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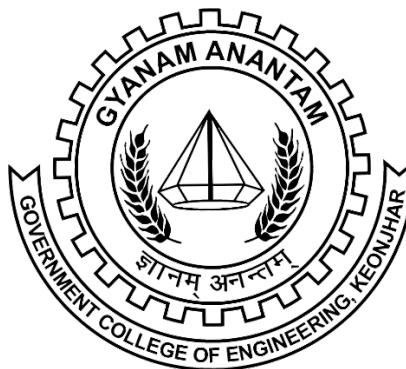
PAPER BATTERY

Seminar report submitted for the award of the degree of
Bachelor of Technology

In
Electrical Engineering
Of
Biju Patnaik University of Technology

By
Name-Kajal Panda
Regd No- 1501104111

Supervised by
Asst. Prof. Ramesh Chandra Khamari



Department of Electrical Engineering
Government College of Engineering
Keonjhar-758002
(Biju Patnaik University of Technology, Odisha)
February-2019



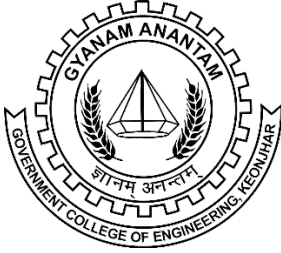
Department of Electrical Engineering
Government College of Engineering,
Jamunalia, Keonjhar-758002
(Biju Patnaik University of Technology, Odisha)

CERTIFICATE

This is to certify that the seminar report entitled, **“PAPER BATTERY”** submitted by **“KAJAL PANDA”** in partial fulfillment of the requirements for the award of Bachelor of Technology degree in **Electrical Engineering** at **GOVERNMENT COLLEGE OF ENGINEERING, KEONJHAR** under **BIJU PATTNAIK UNIVERSITY OF TECHNOLOGY, ROURKELA, ODISHA** is an authentic work carried out by the student under my supervision and guidance. To the best of my knowledge the matter embodied in the report has not been submitted to any other University/Institute for the award of any degree or diploma.

SUPERVISOR

HOD (EE)



Department of Electrical Engineering
Government College of Engineering,
Jamunalia, Keonjhar-758002
(Biju Patnaik University of Technology, Odisha)

DECLARATION

I certify that

- a. The work contained in this report is original and has been done by me under the guidance of our supervisor.
- b. The work has not been submitted to any other Institute for any degree or diploma.
- c. I have followed the guidelines provided by the Institute in preparing the report.
- d. I have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.
- e. Whenever I have used materials (data, theoretical analysis, figures, and text) from other sources, I have given due credit to them by citing them in the text of the report and giving their details in the references.

Name and Signature of Student

ACKNOWLEDGEMENT

Presentation, inspiration and motivation have always played a key role in the success of any venture.

We express our sincere thanks to **Mr Ramesh Chandra Khamari, Assistant Professor**, our supervisor, Govt. college of Engineering, Keonjhar. We our deep sense of gratitude to **Prof. (Dr.) Trilochan Sahu**, Principal ,Govt. college of Engineering, Keonjhar to encourage us to the highest peak and to provide us the opportunity to prepare this report.

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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 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.

ABBREVIATIONS USED:

1. Carbon Nano tubes (CNT),
2. Single walled carbon Nano tubes (SWCNT),
3. Multi walled carbon Nanotubes (MWCNT),
4. Lithium ion (Li-ion)

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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.



Figure-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.

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

➤ **NiCad & 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.

➤ **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.

2. MOTIVATION

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.

2.1 THEME

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 be recharged efficiently and is much safer than conventional Li-ion batteries. The CNT based paper battery is bio degradable, eco-friendly and can be cycled many times. They have a wide range of operating temperature. The overall efficiency of the paper battery is high.

3.LITERATURE SURVEY

There has been a constant search for super battery. The ones 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.

Significant works have been carried out independently, notable among which are by Pushparaj et al. [2007] and YiCui 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.

4.OBJECTIVE

To study the following;

- The use of self-rechargeable thin film batteries, their performance and application.
- The glucose activated paper battery based on glucose oxidised enzyme.
- Ultra-fast all polymer paper-based batteries.



Figure 1.1 Sample of Paper Battery

5.Specification of Paper Battery's

5.1 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.

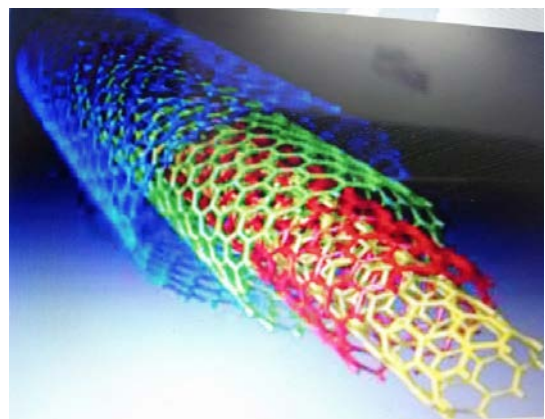
CNT's where discovered by Japanese scientist name Iijima in 1991. They are now considered as top-class subject in academic researches and industrial areas CNT"s are allotropes is carbon made of graphite and have be constructed in cylindrical tubes with Nano meter scale in diameter and several millimetres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

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.

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 (SWCNT)



2. Multi Walled (MWCNT)

Figure.2 Structure of CNT

Table:1

<u>Single Walled</u>	<u>Multi Walled</u>
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 productions are:

Arc-Discharge method (using arc vaporization of two carbon rods), **Laser Ablation method** (using graphite), and **Chemical Vapour 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. Pristine CNTs are now synthesized and marketed by many chemical firms worldwide.

6. Construction of a Paper Battery

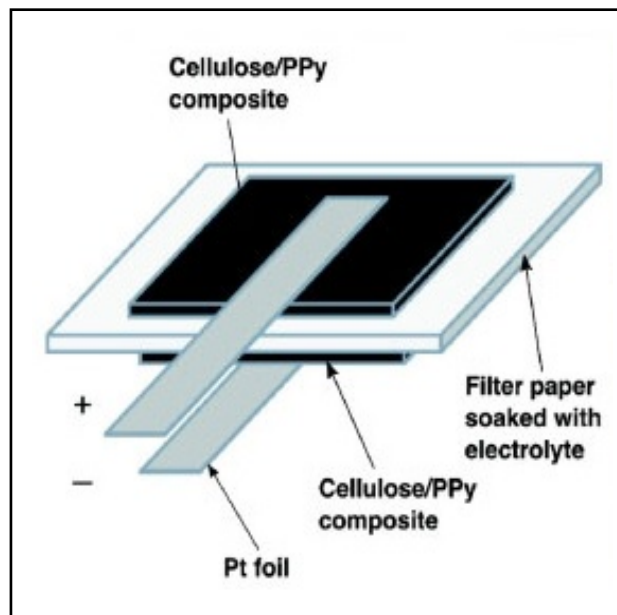


Figure 3. Construction of paper battery

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 etc.)
- 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.

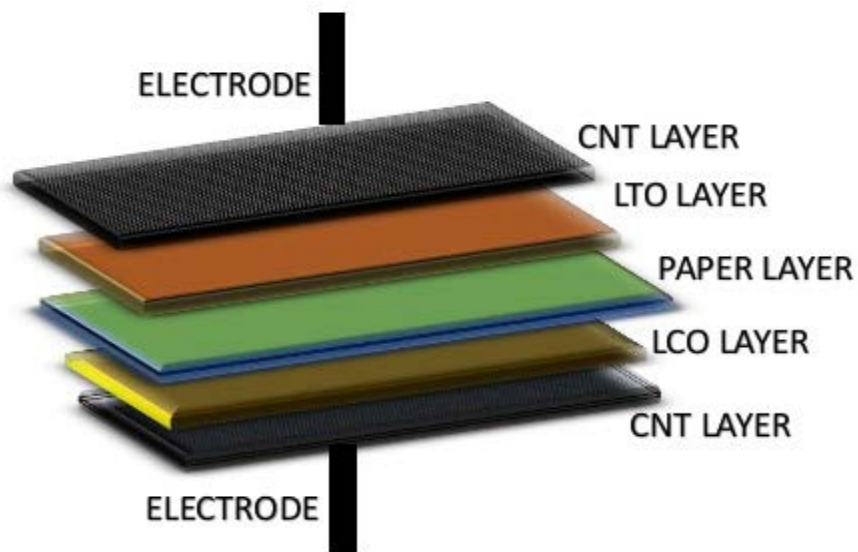
Step 4: The cellulose paper is heated at 80°C for 5 minutes.

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 ($\text{Li}_4\text{Ti}_5\text{O}_{12}$) and another film is pasted to the electrolyte LCO (LiCoO_2).

Step 7: Next, connect a LED on both the ends of the battery and check its functionality.

Structure



Microscopic View of the Layers

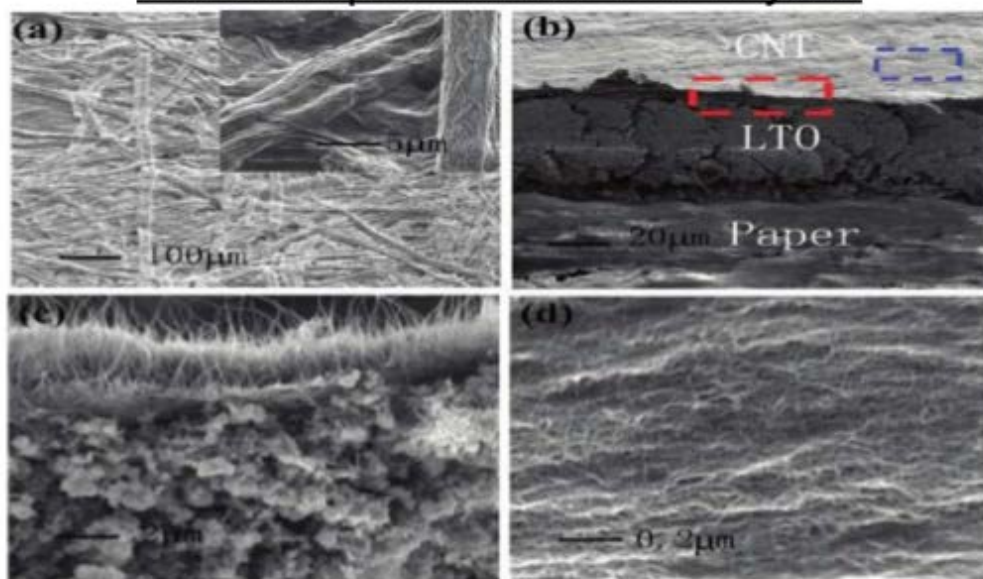


Figure 3.1 Structural view of a Paper Battery

7. WORKING OF PAPER BATTERY

A conventional battery or Rechargeable battery contains a number of separate components that produce electrons through a chemical reaction between the metal and the electrolyte of the battery. The Paper battery works when the paper is dipped in the ion-based liquid solution; next a chemical reaction occurs between the electrodes and liquid. The electrons move from the cathode to anode to generate electricity. The paper electrode stores energy while recharging within 10 seconds because the ions flow through the thin electrode quickly. Figure 4 shows the working of a paper battery. The best method to increase the output of the battery is to stack different paper batteries one over the other.

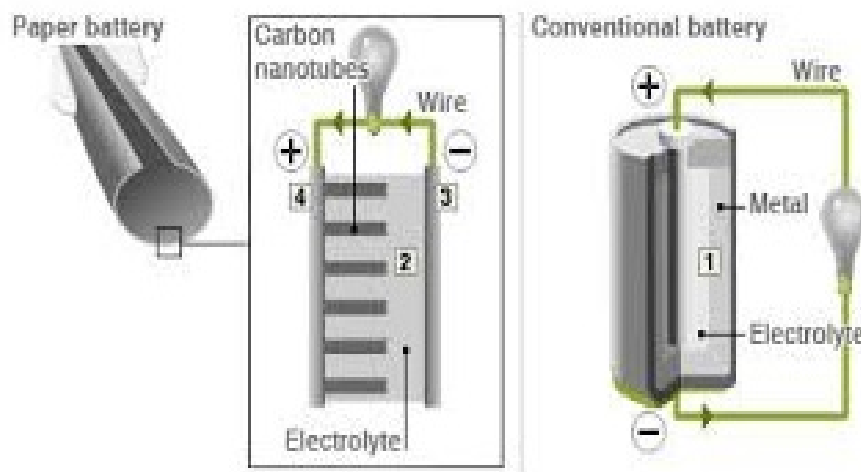


Figure 4. Working of Paper Battery

8. 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

9. 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 life damaged by CNT

10. 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)

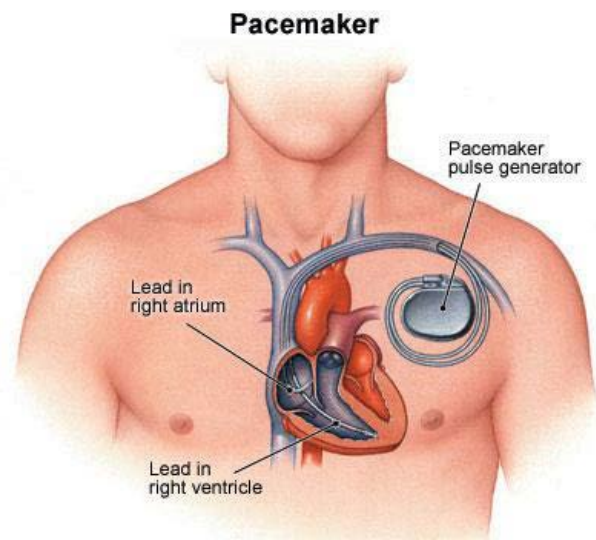


Figure 5. Applications

11. COMPARISION BETWEEN PAPER BATTERY AND LITHIUM-ION BATTERY

Table:2

Performance Comparison	Between Super Capacitor & Li-Ion	
Function	Super Capacitor	Li-Ion
Charge Time	1-10 Sec	10-60 Mins
Cycle Life	1 Million or 30,000Hr	500 & Higher
Cell Voltage	2.3 – 2.75 v	3.6 – 3.7 v
Specific Energy (Wh/Kg)	5 (Typical)	100-200
Specific Power (W/Kg)	Up to 10000	1000 to 3000
Cost per whr	\$20 (Typical)	\$0.5 to \$1.00 (Large System)
Service life in Vehicle	10 to 15 years	5 to 10 years
Change Temp	-40°C to 60°C	0 to 45°C
Discharge Temp	-40°C to 60°C	-20 to 60°C

12.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 fibre, resins, plastics etc.

Further research is needed in Nano toxicology 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.

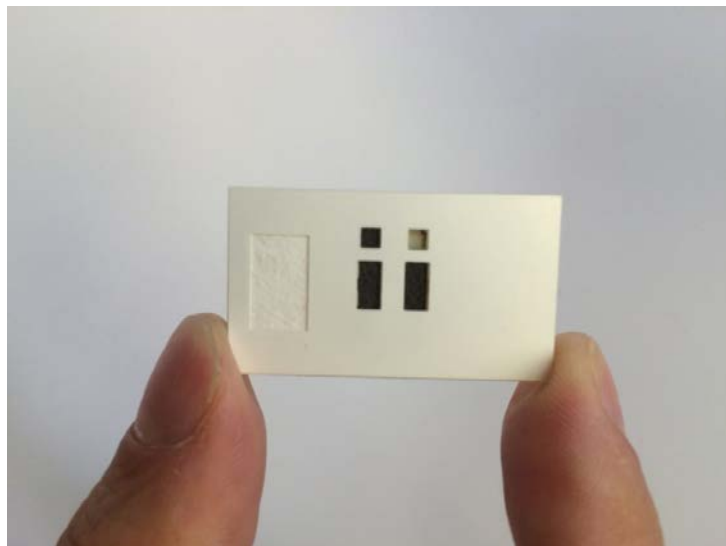


Figure 6. Paper Battery

13.FUTURE WORK

There are many technologies which are coming in future which may use it. One important technology is about Transformers. Transformer is a Turkish company named Let vision 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 starts exploding it may be due to the battery issue. But it won't happen if they used the paper.

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