Review on Nanotechnology Based Paper Battery

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Abstract: The Paper batteries are the key enabling technology in portable electronics applications. These batteries in use today take advantage of the composite materials. Electronic devices have evolved from large desktop computers to compact pocket-sized smart phones capable of running numerous applications; as technology slims down, engineers must find a way to pack more power into smaller spaces. One innovative solution is the paper battery However, there is still plenty of room for advancing the paper batteries by utilizing nanocomposite materials and Seaweeds instead of paper made up of wood. A battery made up of paper is a rechargeable device to store energy that is used as a battery as well as a super capacitor. It is manufactured by combination of: Seaweeds sheet and nano technology-based carbon (Seaweed sheet made from Algae and nanotubes made from carbon). Paper is nano composite that acquire the very high capability to retain energy like a battery and high energy density like a super capacitor.

Paper Battery= Nano composite paper + Carbon Nanotube.

Keywords: Brown Algae (Phaeophyta), Carbon nano tubes, Green Algae (Chlorophyta), Lithium Cobalt Oxide, Lithium Titanium Oxide, Red Algae (Rhodophyta), Seaweeds.

I.INTRODUCTION

A paper battery allows facilitating pliable and slim battery with both durable more energy as well as stable power production. This battery will be capable of supplying tremendous power for coming era in field of electronics, automobiles, space and health care devices.

Figure 1. shows the basic construction of paper battery.

Paper batteries can be folded, crushed, acquired various shapes, perverted, wrapped, twisted, molded and shaped for various devices without any change of efficiency. [1,2,3,4]

As per title of the review paper woodless paper battery is planned to be made up of seaweed. It is the common name for marine algae, they are not plants at all, although they do have plant-like cell walls and they do use chlorophyll for photosynthesis. In different areas they are available in different colour and texture. They are abundantly available at sea shore. Marine algae are categorized into three groups: Brown coloured Algae known as (Phaeophyta), Green coloured Algae known as (Chlorophyta), Red coloured Algae known as (Rhodophyta).[5]

To design a battery made up of seaweed using carbon nano tubes following steps are needed

Components required and steps:

- Cathode: Carbon nano tubes (CNT),
- Anode: Lithium Metal (Li+)
- Electrolyte:(salt water),
- Separator: Paper (cellulose).[6]
- A rectangular shaped paper was used.
- A thin lithium film is laminated over the exposed cellulose.
- The microfibers were individually coated through (Layer by layer) Nano assembly with CNT
- The resistivity of the microfibers was measured after each layer coating in the Layer By Layer Nano assembly process.
- Applied Positive and negative electrodes as slurries dried on the paper, various combinations.
- Outputs was monitored on field by a multimeter with data acquisition, and by getting the voltage and current values, a charge-discharge profile will be analysed.

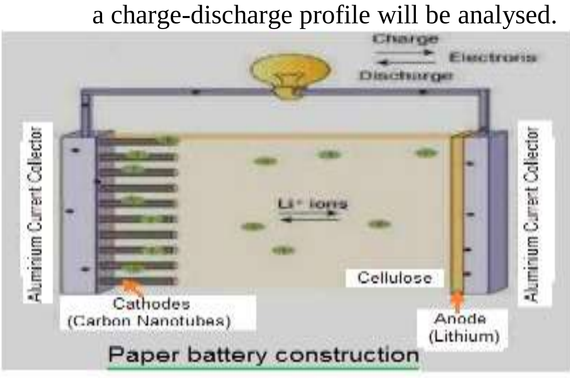

Figure 1. Diagram of a battery made from paper [7,8,9]

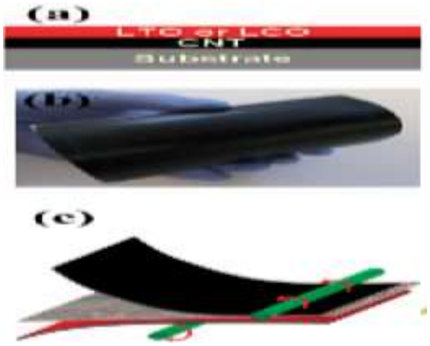

Figure 2 Thin, flexible paper batteries already made.

II. DETAILS OF WORK DONE AND DRAW BACK

2.1Nanotechnology:

Nanotechnology based papers are studied. It has been observed that developments in Nano electromechanical system technologies have contributed to many electronics related applications, and the semiconductor-based devices.[10]

The materials that are composed, show an energy conversion mechanism efficiently as photon energy from the conducting nanoparticles to another semiconductor particles. Unlike pure semi-conductor devices, nanoparticles show the better energy level responsible for a more concentration of free electrons as well as electron and hole pairs on the semiconductor surface with better photo catalytic rates. [11,12,13]

This technology can play very important role in manufacturing batteries which is the primary requirement of any electronic gadgets like mobile, watch, laptop, health care devices and even automobiles now a days.

Nanotechnology still needs to be explored for various applications where charging of devices becomes easy and ecofriendly.

2.2 Traditional batteries:

Traditionally, batteries are made up of a negative electrode, called an anode, and a positive electrode, called a cathode. These electrodes take up the majority of the space in the battery. They are separated by an electrolyte, which in traditional batteries is usually a liquid solution. This is embedded in a separator. The separator prevents the anode and cathode from touching, but still allows electrons to be transferred between the two. Charge collectors made of metal sheets, meshes, or films provide charge transport to the battery's terminals, thus allowing the electrical energy to be transported to whatever device is attached to the battery. Electrochemical charge-transfer reactions occur in the electrodes, converting chemical energy into electric energy that can be used. The amount of energy created depends on the type and amount of materials used. Lastly, all of these components are contained inside a metal or plastic case [14,15].

2.3 Super-capacitors:

Further research has been done on Super-capacitors to enhance the features of traditional battery.

These are energy storage devices that are followed by the same concept as conventional capacitors but uses higher surface area electrodes and slimmer dielectrics to achieve more capacitances values (up to 3000F).

This allows for energy capacity greater than those of the traditional capacitors and power efficiency greater than those of the old batteries.Along with super capacitor, properties of super battery are also needed [16].

Several steps to improve battery capacity in mobile applications have been taken, like use of super capacitors to extend the runtime.An overall decrement in the internal losses became possible by cascading super capacitors in parallel providing an improved run-time. A battery runtime extension of 7% and 15% is possible with the combined use of battery and Super capacitor.The batteries should be lighter, smarter, cheaper and reliable even smaller with fast charging and discharging. the overall runtime of mobile phone battery needs to be improved more. [17]

2.4 Sources of batteries:

Research work done in domain of battery formation provide details about few sources of batteries like

2.4.1 Dye-sensitized solar cells

(DSCs) became a very demanding substitute of Germanium based solar cells due to their capabilities to convert natural energy into electrical energy at minimum expenditure. This cell can be manufactured from inexpensive material like inorganic and organic dyes. They do not require to be much pure like that for semiconductor wafer. The dye-sensitized named Gratzel on name of its inventor, this solar cell is the earliest solar cell using Nano scale components like Titanium Oxide for its performance. [18]

2.4.2 Fuel cells

(FC) are devices that use a fuel such as methanol or hydrogen electricity conversion with the help of an electro catalytic process instead of using combustion process, thus producing very higher energy transfer efficiencies than traditional combustion machines. By using hydrogen as a fuel, the fuel cell is a very pure energy translator. At the middle of a Fuel Cell there are the electrodes, where the real electro-chemical conversions take place. Metal hydrides proved the best source as one of several substitutes to preserve hydrogen in a hydrogen-based system.

2.4.3 Hybrid Batteries:

Hybrid Batteries are energy preserving systems, that reduce the batteries strain in Hybrid Renewable Energy System done due to high current spikes caused by machine startup process.

These batteries are not ecofriendly, e-waste has to be avoided, as many devices need battery to get operated, so large amount of e-waste is produced which may be proved health hazardous for human as well as animals [19].

2.5 A material to make a battery- Graphene:
Many products are studied for getting inexpensive and reliable material to make a battery. Graphene has good ability to be utilized for stretchable, inexpensive, and very capable photovoltaic devices due to its appreciable electron-flow capabilities and extremely good charge mobility. [20] Several graphemes based solar cells are found. The reason for the present demand of graphene is the good capability for transparent and conductive electrodes in solar cells. Grapheme is a perfect 2-Dimensional material which can be arranged into film electrodes with great transparency, high conductivity.
Graphene is not available in market for public. [21].

2.6 Lithium-ion paper batteries:
Many papers are studies explaining eco-friendly batteries like Lithium-ion batteries with Carbon nano tubes (CNT) wrapped paper-based current collectors. In these current collectors, microfibers like wood made papers that were covered with CNT through electro- static nano assembly process. The structure of the proposed paper based current collector provides flexibility and improved performance for active materials such as Lithium salts for anode in paper batteries (LTO) Lithium Titanium Oxide and (LCO), Lithium Cobalt Oxide. Moreover, the Layer by Layer covering method uses thin layer of CNT at low cost. [22,23]
Figure 2 shows Thin, flexible paper batteries already made.

With the implementation of a printing method, it would be possible to cut down tremendously on the cost of the fabrication of the batteries and increase greatly the efficiency and speed of the process.[24]
Figure 3. shows the construction of battery made from paper with size of all layers.
Like traditional batteries, paper batteries also consist of two electrodes, an electrolyte, a separator, and charge collectors. However, unlike traditional batteries, paper batteries have one electrode made of conductive carbon nano tubes, the separator is made from plant cellulose (the main ingredient in paper), and the second electrode is made by coating the opposite side of the paper separator with lithium oxide. To provide the electrolyte, the paper is saturated with an ionic liquid – that is, an organic salt that is liquid at room temperature. Since the ionic liquid does not contain water, the batteries do not contain anything that will freeze or evaporate, enabling them to withstand extreme temperatures, ranging from -78°C to 177°C [25]. Also, since the battery is dry, it does not need a sealed case, as do traditional batteries. It is also possible to make a super capacitor from the carbon electrode and paper separator by folding it in half so that the paper is in the middle and both the top and bottom electrodes are carbon. One such postage-stamp-sized super capacitor has a voltage of almost 2.5 volts, which is comparable to other standard super capacitors that are much larger [26,27].

2.7 Comparison of Paper battery with traditional battery:
The capacities of the CNT-microfiber paper-based batteries are compared with traditional batteries made from copper/aluminum current collectors. It is found that properties like flexibility, non-toxicity, biocompatibility, rechargeability, recyclability, reusability, electrical conductivity, durability, tensile strength and efficiency are more as compared to traditional battery.[28]
Few properties like leakage, overheating E-wastage are lesser.
It uses paper that is made up of wood, which should be avoided to save wood.

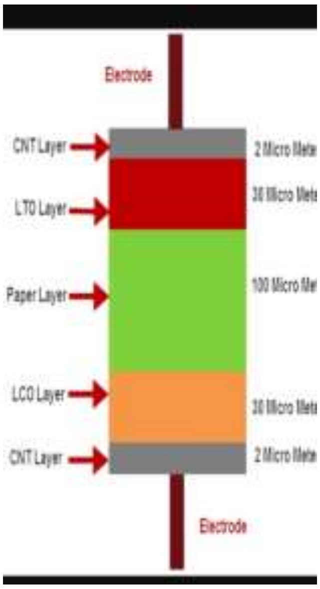

Figure 3. Lithium ion paper battery

Now phone is more and more smart, even lithium ion-based battery couldn't cope up with the development of the mobile phone capabilities. People are not satisfied with the current lithium-ion batteries; need to develop a new battery. With the advancement in technologies, the new concept about battery will be more and more required by the people [29,30].

2.8 Flexible paper battery:
Black carbon paper based polyanthraquinone coated exfoliated graphite made for flexible paper battery:

- Natural graphite flakes were immersed into a concentrated acid mixture (3:1, H_2SO_4: HNO_3) for 5 days and then filtered, rinsed with excess water until the pH was neutral.
- The acid treated graphite flakes were then dried in a vacuum oven for 24 h at 85–90 C. Dried graphite oxide flakes were immersed in paraffin oil and coated on black carbon paper and keep it for drying at 60 C for 12 h.

- The graphite-coated black carbon paper was used as the working electrode in a three-electrode electrochemical system with Ag/AgCl as the reference electrode and platinum wire as the counter electrode [31]

2.9 Alternate for paper made up of wood:

To avoid use of paper made up of wood and to make battery with better performance, substitute is searched; a name came from many research papers that is Alginate. It is a high-modulus natural polysaccharide drawn from brown algae available in sea. It yields a quite stable battery anode unlike many polysaccharides available in terrestrial plants. In addition to enhance performance of Si anodes, the alginate properties may provide efficiency to other electrodes, such as conventional graphitic anodes. As an example, replacing Polyvinylidene difluoride PVLD with minimum expenditure, eco efficient [32] Figure 4. shows the structure of seaweed.

Seaweeds are the eatable plant with a old story in some Asian cuisines, and which has also become part of the Western food trend. Figure 4. shows the basic structure of seaweed.[33]

It made possible, the invention of more successful ways to empower our devices. Discoveries have made a seaweed-derived material to help enhance the performance of conductors, lithium-ion based batteries and fuel cells. 'upgraded' reversible capacity.

Aging effect, shear strength and cost are the issues that have to be tackled while designing seaweed made paper battery.

One of the major ethical issues regarding paper batteries is the potential adverse health effects of carbon nanotubes on the human body and the environment [34]

any possible damage to the electronic that would perhaps break the case and expose the nanoparticles to air and the user. More importantly, any adverse health effects create occupational hazards for those manufacturing the paper batteries.[35]

(a)

(b)

Figure 4. (a) and (b). Seaweeds photo and role in battery

The use of a paper separator has several key advantages over traditional mediums used. First, because of the intrinsic porous structure of paper, it not only serves well as a separator with lower impedance than commercial separators, but it also has good cyclability. Researchers at Stanford

University found no degradation after 300 cycles of recharging. Furthermore, a paper separator can also function as the mechanical support for the battery, making the battery cheaper and easier to manufacture since no additional materials are needed to provide the support [36].

III *RESEARCH GAP*

3.1 Limited capacity

Lithium ion batteries that are in picture now days basically they are made from graphite carbon anodes, which is one of the components in which battery energy is stored.

Inspite of providing durability by graphite anodes, the material is having limited capacity to absorb ions and this is the main reason of limiting factor in improving energy density. This problem has to be considered for research work.

3.2 Require wood as a raw material

To trim weight, the use of thin films of materials laid down as inks. Which needs paper because of its porous microscopic structure, which makes it ideal for holding onto inks, but to manufacture the papers needs paper made up of wood which has an adverse effect on nature. To resolve this problem has a scope for researchers for fabrication of paper-based battery avoiding wood as a raw material. [37]

IV. *NANOTOXICOLOGY*

4.1Challenge in nano toxicologic studies.

Because of the size of nanoparticles, imaging the nanoparticle in tissue has been a challenge in nano toxicologic studies. Many of the studies use cellular responses to assess the effects of carbon nanotubes. A study presented at the American Chemical society national Meeting in 2004 showed that exposing single wall carbon nanotubes to in vitro keratinocytes and bronchial epithelial cells "resulted in oxidative stress, as evidenced by the formation of free radicals, accumulation of peroxidative products, and depletion of cell antioxidants" [38]. These free radicals are molecules that can react with chemicals in the body and induce cellular damage; since the exposure displayed decreased levels of antioxidants, which work against free radicals, it is clear that the carbon nanotubes had a negative effect on cells. A study using live mice showed similar adverse effects; after exposure to single walled carbon nanotubes, the mice developed fibrosis in their lungs, as early as one day following exposure. In other words, when the lungs of mice were directly exposed to carbon nanotubes, the mice showed significantly increased formation of connective tissue; since this sort of overgrowth can block fluids from bringing nutrients to cells, it shows that the nanotubes can have harmful.[39]

4.2Environmental Effects

Additionally, the carbon nanotubes could potentially end up in the environment, as paper batteries from smart cards and used temperature monitors are disposed, causing damage to the soil and plants. Ecological studies have shown that the exposure of nanoparticles to largemouth bass fish resulted in lipid damage in the brain. Also, other studies have demonstrated an up regulation of immune system and tissue repair proteins in fish exposed to nanoparticles [40]. Because nanoparticles have been found to have these negative effects on animals in the environment, the use of nanotechnology also raises environmental concerns. For instance, is it ethical to continue using nanotechnology when products like the battery could potentially harm the wildlife? Another important aspect to consider is whether mass production of nanotechnology will result in nanotubes appearing in the environment, and thus our food and water supply. Furthermore, even if the nanoparticles are manufactured to be biocompatible, it is possible that upon disposal, the environmental factors, such as the air and ultraviolet radiation, could cause the coatings to deteriorate, exposing the perhaps harmful material [41].

4.3 Ethical Concerns Regarding the Use of Nanotechnology:

Before encouraging the widespread use of a new technology, one must always consider the possible ethical concerns surrounding that technology. One of the major ethical issues regarding paper batteries is the potential adverse health effects of carbon nanotubes on the human body and the environment. Nanotoxicology studies have shown that the surfaces of certain nanoparticles have many sharp points, much like asbestos. These sharp points make it difficult for macrophages, or immune cells, to clear foreign particles from the body. Moreover, as the size of these particles decreases, the surface area increases, allowing for better transport across cell barriers and increased ability to react with important cell structures, such as microtubules and DNA. As a result, nanoparticles can have potential harmful health effects, especially in the lungs. Although direct exposure with nanoparticles or fibers is unlikely in many of these applications, as it will be stored away in part of the electronic, it is important to consider, for instance, any possible damage to the electronic that would perhaps break the case and expose the nanoparticles to air and the user. More importantly, any adverse health effects create occupational hazards for those manufacturing the paper batteries.

V.AFFECTS OF NANOTOXICOLOGY ON PAPER BATTERY

In spite of these risk factors associated with nanotechnology, we still support the production and development of paper batteries. With the paper battery, it is unlikely that such direct and concentrated exposure will occur. Also, the battery would be encased and, in many applications, such as solar panels, boats, wind farms, there would be little human contact with these devices. The paper battery is relatively safe compared to other nanotechnology products such as sunscreen and various medical diagnostic tests where nanoparticles are directly exposed to the body and where absorption of nanomaterials is more likely.

Therefore, we suggest that researchers and engineers address these health concerns rather than eliminating the paper battery as a potential power source. we should take care about any health effects by testing the toxicity of manmade nanoparticles and carbon nanotubes prior to using paper batteries. Since nanotechnology has appeared in a variety of products besides the paper battery, such as cosmetics, tires, and filters, an effort to study nanotoxicology would be a valuable use of time and money. Once we can define safety procedures for carbon nanotubes used in paper batteries, it would be possible to better protect manufacturing workers from carbon nanotube exposure and then commercialize the paper battery.

A simple and cheap fabrication process for the paper batteries has been developed which is compatible with the existing plastic laminating technologies or plastic molding technologies. In this battery, a magnesium (Mg) layer and copper chloride (CuCl) in the filter paper are used as the anode and the cathode, respectively. A stack consisting of a Mg layer, CuCl-doped filter paper and a copper (Cu) layer sandwiched between two plastic layers is laminated into the paper batteries by passing through the heating roller at 120 °C. The paper battery is tested and it can deliver a power greater than 1.5 mW. In addition, these urine-activated laminated paper batteries could be integrated with bio MEMS devices such as home-based health test kits providing a power source for the electronic circuit. [42,43]

VI..PAPER BATTERY TO DESIGN ELECTRONICS

One of the most remarkable aspects of the paper battery is its ability to be rolled and folded without any loss of efficiency. "Being able to mold the battery to any shape that corresponds to the space available is a real advantage". This is clear when one considers the dependency of electronics today on their batteries. With more flexible batteries, electronics will be able to take on any shape or form. Along the same lines, the paper battery's capacity is proportional to its area. "The more area, the more energy, so you adjust the battery to the needs of the product, not vice versa" [44]. So, if a product requires more or less energy, one can simply change the size of the battery, rather than having to design the product around set amounts of power that a given battery can supply. This opens doors for new electronics to take on any shape or form imaginable. They no longer have to be held back by the constraints of their batteries.

VII..HOW USING PAPER MAKES A BATTERY BATTER

As Yi Cui of Stanford University points out, nanomaterials – such as the carbon nanotubes in paper batteries – are better conductors than traditional materials because they are able to move electricity more efficiently [45]. In other words, paper batteries will lose less electricity due to inefficient conductors than traditional batteries lose.

Since paper batteries are dry they require no casing while traditional batteries must be encased and sealed in metal or plastic. Not having a case eliminates a step in the manufacturing process and cuts down on the cost of manufacturing the battery. In addition, the paper substrate and the electrolytes used in paper batteries are environmentally safe and nontoxic. Therefore, paper batteries would have less of an impact on the environment than traditional batteries, which contain harmful acids.

Perhaps the most obvious advantage of paper batteries over traditional batteries is their size. One square-inch of a Power Paper battery can provide a voltage of 1.5 V – as much as common consumer batteries – and hold its power for over two years. So, in a time when electronics are shrinking to paper-thin dimensions, a battery as thin as a paper battery is almost necessary, and it has already been developed enough to have comparable outputs to traditional batteries. Further research into the types of materials best suited for paper batteries can only lead to more breakthroughs in the field of paper electronics. As an example of the advantages of a paper battery over more traditional batteries, researchers at Stanford University compared a paper battery that they made to a soft battery.[46]

VIII.APPLICATIONS OF THE PAPER BATTERY

The paper battery has many applications ranging from greeting cards to medical devices; its flexibility and paper-thin thickness allow it to be utilized in a wide array of products. Additionally, its biocompatibility allows for potential use in medical products and artificial organs. Moreover, stacking sheets of paper batteries could increase the overall power and lead to potential applications in larger electronics.

*8.*1 Identification of Radio Frequency

One important application of the paper battery is its use in powering radio frequency identification devices or RFID. In the past, RFID tags have been used to keep track of cattle and livestock. However, paper batteries could allow companies to place RFID tags and smart labels on almost all products. For instance, in a grocery store using these RFID tags, the shopping cart could automatically process which items are placed in the cart, charge the customer's credit card and keep track of the store's inventories. Although many supermarkets do not have this technology in store now, with the help of the paper battery to power these RFID tags and labels, this sort of technology could appear in the near future. RFID electronics also appear in road toll collection, animal tracking, passports and airline baggage management; all these potential uses could benefit by having a more powerful and light weight. Battery, allowing for a longer lasting tag and better data storage [47].

*8.*2 Media

Besides tracking devices, paper batteries could also play a large role in media and advertising. For instance, researchers from Rensselaer Polytechnic Institute suggested that the paper battery has enough power to light a small light emitting diode. Therefore, paper batteries could be used in greeting cards to power electronic displays or lights embedded in the card; they could also power any sort of audio device that would play a song or recording upon opening of the card. Other potential applications include using paper batteries to power electronic displays on packaging for items such as cereal boxes. The lightweight and compactness of a paper battery would allow the device to be easily fit into the cardboard design of a cereal box and display videos and play music, attracting more attention, and thus providing better advertising.[48]

8.3 Medical Devices

In addition to packaging and greeting cards, the size and flexibility of the paper battery also make it an advantageous power source for medical devices. For instance, the paper battery can be fit to the shape of a pacemaker, and because it is very light, it will not weigh down the devices, making it easier for the patient to hold inside them. Moreover, the paper battery is biocompatible. High paper content and lack of toxic chemicals, make it safer than other batteries, even for use in body. So, the paper battery would be an optimal solution for powering devices that work inside the body such as artificial organs. In fact, the paper battery can even use blood, sweat, or urine as the electrolyte. This would be an ideal power source for artificial organs where bodily fluids are abundant and can recharge the device. Another application is temperature monitors on blood bags. Since they are lightweight and flexible, it would be an efficient way to monitor the temperature of blood throughout transportation and storage.[49]

8.4 Large Scale Electronics

Although the compactness of the paper battery is one of its major benefits, the paper battery is not limited to small devices; in fact, it has many potential applications in larger devices such as cars, laptops and wind farms. Because the paper battery has the ability to be recharged, it could be used in a typical car battery. By integrating the paper battery into the design of a traditional battery, it is possible to decrease the weight of the battery by up to twenty percent; this would be especially relevant for electric and hybrid cars, since a reduction in weight could potentially increase efficiency. It has also been suggested that the paper battery could power car doors since the paper battery can be formed to fit the curved shape of a vehicle. "paper batteries' light weight could make them ideal for use in automobiles, aircraft, and even boats". By stacking large sheets of paper batteries on top of each other, it would be possible to increase the voltage and increase the power, thus making the paper battery capable of providing energy for larger machines. Furthermore, according to Yi Cui of Stanford University, this pile of paper batteries “could also inexpensively help solar and wind farms store what energy they generate” [50]. For instance, the flexibility of the paper battery could allow it to be used in solar panels of varying shapes and its ability endure numerous recharge cycles would make it an ideal device to capture the energy from solar power or wind power.[51]

8.5 Endless Possibilities

There exist many potential applications of the paper battery that have not yet been fully explored; such applications include smarts cards where debit cards which could electronically display the amount of money left on the card, thus eliminating the need to check one’s balance online. Others include possibilities include wearable electronics and flexible solar panels and with such a wide range of applications from greeting cards to medical devices to cars, it becomes evident that paper battery will have an extensive impact on daily life.[52]

IX.CONCLUSION

The combination of Nano composite paper and Carbon Nanotube allows the battery to provide remedy of the problems of convectional battery. This battery will be capable to provide tremendous power for coming era in field of electronics, automobiles, space and health care devices.

Paper battery can give perfect response for areas where strechability, mobility and size are the concern. Today electronic devices like automobile fulfill the need of slim batteries that are durable as well as ecofriendly. It can also be utilized in small equipment like, watches and wireless devices like calculators etc So it’s observed that by using Paper made Battery many devices can be easily served for storage of energy. Today we have compact devices which are used wirelessly so needs something like this battery so the device remains light weight with better performance.

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