Experimental Study Of The Nano Based Paper Battery

Pulla Sammaiah¹, Md. Yakub Baba² and N. Praveena devi³ and I Rajasri Reddy⁴

¹Centre for Materials and Manufacturing, Dept. of Mechanical Engineering, SR Engineering College, Warangal, Telangana, India.
²,³Dept. of Mechanical Engineering, S R University, Warangal, Telangana, India.
⁴Sumathi Reddy Institute of Technology for Women, Warangal, India.

Email: pullasammaiah@gmail.com

Abstract: Recent Industry looking for paper battery with highly flexibility, easily handling and high voltage. Currently, battery occupies a large quantity of vicinity and contributes to a big part of device weight. In this paper, we use carbon nanotubes with conventional sheet of cellulose based paper as cathode, aluminum foil as anode and a polyethylene (plastic paper) of 50µm as a separator to obtain adaptability, ultra-thin electricity storage without a loss of integrity and performance. In this attempt folded anode and cathode sheets which resulted increase in voltage and achieved approximately 40% more than other paper batteries. Voltage 3.38V is achieved which is better than the preceding existing paper battery voltage.

Keywords: Paper Battery, Nano Tubes, Ultra thin storage battery, digital design.

1. Introduction
A paper battery is an electric powered battery made to apply a spacer since quite a while back settled extensively taking of cellulose (the basic time of paper). It arranges nano scale structures to go about as outrageous surface-territory anodes to update conductivity. Despite these incredibly thin, paper batteries are bendy what's more earth tasteful, permitting joining legitimately into a wide display of contraptions. Their general execution is a great deal of like standard compound batteries with the earnest complexity that they're non-ruinous and besides do no longer require beast veritable property. The structure of those batteries is what sets up them despite standard batteries. Paper is sufficient despite self-proceeding, that makes paper more affordable. Disposing of paper is essentially less and is ignitable similarly as eco-obliging. Using paper gives the battery a first-class period of flexibility. The battery can be bowed or twisted round things rather than requiring a managed case. In like manner, being a limited, acknowledgment sheet, the paper battery can result adequately perfectly healthy tight regions, diminishing the size and weight of the instrument it powers. The usage of paper underpins the electron stream that is suitably planned for high all things considered execution programs. Using paper in batteries manufactures the floor region that may be used consolidate reagents. The paper used in paper batteries can be upgraded to improve its general execution designs. Planning techniques, for instance, photolithography, wax printing, further to laser micromachining are utilized to stretch out hydrophobic similarly to hydrophilic regions at the paper to convey a pathway to deal with the tight enthusiasm of the beverages applied in...
batteries. Proportionate methods can be used to enlarge electric pathways on paper to expand paper electric energized gadgets and may join paper power garage.

As computerized instruments have progressed from large household PC to little pocket-sized cell phones ready to walking numerous applications; as front-line innovation thins down, fashioners should discover a way to rate more quality directly into litter regions. One contemporary supplier is the paper battery. The cutting-edge advancement of the paper battery utilizes carbon nanotubes as cathodes just as an incorporated plan of layers of electrolytes to make a slight and also versatile battery. The paper battery is exceptionally mammoth as it might open opportunities for keen names, clinical apparatus, and advanced screens in publicizing and advertising. The paper battery separates itself from different various batteries in its utilization carbon nanotubes, which license electric viability and viable use room, the realities of as an approach to be explored inside the sticking to districts.

2. Literature survey
Paper Battery was first presented by Pushparaj et al. [1], In which creators-built paper battery with multiwalled nanotubes (MWNT) as cathode and lithium (Li) as anode. They accomplished voltage at scope of 0.5 volts to 2.5 volts. Fabricated nanotubes for battery just as super capacitor. Yi Cui [2] utilized CNT as both cathode, anode alongside Li-particle battery segments by overlaying on to piece of paper and acquired voltage of 1-4.3 volts which brings about extraordinary execution improvement. They accomplished powerful mechanical adaptability and high vitality thickness. Because of utilization of Li-particle battery which could prompt poisonous compound responses when breakdown and isn't eco-accommodating. Anil Tekale [3], S.Balu [4], Shaikh Shoeb [5], A. Ganguly [6] likewise utilized CNT as cathode and Lithium as anode to get high battery-powered limit with regards to batteries. They got battery which is very nearly multiple times battery-powered. These are not very financially savvy because of their utilization of lithium. With the goal that these batteries can't fulfill the flexibly needs. Ki Bang Lee [7] utilized a pile of magnesium layer as anode, spongy paper, copper chloride as cathode and developed battery of half charge card measured. Creators accomplished greatest voltage of 1.56 volts inside 10s.

In 2019 A.R.Dehghani-Sanjij[8] evaluated various batteries with different viewpoints including configuration highlights, favorable circumstances, hindrances and natural effects. Lorenzo Zolina[9] considered micrometric-sized graphite (anode) and LiFePO4 (cathode) to make easy and low ecological effect all-paper-based Li-particle cells. They haven't used organic solvents or manufactured polymer folios, which can be effectively re-scattered in water by straightforward mechanical mixing just as normal paper handsheets. Sung- Ju [10] took a stab at utilizing LiFePO4 (cathode), Li4Ti5O12 (anode), single-walled carbon nanotube (SWNT)- got and cellulose nanofibril (CNF) as separator to accomplish progresses in execution, shape adaptability and wellbeing resistance. KeSun [11] developed Aqueous paper batteries which depend on LiMn2O4 and carbon covered TiP2O7 displaying magnificent rate ability and sensible cycling life. According as far as anyone is concerned, we are the first to utilize Aluminum as anode which is acceptable conductor. Various author performed testing and characterization of the fabricated components includes tensile strength, hardness, joint quality such as surface roughness [12-15].

3. Construction and working
3.1 Construction:
Paper battery constructed with three layers as shown in Figure 1. The internal layer is cellulose based paper with carbon nanotube as cathode the centre layer is of Polythene utilized as separator (to stay away from the contact among anode and cathode) which is 50µm. The external layer is Aluminum (acceptable conduit of power) utilized as anode. Size of the battery considered is 13.5cm length, 8.5cm height. At the
point when sheets are collapsed once then voltage gets multiplied. So collapsing sheets (carbon nanotube, Aluminum) has five times to build the voltage. As sheets can be collapsed the size of battery is decreased and can be utilized in any sort of electronic gadgets (even in exceptionally little electronic gadgets in view of its temperament).

![Layers of Battery](image)

*Figure 1. Layers of Battery*

The PCB board, display device and other items are collected to design the paper battery as shown in Figure 2. All the parts connected and specifications are recorded as shown in Figure 3. After that the paper is completely sealed with CNT and aluminum foil to avoid the exposure with atmosphere as shown in Figure 4 and connected to the system to record the voltage as shown in Figure 5.

![Construction of Paper battery](image)

*Figure 2. Construction of Paper battery.*
Figure 3. Opened paper battery with parts specificationn

Figure 4. Paper Battery completely sealed with CNT and Aluminum foil

Figure 5. Voltage measurement in the initial stage
3.2 Working
In paper battery, both oxidation and reduction happens to CNT oxidizes (i.e. loses electrons and get positively charged) then reduction happens with aluminium where it observes ions. This process creates the flow of electrons which results in energy. As we folded the sheets in five folds to determine the size of the battery as displayed in the Figure 5, point of connecting these folded sheets results in voltage of 3.38 volts generated inside of the battery as shown in the Figure 6.

![Figure 6. Voltage measurement across the paper battery](image)

4. Results and discussion
The gadgets are typical through joining cellulose with an implantation of fixed carbon nanotubes. In this paper, we blended carbon nanotube paper with aluminum foil and poly ethylene (plastic paper) is utilized to keep away from the contact. The carbon nanotube is applied because of the positive cathode notwithstanding aluminum foil as very negative anode.

Ki banglee (Ref. 7) discussed about paper battery and developed 1.5V using magnesium as anode and copper chloride as the cathode material. In between, spongy paper is used to avoid contact between both anode and cathode to develop the voltage. Pushparaj (Ref. 1) developed 2.5V maximum in paper battery with multi-walled carbon nanotubes as cathode and lithium used as anode.
In this attempt, the voltage developed in paper battery is 3.38V as shown in Figure 7. The paper battery is designed with carbon nanotube is used as cathode and aluminum used as anode. The plastic material is used as separator and placed between cathode (Carbon nanotube) and anode (Aluminum) to avoid the contact between them.

This battery is useful due to its operational temperature range and work under the range of -100°C to 150°C. For different Compositions our battery performed well with respect to voltage when compared with well performed preceding battery. Though the battery is primary battery due to its operational range and cost effectiveness for different kind of devices.

5. Conclusion
The following conclusions have been extracted from this work:
- Paper Battery offers efficiency, compactness and flexibility.
- It can fit into any kind of electronic device so that we can use these batteries with any smaller device.
- Achieved higher voltage efficiently (approximately 40% more than other paper batteries) by piling the sheets 5 times.
- Due to the cost effectiveness and high operational range, battery is useful for many applications.
- Strongly believe that paper batteries can also be used for digital designs.
- As per observation, aluminium is used as anode is eco-friendly, decomposable and achieved high voltage than any other well performing paper batteries.
- Maximum voltage developed in paper battery used carbon nanotube as cathode and aluminum as anode is 3.38V.

6. References
[1] Pushparaj VL, Shaijumon M M, Kumar A, Murugesan S, Ci L, Vajtai R, Linhardt RJ, Nalamasu O and Ajayan P M, 2007 Flexible energy storage devices based on nanocomposite paper. Proceedings of the National Academy of Sciences, 104(34), 13574-13577.
[2] Hu L, Wu H, La Mantia F, Yang Y and Cui Y, 2010 Thin, flexible secondary Li-ion paper batteries. *ACS nano, International Journal of Plastics Technology* (10), 5843-5848.

[3] Hu L, Wu H, La Mantia F, Yang Y and Cui Y, 2010 Thin, flexible secondary Li-ion paper batteries. *ACS nano, 4*(10), 5843-5848.

[4] Balu S and Mahalakshmi, M., 2014. Paper Batteries: Paper Thin Power. *International Journal of Science and Research (IJSR)*, 7.

[5] Quadri SS, Sameer S, Khan PJ and Shoeb S, Paper Battery: The Future of batteries.

[6] Ganguly A and Sar S, 2011 Paper battery-a promising energy solution for India. *International Journal of Advanced Engineering Research and Studies, 1*(1), 130-33.

[7] Lee KB, 2006 Two-step activation of paper batteries for high power generation: design and fabrication of biofluid-and water-activated paper batteries. *Journal of Micromechanics and Microengineering, 16*(11), 2312.

[8] Dehghani-Sanj AR, Tharumalingam E, Dusseault MB and Fraser R, 2019 Study of energy storage systems and environmental challenges of batteries. *Renewable and Sustainable Energy Reviews, 104*, 192-208.

[9] Zolin L, Destro M, Curtill D, Chaussy D, Penazzi N, Beneventi D and Gerbaldi C, 2014 Flexible cellulose-based electrodes: Towards eco-friendly all-paper batteries. *Chemical Engineering Transactions, 41*, 361-366.

[10] Cho SJ, Choi KH, Yoo JT, Kim JH, Lee YH, Chun SJ, Park SB, Choi DH, Wu Q, Lee SY and Lee SY, 2015 Hetero- nanonet rechargeable paper batteries: toward ultrahigh energy density and origami foldability. *Advanced Functional Materials, 25*(38), 6029-6040.

[11] Sun K, Juarez DA, Huang H, Jung E and Dillon SJ, 2014 Aqueous lithium ion batteries on paper substrates. *Journal of Power Sources, 248*, 582-587.

[12] Saikiran M and Ravali G 2019 Comparative study of vegetable based and conventional cutting fluids in machining of copper alloys. *Materials Today: Proceedings, 19*, 611-614.

[13] Babu GK, Kumar P and Chetan R 2018 Optimization of Surface Roughness and Material Removal Rate in Turning of Stainless steel 304. *Research Journal of Engineering and Technology, 9*(4), 323-326.

[14] Chetan R, Kumar P and Ajay P 2018 Effect of Blended Cutting Fluids in Turning of Die Steel D2. *Research Journal of Engineering and Technology, 9*(4), 314-322.

[15] Kumar P and Ravi S 2020 Investigation on effects of vegetable-based cutting fluids in turning operation of “EN 24 Steel”. *Materials Today: Proceedings*. http://doi.org/10.1016/j.matpr.2020.06.315