A

TECHNICAL SEMINAR REPORT

On

"PAPER BATTERY"

Submitted in partial fulfillment of the requirements for the degree of B.Tech. in Electronics and Communication Engineering.

by:

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma by the university or other institute of higher learning, except where due acknowledgement has been made in the text.

Signature:

Vishal Kumar

Roll No: 1702731168

CERTIFICATE

This is to certify that Project Report entitled "PAPER BATTERY" which is submitted by Vishal Kumar, student of ECE 4th year in the partial fulfillment of requirement for the award of degree of Bachelor of Technology (Electronics and Communication Engineering) submitted to A.P.J Abdul Kalam Technical University, Lucknow is a record of students' own work carried out under my supervision. The matter in this report has not been submitted to any University or Institution for award of any degree.

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Prof. P.K. Chopra Date:

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I express my thanks to all staff members and friends for all the help and co-ordination extended in bringing out this seminar successfully in time.

ABSTRACT

This paper reports on the use of cellulose paper simultaneously as electrolyte, separation of electrodes, and physical support of a rechargeable battery. The deposition on both faces of a paper sheet of metal or metal oxides thin layers with different electrochemical potentials, respectively as anode and cathode, such as Cu and Al, lead to an output voltage of 0.70 V and a current density that varies between 150 nA/cm and 0.5 mA/cm, subject to the paper composition, thickness and the degree of OH_ species adsorbed in the paper matrix. The electrical output of the paper battery is independent of the electrodes thickness but strongly depends on the atmospheric relative humidity (RH), with a current density enhancement by more than 3 orders of magnitude when RH changes from 60% to 85%. Besides flexibility, low cost, low material consumption, environmentally friendly, the power output of paper batteries can be adapted to the desired voltage–current needed, by proper integration. A 3-V prototype was fabricated to control the ON/OFF state of a paper transistor.

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CHAPTER 1

1.1 INTRODUCTION

A paper battery is a flexible, ultra-thin energy storage and production device formed by combining carbon nanotube with a conventional sheet of cellulose-based paper. A paper battery acts as both a high-energy battery and super capacitor, combining two components that are separate in traditional electronics. This combination allows the battery to provide both long-term, steady power production and bursts of energy. Non-toxic, flexible paper batteries have the potential to power the next generation of electronics, medical devices and hybrid vehicles, allowing for radical new designs and medical technologies. Paper batteries may be folded, cut or otherwise shaped for different applications without any loss of integrity or efficiency. Cutting one in half halves its energy production. Stacking them multiplies power output. Early prototypes of the device are able to produce 2.5 volt s of electricity from a sample the size of a postage stamp.

The devices are formed by combining cellulose with an infusion of aligned carbon nanotubes that are each approximately one millionth of a centimeter thick. The carbon is what gives the batteries their black colour.

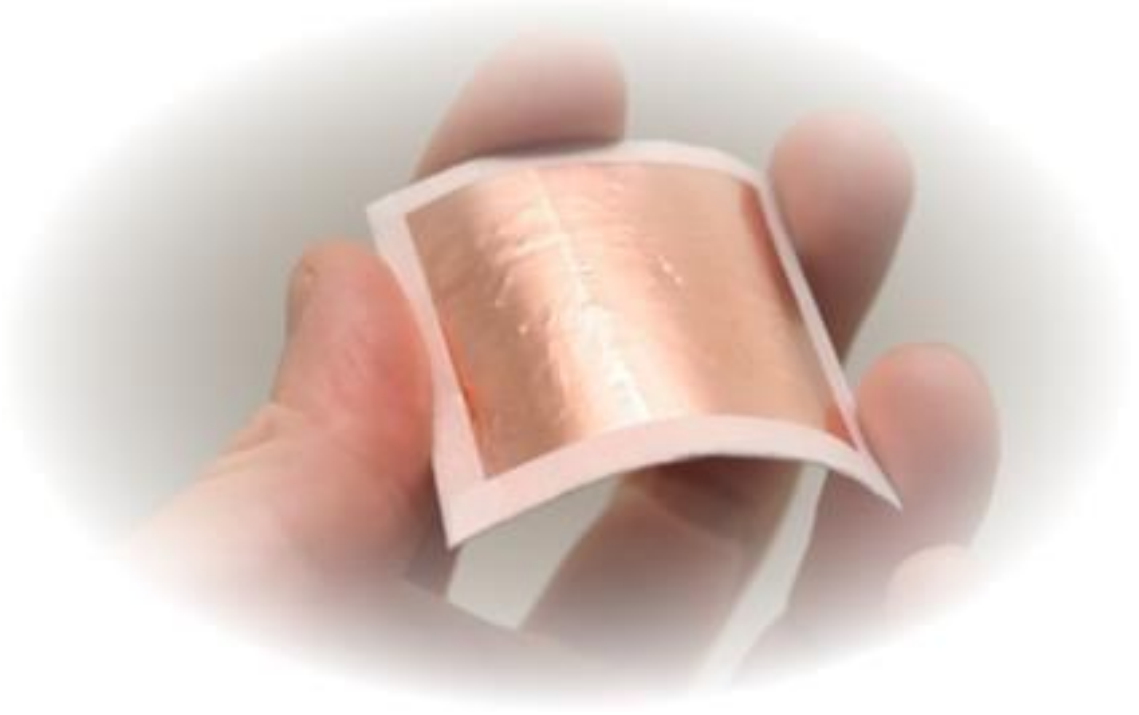

Figure 1.1 Paper Battery

Cellulose based paper is a natural abundant material, biodegradable, light, and recyclable with a well-known consolidated manufacturing process. Here, we expect to contribute to the first step of an incoming disruptive concept related to the production of self-sustained paper electronic systems where the power supply is integrated in the electronic circuits to fabricate fully self-sustained disposable, flexible, low cost and low electrical consumption systems such as tags, games or displays.

In achieving such goal we have fabricated batteries using commercial paper as electrolyte and physical support of thin film electrodes. A thin film layer of a metal or metal oxide is deposited in one side of a commercial paper sheet while in the opposite face a metal or metal oxide with opposite electrochemical potential is also deposited. The simplest structure produced is Cu/paper/Al but other structures such as Al paper WO3/ TCO were also tested, leading to batteries with open circuit voltages varying between 0.50 and 1.10 V. On the other hand, the short current density is highly dependent on the relative humidity (RH), whose presence is important to recharge the battery. The set of batteries characterized show stable performance after being tested by more than 115 hours, under standard atmospheric conditions [room temperature, RT (22 C) and 60% air humidity, RH].

The thicknesses of the metal electrodes varied between 100 and 500 nm. The Al/paper/Cu thin batteries studied involved the use of three different classes of paper: commercial copy white paper (WP: 0.68 g/cm , 0.118 mm thick); recycled paper (RP:0.70 g/cm , 0.115 mm thick); tracing paper (TP: 0.58 g/cm ,0.065 mm thick). The role of the type of paper and electrodes thickness on the electrical parameters of the battery, such as the Voc and Jsc are indicated.

The thickness of the metal layer does not play a remarkable role on electrical characteristics of the batteries. Considering that the tracing paper is less dense and thinner than white and recycled paper, the difference on the current density observed can be related to ions recombination either due to impurities inside the foam/mesh-like paper structure or charge annihilation by vacant sites associated to the surface of the paper fibres, existing in thicker papers. Other possible explanation is that the adsorption of water vapour is favoured in less dense paper. We conclude that this type of battery is a mixture of a secondary battery and a fuel cell where the fuel is the water vapour and so its application requires environment with 40%.

Batteries able to supply a Voc =.70V and Jsc > 100 nA/cm at Relative humidity=60% were fabricated using respectively as anode and cathode thin metal films of Al and Cu as thin as 100 nm.

Carbon nanotubes

- **Carbon nanotubes (CNTs)** are allotropes of carbon with a cylindrical nanostructure. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, electronics, optics and other fields of materials science and technology.
- In addition, owing to their extraordinary thermal conductivity, mechanical and electrical properties, carbon nanotubes find applications as additives to various structural materials. For instance, nanotubes from a tiny portion of the material in some (Primarily Carbon Fiber) baseball bats, golf clubs, car parts or Damascus steel

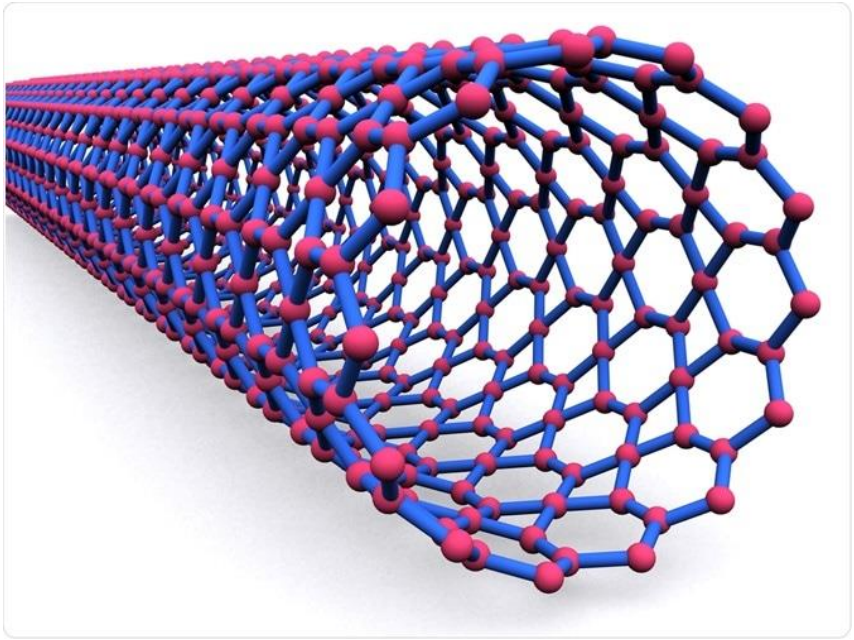

Figure 1.1.1 Carbon Nanotubes

1.2 Properties of Paper Batteries

The properties of Paper Batteries are mainly attributed to the properties of its constituents.

1.2.1 Properties of Cellulose:

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

- Non –Toxic

1.2.2 Properties of Carbon Nanotubes:

- Ratio of Width: Length: 1:107
- High tensile Strength (Greater than Steel).
- Low Mass density & High Packing Density.
- Very Light and Very Flexible.
- Very Good Electrical Conductivity (better than Silicon).
- Low resistance (~33 ohm per sq. inch).
- Thickness: typically about 0.5-0.7mm.

1.3 Life Of Battery

- Even if never taken out of the original package, disposable (or "primary") batteries can lose 8 to 20 percent of their original charge every year at a temperature of about 20°–30°C. [54] This is known as the "self-discharge" rate and is due to non-currentproducing "side" chemical reactions, which occur within the cell even if no load is applied to it. The rate of the side reactions is reduced if the batteries are stored at low temperature, although some batteries can be damaged by freezing. High or low temperatures may reduce battery performance. This will affect the initial voltage of the battery. For an AA alkaline battery this initial voltage is approximately normally distributed around 1.6 volts.
- Rechargeable batteries self-discharge more rapidly than disposable alkaline batteries, especially nickel-based batteries a freshly charged NiCd loses 10% of its charge in the first 24 hours, and thereafter discharges at a rate of about 10% a month. Most nickel- based batteries are partially discharged when purchased, and must be charged before first use.

1.4 DURABILITY

The use of carbon nanotubes gives the paper battery extreme flexibility, the sheets can be rolled, twisted, folded or cut into numerous shapes with no loss of integrity or efficiency, or stacked, like printer paper(or a voltaic pile),to boost total output. As well, they can be made in a variety of sizes, from postage stamp to broadsheet. It is essentially a regular piece of paper, but it is made in a very intelligent way,

”said Leichardt, ”We are not putting pieces together-it is a single, integrated device,” he said. “The components are molecularly attached to each other .The carbon nanotube is embedded in the paper, and the electrolyte is soaked into the paper. The end result is a device that looks, feels, and weighs the same as paper.”

CHAPTER 2

CONSTRUCTION AND WORKING OF PAPER BATTERY

2.1 MANUFACTURING OF CARBON NANOTUBES

One method of manufacture, developed by scientists at Rensselaer Polytechnic Institute and MIT, begins with growing the Nano tubes on a silicon substrate and then impregnating the gaps in the matrix with cellulose. Once the matrix has dried, the material can be peeled off of the substrate, exposing one end of the carbon nano tubes to act as an electrode.

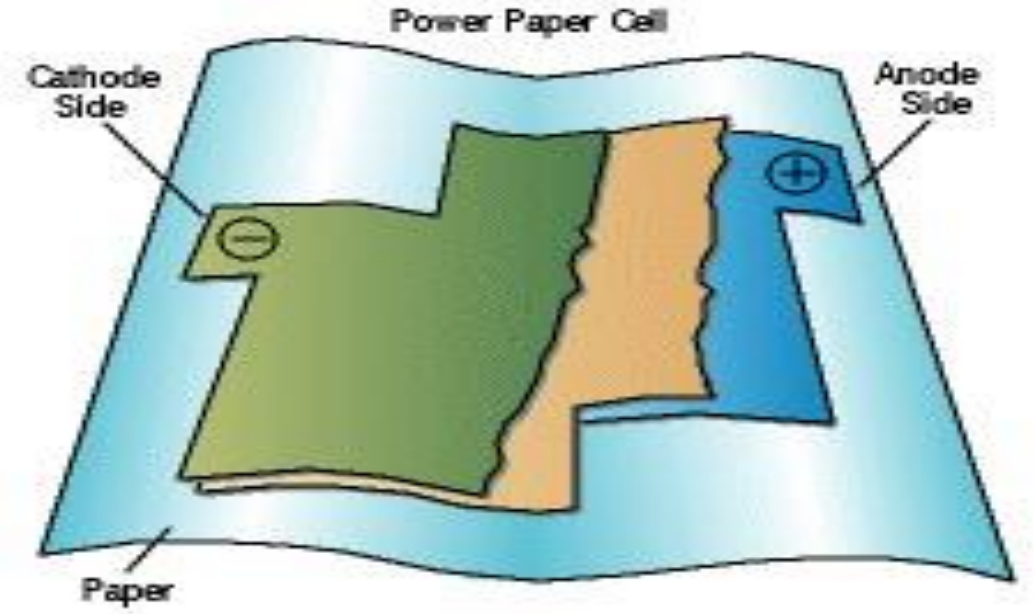

Figure 2.1 manufacturing of paper battery

When two sheets are combined, with the cellulose sides facing inwards, a super capacitor is formed that can be activated by the addition of the ionic liquid. This liquid acts as an electrolyte and may include salt-laden solutions like human blood, sweat or urine. The high cellulose content (over 90%) and lack of toxic chemicals in paper batteries makes the device both biocompatible and environmentally friendly, especially when compared to the traditional lithium ion battery used in many present-day electronic devices and laptops.

Specialized paper batteries could act as power sources for any number of devices implanted in humans and animals, including RFID tags, cosmetics, drug-delivery systems and pacemakers. A capacitor introduced into an organism could be

implanted fully dry and then be gradually exposed to bodily fluids over time to generate voltage. Paper batteries are also biodegradable, a need only partially addressed by current e-cycling and other electronics disposal methods increasingly advocated for by the green computing movement.

2.2 DEVELOPMENT

The creation of this unique nano composite paper drew from a diverse pool of disciplines, requiring expertise in materials science, energy storage, and chemistry. The researchers used ionic liquid, essentially a liquid salt, as the battery's electrolyte. The use of ionic liquid, which contains no water, means there's nothing in the batteries to freeze or evaporate. "This lack of water allows the paper energy storage devices to withstand extreme temperatures," Kumar said. It gives the battery the ability to function in temperatures up to 300 degrees Fahrenheit and down to 100 below zero. The use of ionic liquid also makes the battery extremely biocompatible; the team printed paper batteries without adding any electrolytes, and demonstrated that naturally occurring electrolytes in human sweat, blood, and urine can be used to activate the battery device.

Cellulose-based paper is a natural abundant material, biodegradable, light, and recyclable with a well-known consolidated manufacturing process. These attributes turn paper a quite interesting material to produce very cheap disposable electronic devices with the great advantage of being environmental friendly. The recent (r) evolution of thin-film electronic devices such as paper transistors [1], transparent thin-film transistors based on semiconductor oxides [2], and paper memory [3], open the possibility to produce low cost disposable electronics in large scale. Common to all these advances is the use of cellulose fiber-based paper as an active material in opposition to other ink-jet printed active-matrix display [4] and thin film transistors [5] reports where paper acts only as a passive element (substrate). Batteries in which a paper matrix is incorporated with carbon nanotubes [6], or biofluid - and water-activated batteries with a filter paper [7] have been reported, but it is not known a work where the paper itself is the core of the device performance.

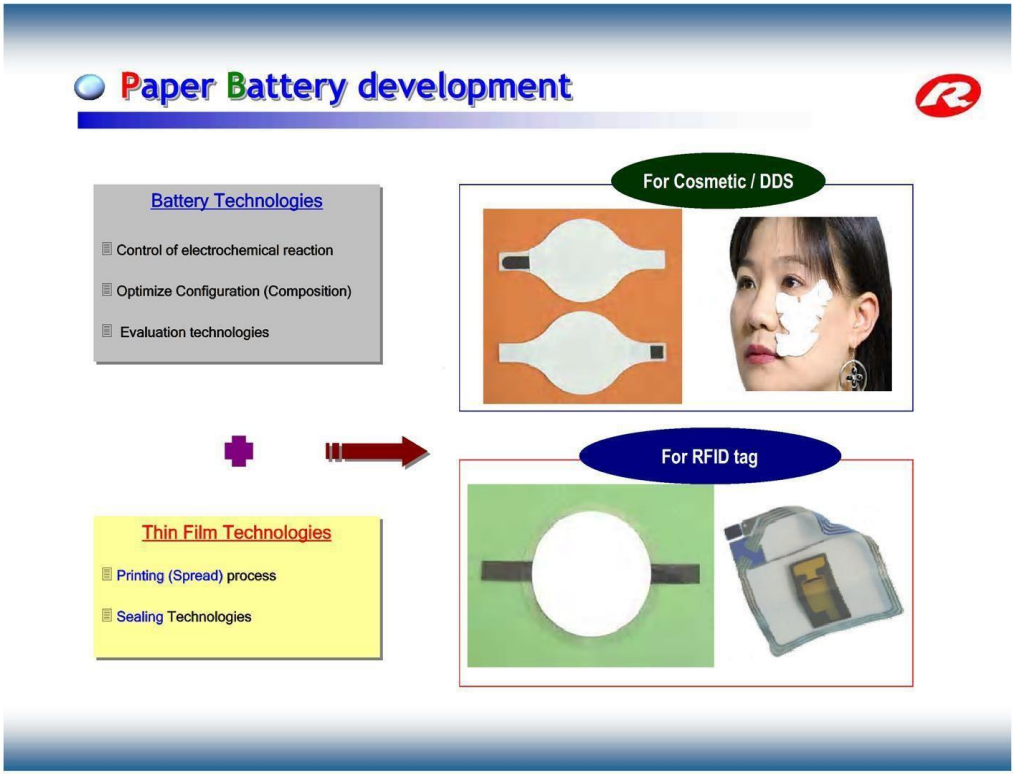

Figure 2.2 development of paper battery

With the present work, we expect to contribute to the first step of an incoming disruptive concept related to the production of self-sustained paper electronic systems where the power supply is integrated in the electronic circuits to fabricate fully self-sustained disposable, flexible, low cost and low electrical consumption systems such as tags, games or displays.

In achieving such goal we have fabricated batteries using commercial paper as electrolyte and physical support of thin film electrodes. A thin film layer of a metal or metal oxide is deposited in one side of a commercial paper sheet while in the opposite face a metal or metal oxide with opposite

Electrochemical potential is also deposited. The simplest structure produced is Cu/paper/Al but other structures such as Al paper WO TCO were also tested, leading to batteries with open circuit voltages varying between 0.50 and 1.10 V. On the other hand, the short current density is highly dependent on the relative humidity (RH), whose presence is important to recharge the battery. The set of

batteries characterized show stable performance after being tested by more than 115 hours, under standard atmospheric conditions [room temperature, RT (22 C) and 60% air humidity, RH]. In this work we also present as a proof of concept a paper transistor in which the gate ON/OFF state is controlled by a non-encapsulated 3 V integrated paper battery.

2.3 Construction of Paper Battery:

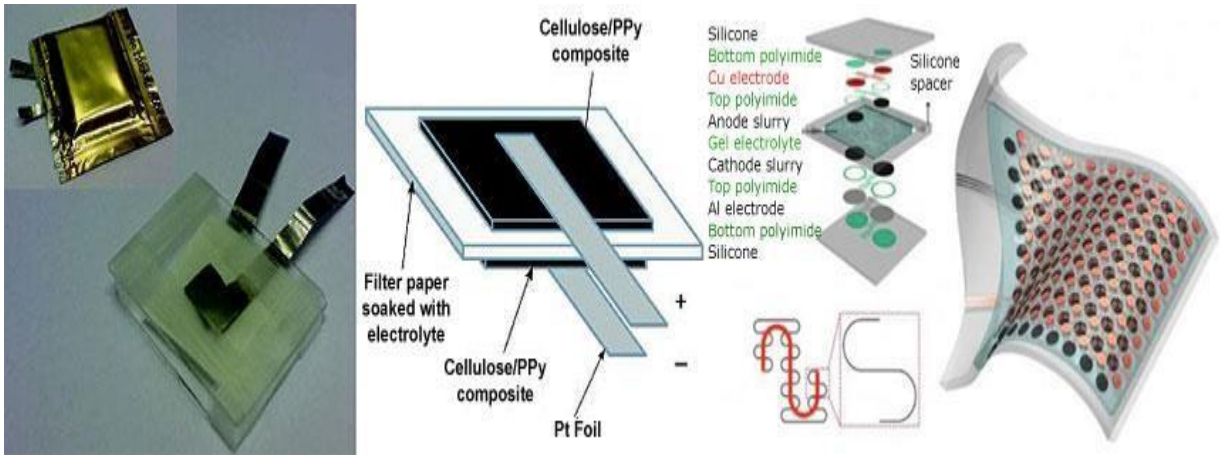

Figure 2.3 Construction of paper battery

Given below are three ways 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

2. **The 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.

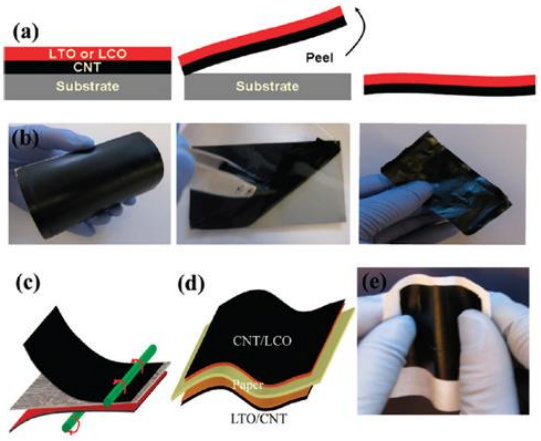

Figure 2.3.1 Method to Construct

3. **The 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.

2.4 Working Principle of Paper Battery:

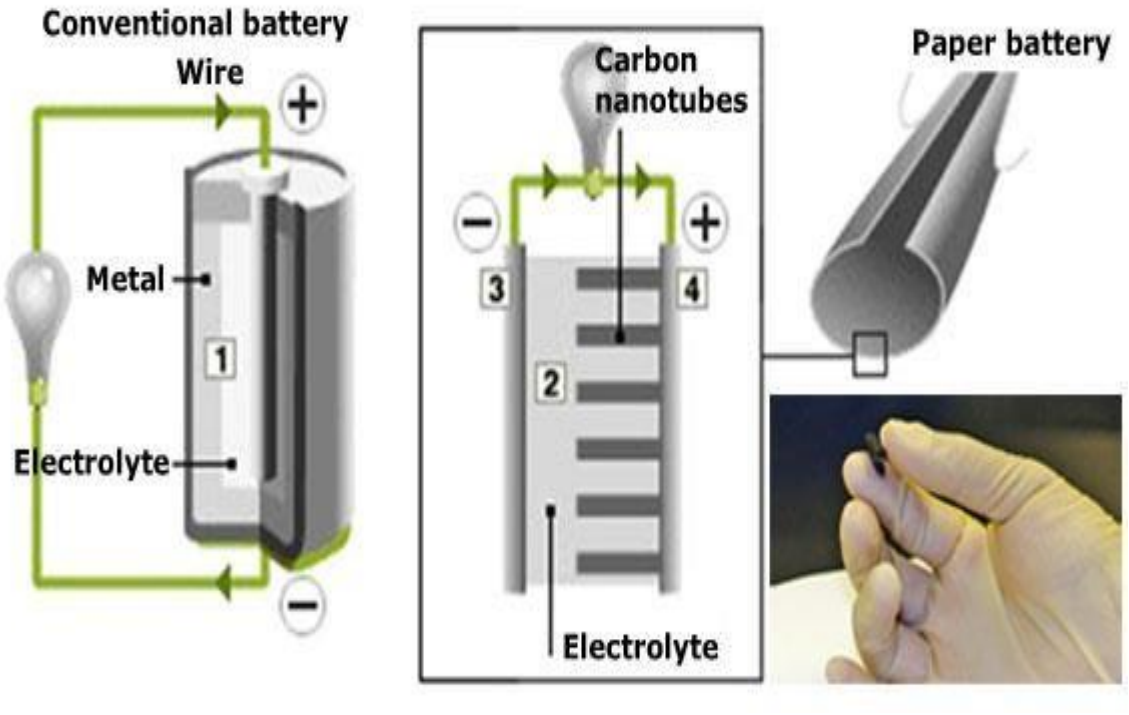

Figure 2.4 Working of paper battery

Internal operation of paper batteries is similar to that of conventional batteries with each battery generating about 1.5V.

If one can recall traditional batteries work in the manner where positive charged particles called ions and negative charged particles called electrons move between positive electrodes called anode and negative electrode called cathode. Current flows as electrons flow from anode to the cathode through the conductor, since the electrolyte is an insulator and doesn't provide a free path for electrons to travel.

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

- Separator: Cellulose or Paper

Similarly 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 starts flow through the external circuit from cathode to the anode.

While a conventional battery contains a number of separate components, the paper battery integrates all of the battery components in a single structure, making it more energy efficient, Integrated devices. • The battery contains carbon nanotubes, each about one millionth of a centimeter thick, which act as an electrode. The nanotubes are embedded in a sheet of paper soaked in ionic liquid electrolytes, which conduct the electricity.

Where can Paper Batteries be used?

Paper Battery can shows favourable for applications where size and portability is the major necessity. Most modern electronic devices like digital watches, smart cards etc. facilitate the necessity of ultra-thin batteries which are nontoxic, flexible and long lasting. The Paper battery can be rolled, twisted, folded and even cut into your desired shape and size without any drop in its efficiency. The **applications of Paper battery** are given below.

- Paper Battery can be now implemented in wearable technology like Google Glass, Wearable Biosensors, and Wearable computer etc.
- Used in entertainment devices.
- Used in tags and smart cards.
- For medical applications like disposable medical diagnostic devices and also can be used in pacemakers due to the paper batteries nontoxic and biodegradable nature.
- Ideal for aircraft, automobiles, remote controllers etc.

CHAPTER 3

APPLICATIONS

Paper battery can actually prove beneficial for applications where portability and size is the main requirement. Modern day electronic equipment's like smart cards, digital watches facilitate the requirement of thin batteries which are long lasting and non toxic. With the developing technologies and reducing cost of CNTs, the paper batteries will find applications in the following fields:

1. in Electronics:

- In laptop batteries, mobile phones, handheld digital cameras: The weight of these devices can be significantly reduced by replacing the alkaline batteries with lightweight Paper Batteries, without compromising with the power requirement. Moreover, the electrical hazards related to recharging will be greatly reduced.

- In calculators, wrist watch and other low drain devices.
- In wireless communication devices like speakers, mouse, keyboard, Bluetooth headsets etc.
- In Enhanced Printed Circuit Board (PCB) wherein both the sides of the PCB can be used: one for the circuit and the other side (containing the components) would contain a layer of customized Paper Battery. This would eliminate heavy step-down transformers and the need of separate power supply unit for most electronic circuits.

2. In Medical Sciences:

- in Pacemakers for the heart
- in Artificial tissues (using Carbon nanotubes)
- in Cosmetics, Drug-delivery systems
- In Biosensors, such as Glucose meters, Sugar meters, etc.

3. In Automobiles and Aircrafts:

- in Hybrid Car batteries
- in Long Air Flights reducing Refueling
- for Light weight guided missiles
- for powering electronic devices in Satellite programs

CHAPTER 4

4.1 ADVANTAGES

There are various advantage of paper battery over existing battery which is as follows:

1. Biodegradable & Non Toxic: Since its major ingredients are of organic origin, it is a biodegradable and non toxic product.
2. Biocompatible: They are not easily rejected by our body's immune system if implanted into human body.
3. Easily Reusable & Recyclable: Being cellulose based product it is easily recyclable and reusable, even with the existing paper recycling techniques.
4. Durable: It has a shelf life of three years (at room temperature). Under extreme conditions it can operate within -75° to +150°C.
5. Rechargeable: It can be recharged upto 300 times using almost all electrolytes, including bio-salts such as sweat, urine and blood.
6. No Leakage & Overheating: Owing to low resistance, 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.
7. Very Light Weight & Flexible.
8. Easily Moldable Into Desired Shapes & Sizes.
9. Customizable Output Voltage:

- By varying CNT concentration.
- By stacking & slicing.

4.2 LIMITATIONS

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

- Have Low Shear strength: They can be ‘torn’ easily.
- The Techniques and the Set-ups used in the production of Carbon Nanotubes are very expensive and very less efficient. These are:
    - Arc discharge
    - Chemical Vapour Deposition (CVD)
    - Laser Ablation
    - Electrolysis

.

If we inhaled the paper battery, they start interacting with the Microphages present in the lungs. This is very similar to that with asbestos fibers, hence may be seriously hazardous to human health.

These Batteries generates a E-wastage

CHAPTER 5

5.1 FUTURE SCOPE

Researchers at Rensselaer Polytechnic Institute have developed an energy storage material that simultaneously performs the functions of both a rechargeable battery and a super capacitor, yet has the physical properties of a sheet of paper (see the Figure). This Nano composite paper material is nontoxic, highly biocompatible with human tissue, and robust—both physically and thermally. It therefore 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 creation of the Nano composite paper draws from a diverse pool of disciplines, requiring expertise in materials science, energy storage, and chemistry. Robert Leichardt, the Ann and John H. Broadbent Senior Constellation Professor of Biocatalysts and Metabolic Engineering at Rensselaer, is one of the researchers who developed the technology. Leichardt states that 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 discussed.

According to Leichardt, this is mainly because the material may enable energy storage devices that can be placed directly beneath the skin, rather than deep inside the body, which is the usual practice. Such thin devices would have the dual advantages of being less invasive and easier to recharge. Of course, other properties of the material that favour such applications are its high levels of biocompatibility and mechanical flexibility.

5.2 PAPER BATTERY: INDIAN SCENARIO

Unfortunately, not much work has been carried out 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. Haran Kumar brought optimized cathode materials (CNT) to Tohoku University's laboratories for three months of joint development. Research is ongoing.

CONCLUSION

One of the major problems bugging the world now 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 there can't be a day without power, Paper Batteries can provide an altogether pathbreaking solution to the same.

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.

As this technology is adapted it will prove to be extremely useful and could even save not only cost but lives also

Being Biodegradable, Light-weight and Nontoxic, 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. 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 inquisitiveness is indefinitely vast and this paper is just a single step towards this direction.

REFERENCES

- Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-5, 2016 Paper Battery the Solution for Traditional Battery
- Paper-based batteries: ELSEVIER Biosensors & Bioelectronics Thu H Nguyen, Arwa Fraiwan, Seokheun Choi n Bioelectronics & Microsystems Laboratory, Department of Electrical & Computer Engineering, State University of New York at Binghamton, 4400 Vestal Pkwy, Binghamton, NY 13902, USA https://www.researchgate.net/publication/259318076
- www.wikipidea.com
- www.google.com/.electronicshub.org%2Fpaper-battery-construction-working%2F&psig=AOvV
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