IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 12-15

Review on the Applications of Graphene

Ekta Kamble[1], Furqaan Makba[2], Samiullah Shaikh[3], Sanchita Sutar[4], Sangeeta Kotecha[5], Priti Singh[6]
[1] *(Electrical, Atharva College of Engineering, Mumbai University, India)*
[2] *(Electrical, Atharva College of Engineering, Mumbai University, India)*
[3] *(Electrical, Atharva College of Engineering, Mumbai University, India)*
[4] *(Electrical, Atharva College of Engineering, Mumbai University, India)*
[5] *(Electrical, Atharva College of Engineering, Mumbai University, India)*
[6] *(Electrical, Atharva College of Engineering, Mumbai University, India)*

Abstract: *Graphene is one of the world's most thinnest, strongest and highly conductive material of heat and electricity and it has many potential future applications. The research related to these applications are being carried out from past many years and it still has a lot more scope of research even now. We have studied and summarized different applications of Graphene ranging from electricity generation in thermo-electric generators, electronic/photonic circuits, solar cells, biomedical applications in this paper.*

I. Introduction

Since the emergence of the 'graphene epoch' post-2004, there has been notable engrossment in flourishing a high purity, high bear, and scalable fabrication route toward graphene materials for both primary research purposes and industrial production. Graphene was discovered in the UK eight years ago. It is a single layer structure which is stronger than diamond but stretches like rubber and conducts electricity 1m times better than copper. The material's possible applications are so multifarious that it is difficult to envisage more than a few of them at this stage.

Graphene is a 2D atomic crystal made up of carbon atoms arranged in a hexagonal lattice. Due to its unique combination of elite properties, graphene is a feasible starting point for new disruptive technologies across a wide range of sectors. It is highly electrically and thermally conductive – graphene enables electrons to flow much faster than silicon. It is also a transparent conductor, combining electrical and optical properties in an exceptional way.

It is also comparatively cheap to produce in comparison with other materials. The 'Scotch tape method' used at Manchester was so simple and effective that this area of science grew extremely quickly, and now hundreds of laboratories around the world deal with different aspects of graphene research. Also known as the micromechanical cleavage technique, the Scotch tape method does not require large investments or complicated equipment, which has helped to broaden the geography of graphene science considerably.

Recently, graphene has attracted a lot of interest due to its unique electronic properties, such as ballistic transport etc.There have been a number of interesting theoretical investigations on the graphene superlattices with periodic potential structures for application in graphene-based electronic devices like electron wave filters, electron beam splitter, electronic switch and thermoelectric generators. The periodic potential structures can be generated by applying electrostatic potentials on metallic electrodes placed near the graphene layer. However, efficiency has been the main concern in such thermoelectric devices especially for non-conventional sources of energy. Currently, most investigations are focused on the development of the efficient thermoelectric device.

II. Graphene filters reorient the Money-spinning

New approaches to filtration and extracting moisture from air promise to diminish the world's materialize water scantiness catastrophe.Thin sheets of graphene is transformed by filtration. Graphene has the capability to provide large quantities of clean water via desalination and the removal of pollutants. The filters were recently shown to be able to filter even the colourant molecules of whisky, turning the liquid colourless. The researcher hopes full-sized desalination plants with graphene membranes will be possible within five years. Commitments to existing desalination technology may hold back large-scale commercial development of graphene systems in the short term, Prof Nair says. "Graphene has the potential to create the ultimate filter that can also take out chemicals, solutes, salts and compounds such as pesticides.[1] The ultimate water filter use to convert impure water to drinkable water. Researchers is testing graphene filters in drinking bottles. Graphene filters would have the further advantage that they will not let any liquid through when they come to the end of their life.

III. Graphene based Electronics Applications

Through Graphene more electric current and efficient energy conversion can be acheived, and it can be used as the electrode material in thermionic energy converters (TECs) for harvesting heat energy as it has the different unique propertieslike the linear band structure [2], excellent mobility [3], and ultrahigh electrical conductivity [4].
Yuan et al. [5] had proposed the prototype of thermionic energy converters (TEC) with a backgated graphene anode, in which the maximum efficiency is 6.7 times higher than that of a thermionic energy converters (TEC) with a tungsten anode but analysis and performance partfor designing and manufacturing of solar-driven graphene-based thermionic energy converters (TEC)s is not studied in that.

Being in between the solar concentrator and the thermionic emission device in the solar cell construction, the broad solar spectrum is absorbed by the absorber fromthe photonic crystal and is changedinto heat, which is transferred to the cathode and converted to a narrower thermal spectrum [6]. When the heat q_H is absorbed by the cathode from the absorber and the cathode is heated to high temperatures, electrons rapidly thermalize to the equilibrium thermal distribution and diffuse throughout the cathode. Electrons then gain sufficient energy that can overcome the potential barrier available at the graphene near the cathode surface and escape from the cathode into the vacuum. Electrons present in the gap between the electrodes of vacuum condense at the anode, and return to the cathode through an external load.

A model of **Thermionic Solar Cell (TSC)** which is grapheme based consisting of a concentrator, an absorber, and a thermionic emission device configured with cathodes that were graphene-based was recommended, in which different losses such as the radiation and reflection losses from the absorber to the environment, the thermal radiation between the cathode and the anode electrodes, and the heat losses from the anode to the environment were considered. The performance characteristics of the TSC wasanalyzed by numerical calculations. It was found that the maximum efficiency can reach 21% when the area ratio is 0.24 and the voltage output is 2.01 V. [7]

Supercapacitors are also known as Ultracapacitors or **EDLC (electric double-layer capacitor)** are different from regular capacitors in the way that they can store high amounts of electrostatic energy. Graphene is recommended in supercapacitors as a replacement for activated carbon, due to its high relative surface area (which is even more substantial than that of activated carbon). One of the limitations of capacitance is the surface area and a higher surface area means better electrostatic charge storage. Along with that, the graphene based supercapacitors will utilize its lightweight nature, elastic properties and mechanical strength. Graphene-based supercapacitors are said to store almost as much energy as lithium-ion batteries, and they also charge and discharge very fast that is in very few seconds and maintain all this over tens of thousands of charging cycles. One of the ways to achieve such a fast charging is by using a highly porous form of graphene with a large internal surface area (made by powdering the solid graphene and packing it into a coin-shaped cell and then dry and press it).

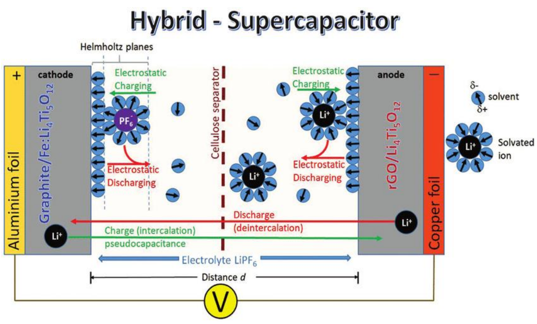

Fig. 1: Schematic illustration of the double layer hybrid supercapacitor consisting of rGO/sLTO and graphite.

In this research, the authors developed reduced graphene oxide (rGO) based electrode materials to achieve a hybrid supercapacitor (SC) function. Also to maintain the high surface area, spinel lithium titanate (sLTO) nanoparticles (NP) were synthesized and deposited on the rGO surface to inhibit the restacking of the rGO layers to graphite. In addition to that the adequate Fe doping of sLTO increased the ionic conductivity and the intercalation capacity, which is necessary for a SC performance. The composites of sLTO/rGO were electrochemically analysed by chrono-potentiometry and electrochemical impedance spectroscopy (EIS) to determine the stability during charge/discharge cycling and the capacity, respectively. The results demonstrated the remarkable cycling performance of the Fe:LTO/rGO composite as well as a higher capacity compared to sLTO/rGO and pure rGO-electrodes. Thermal stability, degradation and the weight loss of the sLTO/rGO in the temperature range between 20 °C and 800 °C were investigated by thermogravimetry (TG)/DTA. As a conclusion, it can be stated that, the Fe-doping increased the ionic conductivity drastically which in turn increased the hybrid capacity of the SC equipped electrodes.[8] The progress of supercapacitor technologies continues to develop in nano-structured materials. Therefore, the nanoscale spinel-Li4Ti5O12 (sLTO) is a promising electrode material for energy storage devices. Moreover, sLTO shows a high coulombic efficiency and remains stable during charge–discharge cycling because of near zero strain in the unit cell.[9] In order to increase the surface area and conductivity, a further development of sLTO related electrodes led to the nano-sizing and carbon-coating of the sLTO particles.[10]

IV. Biomedical Applications

Graphene has extraordinary strengths if we considered in specific way super material. Graphene is used in tissue engineering, drug delivery, cancer therapy for biomedical implants devices and in biosensors. It is also used as scaffolding for tissue regeneration in stem cell tissue engineering. Studies performed with microorganism, cells or biological molecules outside their normal biological context.[11] Extreme strength of single layer graphene enable to hold tissue as scaffold during studies performed with microorganism, cells or biological molecules outside their normal biological context in cell regeneration process.

V. Electrical Applications

Based on thermoelectric devices, Seebeck coefficient and the thermoelectric figure of merit can be increased by using different techniques in graphene superlattices. Efficiency has been the main interest in such thermoelectric devices especially for non-conventional sources of energy[12] The multiple graphene superlattice heterostructures can be formed by graphene superlattices with different periodic electric potentials applied above the superlattices.

In thermoelectric generators figure of merit can be represented by,

$$ZT = \left(\frac{S^2\sigma}{K}\right)T.$$

By increasing the Seebeck coefficient S, the thermoelectric figure of merit ZT can be increased which finally improves the conversion efficiency from heat to electrical energy.

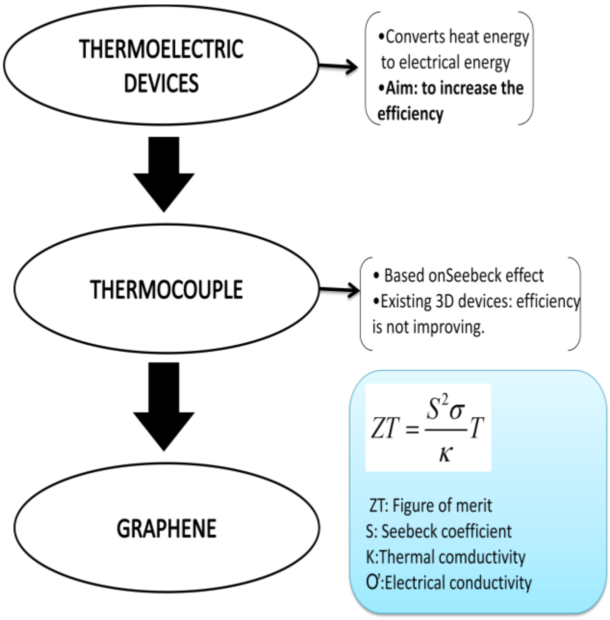

Fig. 2: Flowchart for Graphene based Thermo Electric Generator

VI. Conclusion

This paper represents uses of graphene in various sectors. Graphene is a very promising material for the upcoming new types of systems. Circuits and devices where several functions can be combined into a single material. In current time, most critical issues with the extensive use of Graphene in electronics are related to manufacturing. There are number of technical challenges to be overcome both in terms of cost and also in terms of quality before the first consumer products using Graphene are actually taken up for commercialization.

References

[1]. **Yongchao Si and Edward T. Samulski*** Department of Chemistry, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599 Ali, Prof. Imran & Alharbi, Omar & Tkachev, Alexey & Galunin, Evgeny & Burakov, Alexandr & Grachev, Vladimir. (2018). Water treatment by new-generation graphene materials: hope for bright future. Environmental Science and Pollution Research. 25. 10.1007/s11356-018-1315-9.

[2]. K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, M. I. Katsnelson, I. V. Grigorieva, S. V. Dubonos, and A. A. Firsov, "Two-dimensional gas of massless Dirac fermions in graphene," Nature, vol. 438, no. 7065, pp. 197–200, Nov. 2005, doi: 10.1038/nature04233.

[3]. S. Sun, L. K. Ang, D. Shiffler, and J. W. Luginsland, "Klein tunnelling model of low energy electron field emission from single-layer graphene sheet," Appl. Phys. Lett., vol. 99, no. 1, p. 013112, Jul. 2011, doi: 10.1063/1.3609781.

[4]. A. A. Balandin, S. Ghosh, W. Bao, I. Calizo, D. Teweldebrhan, F. Miao, and C. N. Lau, "Superior thermal conductivity of singlelayer graphene," Nano Lett., vol. 8, no. 3, pp. 902–907, Feb. 2008, doi: 10.1021/nl0731872.

[5]. H. Yuan, D. C. Riley, Z.-X. Shen, P. A. Pianetta, N. A. Melosh, and R. T. Howe, "Back-gated graphene anode for more efficient thermionic energy converters," Nano Energy, vol. 32, pp. 67–72, Feb. 2017, doi: 10.1016/j.nanoen.2016.12.027

[6]. M. Elzouka and S. Ndao, "Towards a near-field concentrated solar thermophotovoltaic microsystem: Part I—Modeling," Sol. Energy, vol. 141, no. 323, pp. 323–333, Jan. 2017, doi: 10.1016/j.s

[7]. IEEE ELECTRON DEVICE LETTERS, VOL. 39, NO. 3, MARCH 2018 383 Graphene-Based Thermionic Solar Cells Xin Zhang , Yanchao Zhang, Zhuolin Ye, Wangyang Li, Tianjun Liao, and Jincan Chen.olener.2015.02.007.

[8]. Synergetic Effects of Fe3+ doped Spinel Li4Ti5O12 Nanoparticles on Reduced Graphene Oxide for High Surface Electrode Hybrid Supercapacitors. Article in Nanoscale December 2017 DOI: 10.1039/C7NR08190A

[9]. J. Su, S. Liu, J. Wang, C. Liu, Y. Li and D. Wu, SolutionBased Synthesis of Carbon-Hematite Composite Thin Films for High-Performance Supercapacitor Applications, MRS Commun., 2016, 6, 367–374.

[10]. H.-G. Jung, N. Venugopal, B. Scrosati and Y.-K. Sun, A High Energy and Power Density Hybrid Supercapacitor Based on an Advanced Carbon-Coated Li4Ti5O12 Electrode, J. Power Sources, 2013, 221, 266–271.

[11]. Sains Malaysiana 46(7)(2017): 1125–1139 http://dx.doi.org/10.17576/jsm-2017-4607-16

[12]. Enhancement of Seebeck coefficient in graphene superlattices by electron filtering technique Shakti Kumar Mishra1,3, Amar Kumar1, Chetan Prakash Kaushik1,3 and Biswaranjan Dikshit2,3