IFERP connecting engineers... developing research

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 1, Issue 8, December 2016

A Review on Graphene Based Supercapacitors

[1] Omkar Ganesh Bhegade, [2] Himkedar Jadhav, [3] Prof.M.Mahajan, [4] Prof.D.Shastri , [5] Dr.N.Patil
[1][2] Third Year Mechanical Engineering Diploma, MAEER"S MIT Polytechnic, Pune,
[3][4] Lecturer Mechanical Department, MAEER"S MIT Polytechnic, Pune,
[5] Mechanical HOD, MAEER"S MIT Polytechnic, Pune

Abstract:-- **This paper looks at the research that is being carried out on use of Graphene as an electrode material for supercapacitors which may be the replacement for the lithium ion batters in future. It also discuss about the scope of graphene based supercapacitors in various fields. Science and technology have been advancing rapidly over the last few decades; storing the energy has always been a problem. The problem faced by conventional energy storage system is that a battery can potentially hold a lot of energy, but it can take a long time to charge and a capacitor, on the other hand, can be charged very quickly, but can't hold that much energy comparatively. The solution emerged was the supercapacitor that is able to provide both of these positive characteristics without compromise. Currently, research is being carried out on enhancing the capabilities supercapacitor and Graphene is proving itself to be the best electrode material for it. Graphene is a nanomaterial of 2D flat monolayer carbon (bonded in hexagonal lattice). Graphene is a parent of all carbon allotropes with versatile properties.**

***Index Terms*— Graphene, Supercapacitor, energy storage system, nanomaterial, carbon allotropes**

I. INTRODUCTION

Energy is one of the most important affairs in this century. Today there is a high demand for efficient use of the energy resources due to the depletion of fossils fuel and rapidly growing market in portable electronic devices, electric vehicle and autonomous vehicle. Thus there is worldwide pursuit for research and development of proficient energy storage material. Engineers have been struggling to develop an energy storage solution such as battery or capacitor that can keep up with the present demand of electronics and would help in its evolution. The point of issue is that, presently we can store large amount of energy in a particular type of batteries but those batteries are heavy, bulky and they are relatively slow in charging; while capacitors on the other hand are small, light and able to charge swiftly, but not able to hold that much of energy as the battery. The optimum solution over the situation was a supercapacitor, also known as ultracapacitor. These capacitors have a tremendously high energy density compared to conventional dielectric capacitors simultaneously they are able to store a large amount of charge which can be delivered at much higher power ratings than rechargeable batteries. While the energy density of supercapacitors is very high compared to conventional dielectric capacitors, it is still significantly lower than batteries or fuel cells.[1] Thus, the researchers are putting all there effort on increasing the energy performance of supercapacitors to be close to or even beyond that of batteries. The versatile carbon allotrope graphene leads us towards the new possibilities for energy storage, with high charge and discharge rates, which can be made cheaply.

II. SUPERCAPACITORS

Supercapacitors, also known as ultracapacitors, has an ability to store hundreds times the electrical charge than that of ordinary capacitors, and are therefore suitable as a replacement for electrochemical batteries in many industrial and commercial applications. Conventional capacitors are made up of two layers of conductive materials known as electrodes, separated by an insulator. The amount of charge a capacitor can hold is totally dependent on the surface area of the conductors, the distance between the two conductors and also the dielectric constant of the insulator. Supercapacitors are slightly different in the fact that of ordinary capacitor because they do not contain a solid insulator. The science behind energy storage in a supercapacitor is based on two principals of capacitive behaviors i.e. the electrical double layer (EDL) capacitance from pure electrostatic charge accumulation at the electrode-electrolyte interface and the pseudo-capacitance due to fast and reversible surface redox processes at characteristic potentials.[2]The key components of supercapacitor are the electrodes, the separator, the current collector, as well as the electrolyte; all are significant aspects influencing the overall performance of the device. In the supercapacitor two conductive plates in a cell are coated with a porous material, most commonly activated carbon and the cells are

IFERP
connecting engineers... developing research
ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 1, Issue 8, December 2016

immersed in an electrolyte solution, which is similar to a battery. The porous material ideally will have an extremely high surface area (1 gram of activated carbon can have an estimated surface area equal to that of a tennis court) coupled with good conductivity, and very high level of charge can be reached because the capacitance of a supercapacitor is dictated by the surface area and the distance between the two layers of the porous material. While supercapacitors are able to store much more energy than standard capacitors, they are limited in their ability to withstand high voltage; Supercapacitors can also work in very low temperatures.. Electrolytic capacitors are able to run at hundreds of volts, but supercapacitors are generally limited to around 5 volts.

III. GRAPHENE

Graphene is an allotrope of carbon in the form of a two-dimensional, atomic-scale, honeycomb lattice in which one atom forms each vertex. In simple terms, graphene is a solitary thin layer of pure carbon bonded together in a hexagonal honeycomb lattice in which the carbon atoms are compacted together. It is the basic structural element of other allotropes of carbon (graphitic materials) i.e. zero-dimensional (0D) fullerenes, one-dimensional (1D) carbon nanotubes (CNTs), two-dimensional (2D) graphene, and three-dimensional (3D) graphite. The wrapping, rolling, and stacking of a graphene nanosheets gives birth to 0D fullerene, 1D CNT, and 3D graphite or diamond, respectively (fig. 1).Thus it is also identified as „the mother of graphitic material". Graphene, with one-atom thick layer 2D structure is emerging as exclusive morphology carbon material with ability for electrochemical energy storage device applications due to its superb characteristics of chemical stability, high electrical conductivity and large specific surface area. [3]

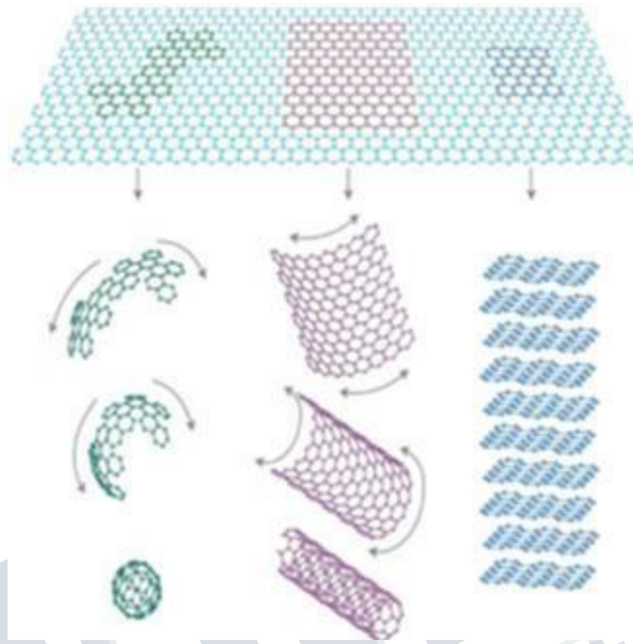

Fig 1: Graphene: the mother of all graphitic carbon materials

IV. SYNTHESIS OF GRAPHENE AND GRAPHENE OXIDE

There are many methods to synthesize graphene sheets such as mechanical cleavage of graphite, unzipping carbon nanotubes, chemical exfoliation of graphite and chemical vapour deposition. The most difficult task is to stabilize the single graphene sheets with controllable size and structure.

Generally two methods are mainly focused viz. mechanical exfoliation that produces few layer of graphene of high quality and a chemical method that has been demonstrated to give high throughput. In Mechanical exfoliation, celluphene tape is used to peel off graphene layers from a graphite flake, followed by pressing the tape against the substrate and upon removing the tape a single sheet of graphene is obtained. The chemical method, Hummers method is widely used to synthesize chemically derived graphene. As is schematically illustrated in fig.2, graphite is first oxidized to graphene oxide (GO) using either the Hummers method or the modified Hummers method. After reducing the GO with the help of hydrazine solution or other reducing agents, the chemically derived graphene is found achieved. GO is an excellent foundation to synthesize graphene nanosheets. [4]

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 1, Issue 8, December 2016

V. GRAPHENE BASED SUPERCAPACITORS

Graphene is predicted to be an excellent candidate for electrode material in energy conversion/storage systems because of its high specific surface area (2630 square meter per gram), good chemical stability, excellent electrical and thermal conductivity as well as remarkably high mechanical strength and Young's modulus. Graphene films have been used as stretchable electrodes. Graphene sheets can physically adjust themselves to be accessible to different types of electrolyte ions, free from the use of conductive fillers and binders. Besides, its flexibility facilitates an easy fabrication of supercapacitor devices. Studies have shown that the specific capacitances of graphene can reach 135 F g-1, 99 F g-1and 75 F g-1 in aqueous, organic, and ionic liquid electrolytes, respectively. Despite the intense interest and continuous report on experimental observations, real applications of graphene have yet to be realized. This is mainly due to the aggregation of graphene sheets and the difficulty in reliable production of high-quality graphene from a scalable approach.[2] The mechanical exfoliation produces graphene with the good quality but in low quantity; on the other hand, hummers method produces graphene with good quality and quantity but utilizes toxic materials such as hydrazine.

The electrical double layer capacitance at an electrode/electrolyte interface is mostly seen in carbon material, which is extremely dependent on the specific area of the electrode. Due to unavoidable accumulation of graphene nanosheets, graphene shows unsatisfactory capacitance performance, generally 100-200 F g-1. Whereas conducting.

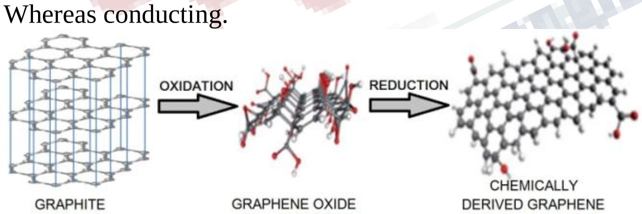

Fig. 2: The chemical route to the synthesis of graphene

Carbon electrode materials	Specific surface area (m^2g^{-1})	Density ($g\ cm^{-3}$)	Electrical conductivity ($S\ cm^{-1}$)	Cost
Fullerene	1100-1400	1.72	10^{-8}-10^{-14}	Medium
CNTs	120-500	0.6	10^{4}-10^{5}	High
Graphene	2630	>1	10^{6}	High
Graphite	10	2.26	10^{4}	Low
Activated carbon fibres	1000-3000	0.3-0.8	5-10	Medium

Table 1: Comparison of various carbon electrode materials

polymers show much higher capacitance due to the pseudocapacitance of the redox reaction of electrode material. However, the poor cycle life of conducting polymers limits their real application in supercapacitors. Engineers are struggling to develop synergistic composite materials with both high capacitance performance and good cycle life. Thus, the Graphene-conducting-polymer composites have received the greatest interest. Recently, aligned polyaniline (PANI) nanowires are delicately synthesized on two-dimensional GO nanosheets by dilute polymerization. Nanocomposites of PANI nanowire arrays on graphene oxide (GO) sheets are efficaciously gained, which demonstrate a synergistic effect, when utilized as the supercapacitor electrode materials. The specific capacitance of the nanocomposite can attain as high as 555 F g-1 at a discharge current density of 0.2 A g-1, which is much higher than 298 F g-1 of random connected PANI nanowires obtained in the same conditions. In addition, the cycle life of this composite is also much better than that of random connected PANI nanowires. [5]

VI. FUTURE SCOPE

While further research and development is required to produce a graphene based supercapacitor with optimum performance and at low cost. This would be the replacement for the lithium ion battery. It shall be offering a clean energy which will help in overcoming the depletion of fossil fuel and development in the domain of electronics. Supercapacitors have found wide range of application in field where a large amount of power is needed for a relatively short time, where a very high number of charge/discharge cycles or a longer life time is required. In consumer electronic supercapacitors can stabilize the power supply in case of fluctuating load in various devices such as laptop, desktops, portable media players and photovoltaic systems. The cordless DC tools with graphene based supercapacitor for energy storage which would charge in seconds and would give output nearly to a battery tool. It would be help full in energy recovery in forklift, tractors, heavy cranes etc. it may also be used in hybrid vehicle for various applications such as regenerative braking, waste heat recovery and many more. Supercapacitors based on graphene will find more applications after the development of an eco-friendly and cost effective manufacturing process for graphene nanosheets with higher throughput and higher quality.

REFERENCES

[1] Meryl D. Stoller, Sungjin Park, Yanwu Zhu, Jinho An, and Rodney S. Ruoff, "Graphene-Based Ultracapacitors," Nano Letters, Vol. 8, No. 10, pp. 3498-3502, Aug. 2008.

[2] Li Li Zhang, Rui Zhou and X. S. Zhao, “Graphene-based materials as supercapacitor electrodes.” J. Mater. Chem., vol. 20, pp. 5983–5992, Aug. 2010

[3] K. Geim and K. S. Novoselov,“The rise of graphene,” Nature Materials, vol. 6, pp. 183–191, Mar. 2007.

[4] Yan Wang, Zhiqiang Shi, Yi Huang, Yanfeng Ma, Chengyang Wang, Mingming Chen and Yongsheng Chen,“Supercapacitor Devices Based on Graphene Materials,” J. Phys. Chem. C 2009, vol. 113, pp. 13103–13107, June 2009

[5] Jingjing Xu, Kai Wang, Sheng-Zhen Zu, Bao-Hang Han, and Zhixiang Wei, “Hierarchical Nanocomposites of Polyaniline Nanowire Arrays on Graphene Oxide Sheets with Synergistic Effect for Energy Storage,” American Chemical Society Nano., VOL. 4, NO. 9, pp. 5019–5026, Aug. 2010.

