Performance Enhancement of Energy Storage Devices used in Electric Vehicle

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Abstract— Since the practical existence of graphene proved in 2004, graphene has generated so much hype in numerous research areas. Graphene is a single layer of carbon atoms with hexagonal lattice structure. Due to its lattice structure graphene has high electrical conductivity rate and many other properties. When layers of graphene stacked on each other it forms into graphite. To separate the graphene from graphite various exfoliation processes are used, but quality of graphene varies for different processes. To produce pure graphene, expensive and time consuming processes are required. This creates hurdles in utilization of graphene for various industrial applications. An energy storage device is one from various applications of graphene, which is liable for adaptation of electric vehicle. Performance of electric vehicle depends on charging time, storage capacity of energy storage device, which can be enhanced by utilizing graphene in their construction. Hence the aim of this work is to enhance performance of electric vehicle by utilizing graphene in energy storage device.

Key words: Graphene; Energy Storage Device; Electric Vehicle; Exfoliation Processes

I. INTRODUCTION

An automobile with internal combustion engine running on fossil fuel is one of the main reasons of global warming. Fossil fuel used in internal combustion engine generates harmful gases which creates bad effect on earth's environment and on human life. Limited sources and increasing price of crude oil in world market arises a question what's next?

That gives way to cleaner, pollution less and environment friendly electric vehicle. In 2018, there are dozens of manufacturers producing electric vehicles but still they are not dominating market. Main reason for their failure is their limited driving range and hours of recharging time, which creates anxiety in end users mind while buying electric vehicle.

To create a path for electric vehicle and to dominate the automobile market, it is must to upgrade existing technology by using graphene based energy storage devices. Graphene has high electricity transfer rate and it can work alongside with any energy storage devices present in industry. India is the second largest producer of graphite and graphite is the main ingredient to obtain graphene. This will increase our economy by exporting graphene based energy storage devices to foreign manufacturers.

Energy storage devices made from graphene will decrease their recharging time. During re-charging process current flows from electricity supply to anode and to cathode. So using graphene as anode will decrease the recharging time of battery.

II. LITERATURE REVIEW

In 1947 P.R.WALLACE [1] wrote in an article about 'the band theory of graphite' in which he worked on physical properties of graphite. He theorized that graphite has a single hexagonal layer which has high electrical conductivity rate. Later on, this single layer of graphite is named as 'graphene'.

Later on in 2004 A.K.GEIM & K.S.NOVOSELOV [2] extracted single-atom-thick crystallites from bulk graphite and isolated graphene from crystallite by transferring those crystallites to silicon wafer. This work proved the theories mention in 'band theory of graphite'. This Nano technique led directly to the first observation of the graphene. The effect was reported by Geim's group, whose papers appeared in Nature in 2005. Geim and Novoselov received awards for their pioneering research on graphene, notably the 2010 Nobel Prize in Physics.

Graphene based supercapacitor was built by ZANG [3] by fabricating crumpled graphene paper. He analyzed different layers of graphene. The specific capacitance of 194 $F\ g^{-1}$ was obtained from the chemically stabilized graphene as a super capacitor electrode at the current density of 1 Ag^{-1}which was partially contributed to a decreased degree of rGO re-stacking and increased wettability in the presence of the surfactant intercalation.

After the development of new graphene based supercapacitor, its performance improvement was done by HAO YANG [4] by using a scalable Nano porous graphene synthesis method involving an annealing process in hydrogen; they showed super capacitor with highly porous graphene electrode capable of achieving power density of 41 kw/kg and energy density of 148wh/kg.

Alongside this work GURSIMRAN SINGH [5] showed a way to reuse discarded battery. His project is environmental friendly, as it takes a discarded battery and turns them into a new one, preventing the creation of electronic waste.

An improved production process of graphene was introduced by YU LIN ZHONG [6] in 2015. He stated that, graphite is a conductive material, which has traditionally been used as an electrode in batteries and other electrochemical devices. He used graphite as an electrode to electrically exfoliate graphene. This process is helpful to produce graphene at mass level. This process is a safe approach to produce graphene compared to other processes like chemical exfoliation and mechanical exfoliation.

In this graphene hypera, AMIN [7] demonstrated a different ways to achieve high performance enhancement of energy storage devices in a paper which he published in 2014. He showed how a maximum current output from charging station can affect charging time of energy storage devices. He also described different charging method for an electric

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vehicle which is on-board method and off-board method. On-board method is conducting charging activity inside the vehicle where off-board method is using external charger to charge vehicles ESS. Detailed description has been shown in Table no 1.

Charging mode	Mode 1`		Mode 2		Mode 3	Mode 4
level	Level 1		Level 2		Level 3	Level 4
Activity method	On-board		On-board		On-board	Off-board
location	Residential area		Residential area		Public facility	Highway/expressway
Electrical specs.	1-phase $120V_{AC}$ 16 amp 3.3 kw	3-phase $400V_{AC}$ 16 amp 10 kw	1-phase $240V_{AC}$ 32amp 7 kw	3-phase $400V_{AC}$ 32 amp 24 kw	3-phase $400V_{AC}$ 63 amp 43 kw	Direct current $50\text{-}700V_{DC}$ 100-1250 amp 50-300 kw
charging period	6-8 hrs.'	2-3 hrs.'	3-4 hrs.'	1-2 hrs.	20-30 min	<20 min

Table 1: Credited to Amin

An important review work was presented by JANIS KLEPERIS [8] in 2013 study. He reviewed the use of graphene in lithium ion battery cathode materials. In which he concluded that graphene forms a 3D electron conducting network in lithium ion battery cathode materials when mixed properly. This increases electron conductivity rate and overall life cycle of the materials.

Different uses of graphene in energy storage device were showed by CHENZHEN ZHANG [9]. He published a paper which primarily focused on different applications of graphene in energy storage devices. Application includes li-ion batteries, supercapacitor and fuel cells. Upgrading these devices with graphene can improve the performance significantly. These enhanced devices can be very helpful for existing electric vehicles.

MAHER F. EL-KADY [10] in 2013 he published paper which showed the use of graphene in miniaturized electronic devices. He and his researchers developed thin film graphene supercapacitor that demonstrated high power performance with superior frequency response. They produce interdigitated graphene micro-supercapacitor using a consumer grade light scribe DVD burner. This showed the versatility of graphene.

But the graphene has its own limitation, which was highlighted by RINALDO RACCICHINI [11]. They addressed the benefits and issues of graphene based materials, as well as outline the most promising results and application in 2014 study. They wrote that the amount of lithium stored by graphene-based anodes in batteries is more strongly dependent on the production method of both the material and the electrode.

A performance simulation of different energy storage devices was done by SOURAV BARUA [12]. In 2015 he published paper which compared graphene based supercapacitor with normal batteries. After performing simulation on MATLAB he stated that normal batteries can last for maximum 1000 full cycles, whereas, graphene based supercapacitor can be up to 1 million cycles and it can retain 94% of their nominal charge after 3000 complete charge and discharge cycles. Li-ion batteries take one to four hours to be fully charged; on the other hand, graphene based supercapacitor provides fast charging time which is 10-30 seconds max. To be fully charged.

YUANLONG SHAO [13] in 2016 published paper they showed that graphene can deliver a theoretical capacity of 744 $mAhg^{-1}$, which is about twice the capacity of conventional graphite electrodes. While these calculations were carried out on perfect and crystalline graphene, real graphene electrodes use chemically modified and defective forms of graphene. The performance of this graphene electrode varies between 100 and 1000 $mAhg^{-1}$ depending on the properties of graphene, electrode processing, mass loading, structural defects and surface area.

After the discovery of graphene various energy storage devices made by scientist. SHAO ING WONG [14] in a review article published in 2018 he showed the various researches of scientists and their results on graphene based supercapacitor to show the enhance energy density over the period of time. He reviewed performances of supercapacitor after the invention of graphene.

A.B. Lopez oyama [16] used alternative method for electrochemical process to obtain graphene. From that process improved graphene flakes were obtained from this process.

Raneen imad jibrael [17] used electrolyte solution of sulfuric acid, nitric acid, and distilled water to electrochemically exfoliate graphene. This method was easy, controllable, and single step process. The structural properties showed good crystalline quality of graphene.

Elisa hellen Segundo [18] produced graphene Nano sheets by exfoliating graphite through underwater electrical discharge. They obtained graphene in both pure water or in IPA water.

Hongwen Chen [19] used nanostructured nb2o5 cathode for high performance li-ion batteries by adding graphene as conductive agent. He stated that the conductive additive can provide a conductive network and a fast and efficient channel for li-ions.

Xiaotian guo [20] reviewed flexible supercapacitor and rechargeable batteries based on graphene material. He found that graphene Nano composites are suitable for flexible energy storage devices.

Yonghe li [21] used graphene and mos2 nanotubes as the anode material of li-ion batteries. This Nano sheets improved cycling performance of batteries.

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III. CRITICAL REVIEW

Work of [1] theorized the existence of graphene in graphite structure, which later practically proved by [2]. They simply used duct tape, graphite lump and transistor to separate graphene. This process was later improved by [6], which can produce mass amount of graphene. A working energy storage device made by [3] based on graphene. Then [4] did a significant performance enhancement in graphene based supercapacitor. Other parameters like charging station output also affects the charging performance showed by [7]. [8] And [9] respectively showed various application of graphene in modern energy storage devices. As the technology improved [10] showed the modern supercapacitor by using DVD but this disk of DVD are vulnerable to low impact force. Therefore this is not available in consumer market. Performance of graphene in energy storage devices is affected by quality of graphene produced is shown by [11]. After the production of multiple energy storage devices based on graphene, a comparison was done by [12]. Researches and their result were shown by [13] and [14]. After reviewing their work we found that all this processes to make energy storage devices are expensive and time consuming excluding work of [6] which greatly saved the time required for production. Then [5] introduced a simple process to make batteries out of waste. This can be helpful to make graphene based batteries without requiring special laboratories and equipment's. These researches are mainly focused on uses of acidic solution in electrochemical exfoliation process. This acidic solution reduces the quality of graphene flakes. Again various variables like input current supply; purity level of graphene; quality of manufacturing etc. affects the performance of energy storage devices. Therefore our primary objective is to find the effect of entry level graphene in energy storage devices. The secondary objective is to obtain graphene flakes by electrochemical exfoliation process without using acidic chemicals.

IV. CONCLUSION

From above reviews we conclude that there are various processes available for production of graphene and its use in energy storage devices, but their cost of production and time consumption for manufacturing creates hurdles for its use in electric vehicle. Thus entire research work on these areas will be done at college level. As stated earlier we have upper hand, so the graphite is inexpensive in our country which will help to produce graphene in mass amount by electrochemical exfoliation process. Thus this paper has presented the methods to produce graphene and options to use graphene in electric vehicles. Need of electric vehicles, its construction of power pack and associated parameters have been presented.

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