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A REVIEW OF PAPER BATTERY-A REVOLUTIONARY ENERGY SOURCE

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ABSTRACT

This paper gives a complete vision on this revolutionizing and valuable solution for energy source through paper batteries associated provides a detailed analysis of same. The paper battery is a flexible, ultra-fine energy storage and production device. The combination of carbon nanotubes with a standard sheet of cellulose-based paper results in the formation of the paper battery. It is known as both a high-energy battery and Super capacitors because its combine two components that are separate in traditional electronics. The properties like long-term steady power production as well as bursts energy are possible due to this combination. In future, paper batteries provide power to the long run generation of electronics, medical devices, hybrid vehicle, giving radical new style and medical technologies because of biodegradable, lightweight and non-toxic nature. This paper will give a brief review of construction and working principle of paper batteries. It aimed at understanding and analyzing the advantages, limitation, and various application of paper batteries. This paper additionally aims at present research and future scope of paper batteries.

KEYWORDS: Paper Battery, Carbon Nanotubes, Cellulose, Super capacitors.

INTRODUCTION

With the fast and continuous rise of technology, electronic devices are getting more dense and slim. This is resulting in increasing need of much better energy sources that are not only more significant and durable but can also be easily adjusted in less and available space [1, 9, 11]. Although there had been a large number of energy sources that fulfill the need up to some extent, the paper battery which is the latest result of continuously developing technology is going to serve the best because of its flexible nature, high efficiency, eco-friendly nature etc. [15, 19]. From the very early time when the concept of something like battery came into existence, the world had been introduced to many types of batteries like electrochemical batteries, lithium-ion batteries, fuel cells etc. Although each of them served the purpose of time with its own pros and cons, the requirement of the present time can be fulfilled only by something like a paper battery.

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The major disadvantage associated with earlier batteries are its limited lifetime. Most of the batteries use till today have a very limited life. Previously the primary batteries came into existence which converts chemical energy into electrical energy which has a very limited lifetime. After that secondary batteries came into existence that can be recharged, that is, they can have their chemical reactions reversed by supplying electrical energy to the cell, restoring their earliest composition. But the cost of rechargeable batteries is higher than primary batteries in developing countries like India. Leakage is the second problem associated with all the batteries that are used till now. If leakage occurs, either spontaneously or through tragedy, the chemicals liberated may be hazardous. For example, replaceable batteries often use zinc "can" as both a reactant and as the container to hold the other reagents. These reagents can come out through the cardboard and plastic that forms the residue of the container. The active chemical leakage can then harm the equipment that the batteries were inserted into. Environmental concerns are the third major problem associated with earlier batteries. The widespread use of batteries has created many environmental concerns, such as toxic metal pollution. Metals such as cadmium, mercury, lead, lithium, and zinc have been recognized as highly toxic metals. Also, batteries may be harmful or fatal if gulp down such as small button batteries has a great probability to be swallowed by young children. The battery's electrical discharge can burn the tissues in the digestive region and can be serious enough to lead to death. Fuel cells are able to generate a large amount of energy but the disadvantage of fuel cells are its cost. Hydrogen-based fuel cells are not used for general consumer use because of its high cost. Their use is still restricted to rocket launch vehicles. Liquid Hydrogen and Hydrogen Peroxide are essential ingredients that make them costly. Another problem is associated with fuel cells are its portability and size. Fuel cells are still not portable in size, which makes it very difficult for use in electronic and medical equipment. Other batteries are the solar cells which are renewable sources of energy but the limitations of solar cells are versatility. In the situations like emergency power-backup, emergency energy purge the solar cells can't be used. It can't be used in all battery-powered equipment. Other disadvantages of a solar cell are portability and size. They are not at all portable or robust. The solar cells need an auxiliary backup battery during failures [4,15, 16,18]. Old designs of flexible devices have been based on separated thin-electrode and spacer layers, whose performance and handling are less than optimum because of the existence of multiple interfaces between the layers [1, 17]. The combination of carbon nanotubes with a standard sheet of cellulose-based paper results in the formation of paper battery that is a versatile, ultra-thin energy storage and production device [3, 4, 6, 11, 13, 15, 21]. It acts as the brilliant electrical condenser and is referred to as nano-composite paper since it's created from carbon nanotubes and cellulose paper [4, 6, 8, 11, 13, 17]. Cellulose paper is a complex organic substance found in paper and pulp and it is not digestible by humans. A Carbon Nanotubes (CNT) is formed from a single sheet of carbon atoms rolled into a tiny cylinder. CNTs have been constructed in such a way that their ratio of length to diameter is maintained up to 132,000,000:1 that is significantly larger than for any other material. The strength of nanotubes is stronger than steel and are more conducting than the best semiconductors. They are of two type: Single-walled or Multi-walled [1, 4, 5, 6, 7, 17]. A paper battery is known as both high-energy battery and super capacitors because its combine two components that are separate in traditional electronics [2, 10, 14]. The properties like long-term steady power production as well as bursts energy are possible due to this combination. Paper batteries have the capacity to power the future generation of electronics, medical devices,

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and hybrid vehicle, because of biodegradable, lightweight and non-toxic nature. They produce high power and current densities [4, 7, 10]. A paper battery is distinguishable from other batteries and is more electrically efficient and effective in space usage due to the use of carbon nanotubes. Paper batteries can function between -75 and 150 degrees Celsius [4, 5, 6, 15].

LITERATURE SURVEY

The paper shows the design, building, and wrapping of flexible CNT-cellulose-RTIL nanocomposite sheets, which can be used in constructing energy-storage devices such as supercapacitors, Li-ion batteries, and hybrids [1]. It is the upgraded version of conventional capacitor known as electrochemical double layer capacitor or supercapacitors [2]. All the components of Li-ion battery are integrated into a single sheet of paper with a simple lamination process. Free-standing, lightweight CNT thin films (0.2 mg/cm2) were used as current collectors for both the anode and cathode and were integrated with battery electrode materials through a simple coating and peeling process [3]. A paper battery is revolutionizing and satisfying solution of energy storage [4]. Papermaking methods were effectively used for the manufacture of low-cost and easily recyclables Li-ion paper-cells, created by two paper-electrodes, one anode and one cathode, and a paper separator [5]. Wood microfibers are used to develop Li-ion paper battery that was layered with carbon nanotubes (CNT) through an electrostatic layer-by-layer nano-assembly method [6]. A paper battery is supposed to be an ideal replacement for traditional power supplies [7]. It is used in the capacitive touch screen, camera flashes, smart watches, personal audio amplifier and medical hearing system [8]. All this application is possible due to its thinner size [9]. Researchers focus on the future of supercapacitor research and development so that supercapacitors may emerge as the solution for many application-specific power systems [10]. Paper batteries is a solution for growing demand of energy requirement [11]. A flexible, lightweight and high conductivity current collector is the key element that enables fabrication of high-performance flexible lithium-ion battery [12]. The conventional cathode is replaced by carbon nanotube in paper battery and conventional anode by carbon nanotube in lithium [13]. This battery is connected to the primary coil of a transformer. The secondary coil of the transformer is linked to full wave rectifier whose output is either connected to a super capacitor or a rechargeable battery. The whole of the setup is referred as Self Recharging Perpetual Paper Battery [14]. One of the main issues bugging the planet now could be Energy crisis. Each nation wants energy and everyone wants power. And this problem that disturbs the developed countries perturbs the developing countries like India to a much bigger extent. Standing at a point within the present where there can't be a day without power, paper batteries will provide an altogether path-breaking resolution to the same [15]. In future, the bacteria-powered paper battery in which microorganism can harvest electrical power from any type of biodegradable source [16]. The development is necessary because of use of non-biodegradable battery cause lot of environmental issues [17]. It is used in pacemakers for the heart, in non-natural tissues (using Carbon nanotubes) in cosmetics, drug-delivery systems, in biosensors, such as glucose meters, sugar meters, etc. [18].

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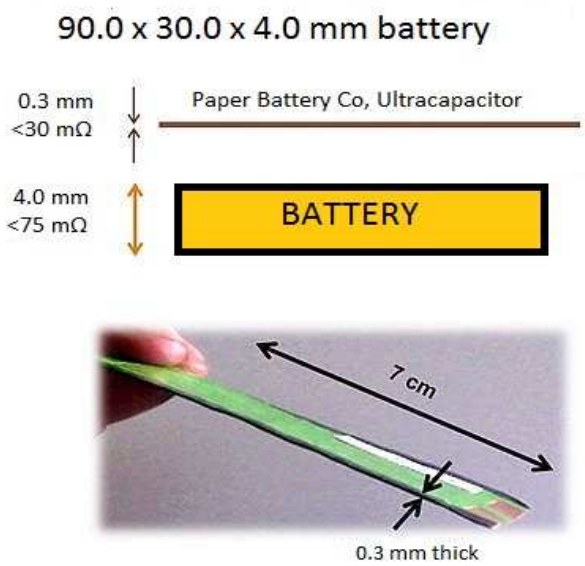

Figure 1.Size of Paper Battery [ref. 8]

The major component of the 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 [19]. In present, research is made on power bank for the laptop using the paper battery which can be carried along with us to any location to contribute more to science and technology [20]. A paper battery is having a number of advantages over other energy producing devices and has found its vast scope in future also [21].

CONSTRUCTION AND WORKING

The paper battery is a flexible, ultra-fine energy storage and production device. The combination of carbon nanotubes with a standard sheet of cellulose-based paper results in the formation of the paper battery. It is known as Supercapacitors and is referred to as nano-composite paper because it's created from carbon nanotubes and paper. Paper Cellulose is a complex organic substance found in paper and pulp not digestible by humans.

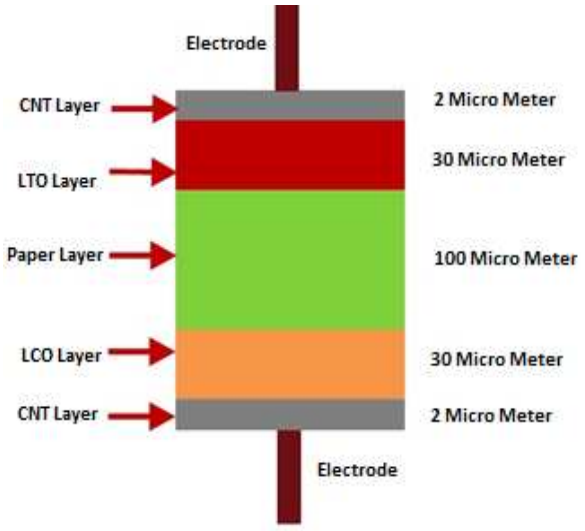

Figure 2.Structure of Paper Battery

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The main component used for the construction of paper battery include the carbon nanotubes (used for cathode terminal), Lithium metal (used for anode terminal), paper (cellulose separator) and different type of electrolytes that include blood, urine, and sweat (which are termed as bio electrolytes). A surface of the cellulose-based paper is painted with the black carbon ink and is laminated with a thin film over the cellulose surface. The thin film is removed from the substrate after heating the cellulose paper for 5 minutes at 800-degree Celsius. The electrode of the paper battery is formed by the film. The LTO and LCO electrolyte are connected to different films. The batteries are formed by combining cellulose with an infusion of aligned carbon nanotubes that are each approximately one-millionth of a centimeter thick. The black color of batteries is due to the presence of carbon. These small filaments act like the electrodes found in a traditional battery and conducts electricity when the paper comes into contact with an ionic liquid solution. Ionic liquids can't be a freeze in extremely low temperature and can't evaporate in extreme high temperature due to the absence of water. So paper batteries can function between -75 and 150 degrees Celsius.

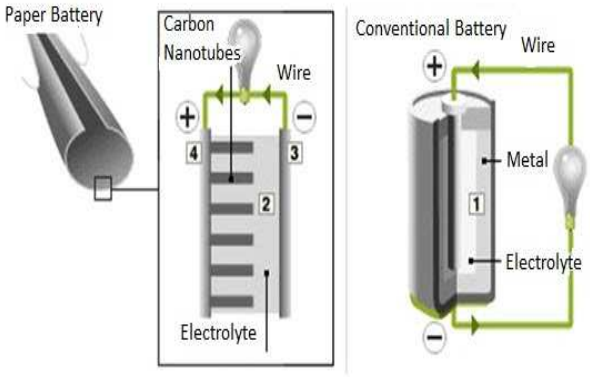

Figure 3.Working of Paper Battery

For manufacturing the batteries, the nanotubes are grown on a silicon substrate and then soaking the gaps in the matrix with cellulose. When the matrix has dried, the material can be peeled off of the substrate, exposing one end of the carbon nanotubes to act as an electrode. Paper batteries act as a super capacitor because a super capacitor is formed on the sides facing inwards when two sheets are combined with the cellulose that can be activated by the addition of the ionic liquid. This ionic liquid performs as an electrolyte and may include salt-laden solutions like human blood, sweat or urine. Due to the presence of high content of cellulose and lack of toxic materials the device like paper battery are both biocompatible and environmentally friendly especially when compared to the traditional lithium-ion battery used in many present-day electronic devices and laptops.

The working of Paper Batteries is similar to that of conventional batteries. Anode and cathode are the metal electrodes and are placed within the battery in such the simplest way that, they're put within the solution. When an external load connected to the battery then the circuit is closed and current start begins to flow leading to the electrochemical reactions occurring within the battery. Oxidation reaction and reduction reaction are the two main electrochemical reactions that take place in any batteries. Reactions take place at anode and reduction takes place at the cathode. Anode loses electrons to the ions from the solution to create a compound and therefore is claimed to be charged. Cathode gains electrons from the solution to create a compound and therefore is charged. Increase in the paper and CNT layers multiplies the output voltage and decrease in the paper and CNT layers divide the output voltage.

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ADVANTAGES

There are many advantages of paper batteries over other previous energy sources. Since the major ingredients of paper battery are of organic nature, it is a biodegradable and non-toxic product. Being cellulose based product it is easily recyclable and reusable, even with the existing paper recycling techniques. It has a shelf life of three years (at room temperature) and under extreme conditions, it can operate within -75° to +150°C. It can be recharged up to 300 times using almost all electrolytes, including bio-salts such as sweat, urine, and blood. It can produce 2.5 volts of electricity from a sample the size of a postage stamp. The paper batteries can also be stacked, like a ream of printer paper, to boost the total power output. It actually can be used as a battery, a super capacitor or a combination of the two, depending on how it's assembled and can produce capacitance up to 200f/g.d. Owing to low resistance, it does not get overheated even under extreme conditions. There is no leakage problem under spontaneous or accidental damage because there is no leaky fluid present in batteries. It is biocompatible and is not easily rejected by our body's immune system. It is very lightweight and flexible. It can easily be molded into desired shapes and sizes.

LIMITATIONS

As is the case with every technical solution, paper battery also has some limitations. Paper Battery has a low shear strength and can be torn easily. It requires greater maintenance than any other batteries. The techniques and the setups used in the production of Carbon Nanotubes are very expensive and very less efficient. The cost is approximately 40% greater than any other batteries. Also, it generates very less voltage so it uses is limited to a certain application. Apart from technical limitations paper battery may be dangerous to the human body if inhaled, their interaction with the Macrophages present in the lungs is similar to that with asbestos fibers, hence may be seriously hazardous to human health. Also, these batteries generate E-wastes.

APPLICATIONS

There are lots of applications of paper batteries in different fields. In electronics field, the size of a large number of devices such as portable computer batteries, mobile phones, handheld digital cameras can be reduced by replacing the alkaline batteries without compromising quality level. Also, the electrical hazards due to recharging are going to be greatly reduced. Paper batteries are also used in the medical field like for creating pacemakers for the heart, artificial tissues, Drug Delivery Systems, cosmetics and in biosensors. The National Science Foundation supported this work. It is also used in vehicles and craft like in lightweight, radio-controlled missiles, hybrid automobile batteries, long air flights and in satellite programs for powering electronic devices. Apart from above applications, there are more points of applications of paper batteries such as RFID tags and other tracking, smart newspapers, credit/ debit cards, greeting card with audio, light, hybrid cards, the printed circuit board(PCB) and smart cards & tags.

PRESENT RESEARCH

In present, Researchers have designed a flexible battery in an innovative way by combining paper and carbon nanotubes that can discharge energy faster than conventional batteries. Over the past few years, scientists have worked on developing new battery materials. For example, researchers have developed new materials called nanomaterials for electrodes that store a greater amount of energy and others that can yield flexible batteries. Lee, along with Sun-Young Lee of Korea Forest Research Institute, in Seoul, South Korea, and their coworkers, starts working with wood to build the new flexible battery. The researchers homogenize wood cellulose to produce fibers at high pressure that are

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nanometers in diameter and micrometers long. They suspend this nanocellulose in water then turn it into paper using vacuum filtration. After that, they take two sheets of cellulose paper and coat one side with a water-based suspension of carbon nanotubes and conventional powdered battery-electrode materials, either lithium iron phosphate to make the cathode or lithium titanium oxide to make the anode. The layers of nanocellulose act as a separator membrane in the finished battery. The two coated papers are put together, with the electrode layers on the outside, then submerged in an electrolyte and sealed in a plastic package to make a complete battery. A materials scientist at the University of Maryland, Liangbing Hu, who is also working on cellulose batteries said that the performance of Lee's devices will be increased by combining nanomaterials in a totally new architecture. Also, the charging speed of this new battery can be increased because the researchers used the nanotube mats instead of polymer binder glues to hold together the energy-storing materials. Lithium ions can easily move through the porous mats than they do through conventional electrodes, where the glues act as roadblocks. Nanotubes are also highly conductive, removing the need for the bulky metal charge collectors that sandwich traditional batteries. Strength and flexibility of the battery are due to the contribution of both nanotubes and nanocellulose. Nanocellulose separators are more porous and more absorbent that results in soaking up more electrolyte and letting ions flow freely than conventional polymer separators [23].

FUTURE SCOPE

The ordinary paper could one day be used as ultra-lightweight, bendable batteries. This type of battery could be especially useful for applications like electric or hybrid cars, which are the next generation transport options and these cars need batteries which depend on the quick transfer of electricity. As the paper batteries do not contain any toxic material, In future it could be used to power pacemakers in the heart. In near future, we will see all our electronic gadgets starting from calculators to our phones becoming lighter and more powerful and efficient. In future, the paper battery will be the only and best energy storage option in all the fields of life starting from household bulbs to powering airplanes and our cars [18].

CONCLUSION

One of the major need of the present world is a good source of energy. Every nation is in need of more and more energy & power. And for a developing country like India, the issue is of much more consideration. Now a day there can't be a single day without power. Day by day the size of the electronic gadgets is decreasing and the requirement of power is increasing. In this situations, the paper batteries act as a solution which provides a large amount of energy. Paper batteries not only provide energy to the present generation but the advancement in the research of the paper batteries can make it able to meet the energy demands of the future generation. In this paper, we can discuss the construction of the paper batteries and its working principle. We also discuss the advantages, limitations and its practical application in real life. Paper batteries are a very thin paper-like structure which is made by combining carbon nanotubes with a thin sheet of cellulose-based paper. Because of its very thin structure, it is used in small electronics gadgets. It is biodegradable and non-toxic in nature so it is used in various medical devices. 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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