lead to death.

1.3 Some other Fuels which come in contact to replace these batteries but still have some limitations

The limitations of Fuel cells are:

Cost:

Hydrogen-based fuel cells are still extremely costly for general consumer use. Their use is still restricted to rocket launch vehicles. Liquid Hydrogen and Hydrogen Peroxide is essential ingredients that make them costly.

Portability & Size:

Fuel cells are larger in size, which reduces portability and makes it very difficult for use in electronic and medical gadgets.

The limitations of Solar Cells are:

Versatility:

Solar cells cannot be used in many situations, like Emergency Power-Backup, Emergency Energy Purge.

Adaptability:

Solar cells cannot be used in all battery-powered Equipment.

Portability & Size:

They are not at all portable or robust. The solar cells need an auxiliary back-up battery during failures.

1.4 Construction

The process of construction consists of the following steps:Firstly, a common Xerox paper of desired Shape and Size are taken.

• CNT ink is spread over paper using Mayer Rod method
• The strong capillary force in paper enables high contacting surface area between the paper and nanotubes after the solvent is absorbed and then it is dried out in an oven.
• A thin lithium film is laminated over the exposed cellulose surface which completes our paper battery. This paper battery is then connected to the aluminium current collectors which connect it to the external load.
• Its is similar to an electrochemical battery except with the constructional differences mentioned before the procedures.

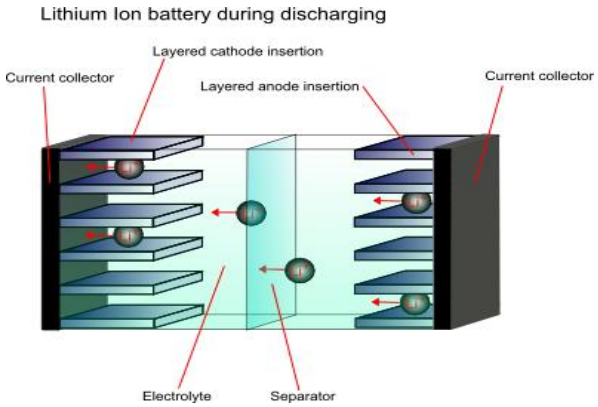

Figure 3

Lithium Ion Battery during discharging

1.5 Advantages

- Biodegradable & Non-Toxic: Since its major ingredients are of organic origin, it is a biodegradable and non toxic product.
- Biocompatible: our body's immune system does not easily reject them if implanted into human body.
- Easily Reusable & Recyclable: It is easily recyclable and reusable, even with the existing paper recycling techniques
- Durable: It has a shelf life of almost 3 years. Under extreme conditions it can operate within -75° to +150°C.
- Rechargeable: It can be recharged more than 250 times using almost all electrolytes, including bio-salts such as sweat, urine and blood.
- No Leakage & Overheating:Due to low resistivity, it does not get overheated even under extreme conditions. Since there are no leaky fluids, so even under spontaneous or accidental damage, there is no leakage problem.
- Very Light Weight & Flexible.
- Easily Moldable Into Desired Shapes & Sizes.
- Customizable Output Voltage:

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- By varying CNT concentration.
- By stacking & slicing[2].

1.6 Applications

As it is the latest technology which can easily reduce the size and weight of modern technologies, so it is going to be used in many fields. Some of them are:

- In Electronics:By replacing the alkaline batteries with light-weight paper we can reduce the weight of laptop batteries,mobile batteries etcIn calculators, wrist watch and other low drain devices.In wireless communication devices like Speakers, Bluetooth headsets etc
- In Medical Sciences:In Pacemakers for the heart,in Artificial tissues (using Carbonnanotubes)
- In Cosmetics, Drug-delivery systems
- In Biosensors, such as Glucose meters,sugar meters, etc.
- In Automobiles and Aircraft
- In Hybrid Car Batteries
- In Long Air Flights reducing Refueling
- For Light weight guided missiles
- For powering electronic devices in satellite programs[3].

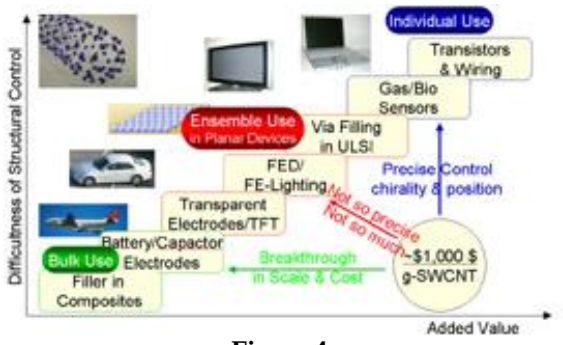

Figure 4

The Indian Scenario of paper battery

Unfortunately, not much work has been carried out in India, except for a few notable ones.The work is carried out as a joint research project of the Kalasalingam University in Krishnankovil, India; the Indian Institute of Technology,Mumbai; and IMRAM Tohoku University in Japan, assisted by India's Department of Science and Technology. Kalasalingam University's G. Hirankumar brought optimised cathode materials (CNT) to Tohoku4University's laboratories for three months of joint development[3].

II. LITERATURE REVIEW

Paper battery mainly constitutes of carbon nanotubes. At carbon nanotubes, significant works have been carried out independently, 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. Pushparaj et al. demonstrated the fabrication of 'electrode-spacer electrolyte. The attempt to integrate the components on to a single unit was revived by Yi Cui et al. in a much simpler and more promising way. In this paper, they integrated all of the components of a Li-ion battery into a single sheet of paper just by doing 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 can be used in two ways as a, separator and mechanical support. Another significant attempt to exploit the properties of Paper batteries was made by Dr. Mangilal Agrawal, Lousiana 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[4].

Since the field is so promising and potent, there has been a huge amount of work done over CNTs and Paper Batteries. However, the entire work in literature is neither comprehensible nor easily Accessible[5].

III. COMPARISON BETWEEN PAPER BATTERY (SUPER CAPACITOR) AND LI-ION BATTERY

PERFORMANCE COMPARISON	BETWEEN SUPERCAPACITOR AND LI-ION	
Function	Supercapacitor	Lithium-ion (general)
Charge time	1–10 seconds	10–60 minutes
Cycle life	1 million or 30,000h	500 and higher
Cell voltage	2.3 to 2.75V	3.6 to 3.7V
Specific energy (Wh/kg)	5 (typical)	100–200
Specific power (W/kg)	Up to 10,000	1,000 to 3,000
Cost per Wh	$20 (typical)	$0.50-$1.00 (large system)
Service life (in vehicle)	10 to 15 years	5 to 10 years
Charge temperature	-40 to 65°C (-40 to 149°F)	0 to 45°C (32°to 113°F)
Discharge temperature	-40 to 65°C (-40 to 149°F)	-20 to 60°C (-4 to 140°F)

Source: Battery University

Figure 5: paper battery and lithium-ion battery

IV. LIMITATION AND DISADVANTAGES

No technology is 100% advantageous, there are some pros and cons to each and every technology.

It would not be logical only to fall over the advantageous properties and applications of Paper Batteries .Things need to be discussed at the flip side As well. Following are some of them:

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• Due to Low Shear strength, they can be easily torned.
• The Techniques and the Set-ups used in the Production of Carbon Nanotubes are very less Efficient and much expensive. These are:Arc discharge,Chemical Vapour Deposition (CVD),Laser Ablation,Electrolysis[6].
• When inhaled, their interaction with the lungs is similar to that with Asbestos fibers, hence may be seriously hazardous to human health[7].

V. RESULTS AND CONCLUSIONS

One of the major problems, the world now is facing is energy crisis. Every nation needs energy and everyone needs power. And this problem which disturbs the developed countries perturbs the developing countries like India to a much greater extent. Standing at a point in the present where we can't imagine a day without power, Paper Batteries can provide a path-breaking solution, yet we know that there are some energy resources but damage environment or may not be sufficient. Being Biodegradable paper batteries have potential adaptability to power the next generation of electronics, and hybrid vehicles, allowing for radical new designs and medical technologies. But India still has got a long way to go if it has to be self-dependant for its energy solution. Literature reflects that Indian researchers have got the scientific astuteness needed for such revolutionary work. But what hinders their path is the lack of facilities and funding. Of course, the horizon of this technology is much wider, but this paper is just a step towards this.

VI. FUTURE WORK

There are many technologies which are coming in future which may use it.One important technology is about Transformers. Transformers is a Turkish company named Letvision make it possible they have converted a BMW Z4 model into a working prototype of transformers. They might be interested in using the paper battery because they need a convenient, light-weight source of energy which provide sufficient energy and even consume less space they might use the paper battery.There is recently in news about the case of giant mobile company SAMSUNG they have created there most powerful smartphone NOTE 7 using li-ion battery but it start exploding it may be due to the battery issue.But It won't happen if they used the paper battery instead of li-ion battery as paper don't explode.

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BIOGRAPHIES

Aryan Sukhija is a student Of Computer Science Engineering from NIET, Gr.Noida and he is writing his first research paper in the area of paper battery
Education and Credentials:
He is pursuing his Bachelors of Technology(CSE) from Noida Institute of Engineering & Technology.
He had completed his senior secondary education from D.P.M Sr, Sec, Public School.
Notable Achievements:
Merit Certificate for securing 1st position in DBMS lab work held in NIET , Gr. Noida**.**
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