STUDIES ON CONDUCTING POLYMER COMPOSITES FOR ENERGY STORAGE APPLICATIONS

Asiya Masarat
Department of Applied Physics
Khaja Banda Nawaz University, Kalaburagi, Karnataka, India
Dr Jakeer Hussain
Department of Applied Physics
Khaja Banda Nawaz University, Kalaburagi, Karnataka, India

Abstract - Energy storage applications require electrodes coated with graphite to have good physical properties as well as good thermal properties. The Graphite/polymer composites have many desirable qualities. In addition to adsorption, antimicrobial, hydrophobic, electrical, and thermal conductivity were found. As electronic devices become more integrated and miniaturized, the growing demand for effective thermal management has driven increased interest in these composite materials. Two significant potential discoveries have further boosted research in this area. researchers have now developed methods for producing Graphite on a large scale, as well as creating flexible Graphite electrodes. These breakthroughs open the door to manufacturing larger Graphite-based items and allow for greater design flexibility by leveraging Graphite's unique properties. Graphite electrodes are commonly used in energy storage applications due to their excellent conductivity and ability to interrelate lithium ions. They play a crucial role in the performance of lithium-ion batteries, providing a stable and efficient medium for energy storage and release. The main focus of this work is on the different methods used to create Graphite as a flexible electrode. Although it mainly covers various production methods, it also briefly mentions large-scale production. The work discusses the different ways Graphite can be made, such as the Hummers' process, CVD, epithelial growth, and graphite oxide exfoliation. These methods enable the utilization of Graphite's mechanical and electrical properties, making it flexible. The research further enhanced for the simulation of different storage devices with graphite electrodes to check the fabricated electrode usage in variable storage needs.

Keywords: Energy storage, polymer composites, XRD analysis.

I. INTRODUCTION

Polymers are familiar to everyone, their familiarity and wide spread use has been due to the advantageous rang of controllable mechanical and viscoelastic properties, where electrical behaviour has been important. Although the major property of polymers has been their high insulating capabilities, except for the special case of tribolelectricity use in electrophotography, but in recent years, it has become increasingly recognise that in the vast class of existing polymers, the range of electrical behaviour is remarkably wide. However, it is only very recent that comprehensive and analytical conducting polymers differs from all the well-known inorganic crystalline semiconductors like silicon in two major areas such as long range order and their nature which is molecular For a polymer to become conducting, the polymer must contain overlapping molecular orbitals and a high degree of --bond conjugation. This comprehensive π-conjugated system of the conducting polymers has irregular single and double bonds all along the polymer chain When the highly conjugated polymer is in its neutral state, it is essentially an insulating material. It is only upon removal of a studies has aimed at understanding the properties and utilization of these polymers. An important characteristic of polymers is the possibility of potential control and modification of properties by using creative chemicals and synthetic concepts resulting from the high level of freedom in carbon--bond electron from the conjugated polymer backbone to form a radial cation defect (called a polaron) that the insulating polymer becomes conductive. Removal of -bond electron causes the remaining electrons in the based chemistry Conducting polymers are new class of materials whose conducting properties were first discovered in 1977 Such materials demonstrate remarkable optical and electrical properties which were formerly found only in inorganic systems. Electronics properties of -orbitals to become delocalized along the length of the conjugated polymer backbone, thereby enabling free movement of the polymer along the chain. The formation of the positive charge polymer backbone is accompanied by the incorporation of a dopant anion which has the effect of electrostatically balancing the positive charges. With the discovery of electrically conducting polyacetylene in 1977 by Shirakawa, MacDiarmid, and

Heeger by the partial oxidation of polyacetylene films with gaseous bromine or iodine resulted in a dramatic increase in the electrical conductivity of the polymer with values in the metallic region. Although polyacetylene is the most characterised and conductive (up to 105 S/cm) conducting polymer, its poor environmental stability has limited its commercial potential [5]. The 2000 Nobel Prize for chemistry was consequently awarded to the scientist who discovered the electrically conducting polyacetylene. Conducting polymers have received enormous interest over the last decade resulting to an explosion of publications. The research in this area has provided the fundamental understanding of the chemistry, physics and material science of these materials and has supported the industrial grwoth of conducting polymer products

II. LITERATURE REVIEW

The review provides an overview of the current and future methods for Graphite/polymer composite preparation, synthesis, fabrication, and use. Research into new polymer materials that combine well with Graphite and Graphite oxide in composites has been extensive, with an emphasis on these materials' electrical, thermal, and other properties.

Aina, O. (2024), Energy in its varied forms and applications has become the main driver of today’s modern society. However, recent changes in power demand and climatic changes (decarbonization policy) has awakened the need to rethink through the current energy generating and distribution system. This led to the exploration of other energy sources of which renewable energy (like thermal, solar and wind energy) is fast becoming an integral part of most energy system. However, this innovative and promising energy source is highly unreliable in maintaining a constant peak power that matches demand. Energy storage systems have thus been highlighted as a solution in managing such imbalances and maintaining the stability of supply. Energy storage technologies absorb and store energy, and release it on demand. This includes gravitational potential energy (pumped hydroelectric), chemical energy (batteries), kinetic energy (flywheels or compressed air), and energy in the form of electrical (capacitors) and magnetic fields. This paper provides a detailed and comprehensive overview of some of the state-of-the-art energy storage technologies, its evolution, classification, and comparison along with various area of applications. Also highlighted in this paper is a plethora of power electronic Interface technologies that plays a significant role in enabling optimum performance and utilization of energy storage systems in different areas of application.

Ning X et al. (2024) a dual-evaporator architecture and a vapour-compression refrigeration cycle as its foundation, the system uses a direct cooling method on the battery side to improve coupling effects. A weight-based fuzzy logic control method, as part of a revolutionary decoupling control technique, guarantees efficient temperature regulation and sensible refrigerant distribution between the battery and cabin sides. Direct cooling TMS in multi-target systems may now be used more widely because of experimental findings showing consistent average temperature management for both the battery pack and the cabin under varied conditions, with variations successfully kept to less than 0.7°C.

Adaikalam, K et al (2024) This research details the process of recovering nanographite from used batteries and transforming eggshell waste into calcium oxide through high-temperature calcination, both of which have potential uses in the energy storage industry. By employing XRD, SEM, TEM, and XPS techniques, the chemical, morphological, and structural compositions of CaO and CaO/graphite were characterised.

M. Yang et al. (2024) proposed an innovative approach to battery thermal management. They introduced intermittent porous zones within a mini-channel of a liquid cooling system, utilizing air as a coolant. Numerical simulations revealed that strategically placing these porous zones significantly improved cooling efficiency, allowing the battery temperature to remain well below the operating limit at the cell level. The proposed method for identifying optimal porous zone locations demonstrated remarkable effectiveness, achieving close-to optimum solutions with minimal computational expense. Applying this approach to a LiPol pouch battery cell showcased a 90% reduction in pressure drop, fan power consumption, and material cost, with only 10% of the mini-channel volume filled with porous blocks providing effective cooling comparable to a fully porous m The effect of airflow, as indicated by different Reynolds numbers, on improving heat transfer in cooling systems for lithium-ion batteries is examined in this work using a CFD simulation.

Chabi, E. , Amadji, P. and Olodo, E. (2024), In the current context of environmental challenges, this study focuses on developing innovative and eco-friendly composites using rice husk and recycled expanded polystyrene. This dual-responsibility approach valorizes a by-product like rice husk, often considered waste, and reuses polystyrene, a plastic waste, thereby contributing to CO2 emission reduction and effective waste management. The manufacturing process involves dissolving recycled polystyrene into a solvent to create a binder, which is then mixed with rice husk and cold-compacted into composite materials. The study examines the impact of two particle sizes (fine and coarse) and different proportions of recycled polystyrene binder. The results show significant variations in the mechanical characteristics of the composites, with Modulus of Rupture (MOR) values varying from 2.41 to 3.47 MPa, Modulus of Elasticity (MOE) ranging from 223.41 to 1497.2 MPa, and Stiffness Coefficient (K) from 5.04 to 33.96 N/mm. These characteristics demonstrate that these composites are appropriate for various construction applications, including interior decoration, panel claddings, and potentially for furniture and door manufacturing when combined with appropriate coatings. This study not only highlights the recycling of agricultural and plastic waste but also provides a localized approach to addressing global climate change challenges through the adoption of sustainable building materials.

III. METHODOLOGY

Experimental investigations into nano-Graphite-coated electrodes on ceramic materials focus on enhancing the performance of ceramic-based devices, such as sensors, fuel cells, capacitors, and batteries. Graphite, a two-dimensional carbon material with high electrical conductivity, mechanical strength, and chemical stability, is an ideal candidate for improving the properties of ceramic electrodes. The integration of nano-Graphite coatings on ceramic materials has emerged as a promising advancement in enhancing the performance of ceramic-based electrodes.

3.1 Fuel cells

Similar to batteries, fuel cells convert the chemical energy of a fuel into electric energy, shown in Figure However, fuel cells require no recharging and the byproduct of the reaction generally is environmentally friendly like water and heat. As long as the fuel supply is adequate and consistent, the cell can work ideally without replacement with outstanding reliability. Compared with thermomechanical methods, fuel cells do not have combustion as an intermediate step, which results in a higher energy conversion efficiency of 40%-60% For these reasons, fuel cell technology has became a clean, economical and reliable solution for power sources. Among all the commercialized energy storage alternatives, fuel cells hold one of the highest energy densities above 500. Wh/kg, although their low power density remains an obstacle for use in high power applications.

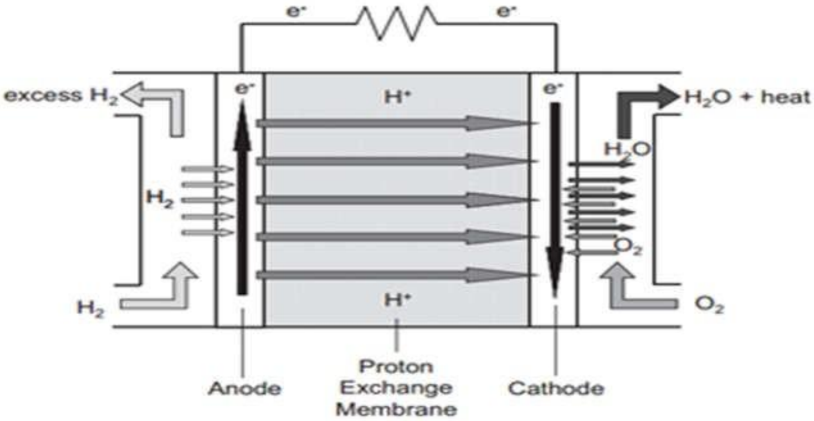


Figure:1 Schematic of a proton exchange membrane fuel cell

Generally, a fuel cell consists of a cathode, an anode and an electrolyte in its construction. The major difference among various types of fuel cells is the electrolyte. Common electrolytes in both research and commercial devices are aqueous alkaline solution, polymer membrane and ceramic oxide. The most popular fuel cell design is the hydrogen proton exchange membrane (PEM) fuel cell

3.2 Fabrication of Graphite / polymer composites

A majority of Graphite/polymer composites investigated are fabricated using GO, chemically reduced Graphite oxide (CRGO), or thermally reduced Graphite oxide (TRGO) as fillers, although they have inferior physical properties than perfect Graphite in many cases. Taking GO as a starting filler for composites, oxygencontaining carboxylic, hydroxyl and epoxy groups on their surface can significantly alter the Van der Waals interactions between the layers of Graphite and improve their dispersion in water. Thus, GO sheets can be easily dispersed in aqueous media and composites with hydrophilic polymers such as poly-ethylene oxide (PEO) and polyvinyl alcohol (PVA) to improve their mechanical properties and thermal stability. GO prefer to disperse in aqueous media that are incompatible with most organic polymers. The resulting composites showed a dramatic increase in mechanical properties In-situ chemical reduction in appropriate polymer solutions not only can restore the conductivity of Graphite but also prevent their agglomeration because of the presence of polymers in their solutions during the reduction. The in-situ CRGO obtained is coated with polymers preventing the restacking of Graphite and maintains the dispersion of GO in polymer matrices. The CRGO/PS composite exhibits a low percolation threshold (φc) of 0.1 vol.% for room temperature electrical conductivity, while the composite samples with unreduced phenyl isocyanate-treated GO are insulating.

3.3 Coating:

Coating Graphite or its derivatives on fibres is a direct way to improve fibres' properties In general, there are two ways to achieve the coating of Graphite and its derivatives. About the first method which we called ‘‘dip and dry”, the fibre was immersed into the dispersion of Graphite and its derivatives, sometimes followed by a reduction or washing process. For the second method, Graphite was sprayed on the fibre directly. Both these techniques were very simple and practical Dip and dry coating have been widely used to prepare Graphite coated fibres. Polyester fabrics coated with RGO have been obtained and characterized by means of chemical and electrochemical techniques The first stage of the synthesis was conducted in contact the GO solution with the fabric to allow the adsorption of GO sheets on the surface of the fabrics. Then, the fabrics with GO were dried in ambient conditions. The second stage of the synthesis was the reduction of GO to RGO (reduced Graphite oxide). Fabrics coated with GO were placed in a solution containing the reducer.

3.4 Modified Hummers' method:

A flexible polyaniline/Graphite/bacterial cellulose supercapacitor electrode Producing large-area, foldable Graphite paper from graphite oxide suspensions by an in situ chemical reduction process Silver fiber fabric as the current collector for preparation of Graphite-based supercapacitors Cu particles induced distinct enhancements for reduced Graphite oxide-based flexible supercapacitors Controllable morphology of polypyrrole wrapped Graphite hydrogel framework composites via cyclic voltammetry with aiding of poly(sodium-4-styrene sulfonate) for the flexible supercapacitor electrode Assembly of Graphite aerogels into the 3D biomass-derived carbon frameworks on conductive substrates for flexible supercapacitors.

IV. EXPERIMENTAL WORK

The importance of this chapter explains a brief description of the materials used and experimental techniques working for various result measurements. The sample preparation techniques are explained in detail. The different analytical techniques like FT-IR, XRD, FESEM, TEM, TGA/DTA/DSC, and measurement techniques such as UV-Visible spectroscopy, Impedance analysis, electrical conductivity, cyclic voltammetry, galvanostatic charging-discharging and electrochemical impedance spectroscopy all these techniques are explained with their operating principles

4.1 Experimental Details:

4.1.1 Fourier Transform Infrared Spectroscopy:

The Fourier transform infrared spectroscopy (FT-IR) is used to determine the functional groups in a molecule due to different interactions and identification of particular bonds in conducting polymer to study the polymer nanocomposites materials.

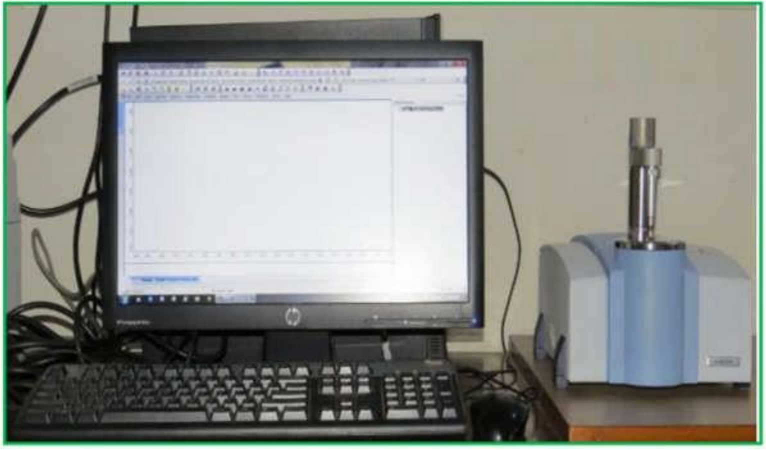


Figure:2 Photography diagram of FT-IR Spectrophotometer

The chemical interaction and the variations in the bonds of nanocomposites were studied by FT-IR spectra using the Bruker Alpha Eco-ATR-FT-IR spectrophotometer in the spectral range 4000-500 cm-1

4.1.2 X-Ray Diffractometer:

X-ray diffractometer (XRD) is used to study the structural and intermediate phase such as amorphous and crystalline phase. The Rigaku Minilex 600 bench top X-ray diffractometer with Cu-target Kα radiation (λ=1.54060 Å) 1° min-1 at scan rate $2\theta = 10° - 60°$ at room temperature. The diffraction pattern of the polymer samples can be determined and the peak hights are measured in terms of intensity. The broadening of diffraction peak indicates the incoherent scattering produced by small crystallites.

.

Figure:3 Photography representation of X-ray diffraction.

The average crystallite size (D) can be calculated by using the Scherer‟s equation, $D=K\lambda/\beta\cos\theta$, where λ is the wavelength, K is the shape factor ($K\approx0.9$), β is the full width half maximum (FWHM) of the peak and θ is the Bragg‟s angle of diffraction [6]. The degree of crystallinity of the systems is determined and the area under the diffraction peaks was calculated by using the equation, $\chi c = \{Ac/(Aa+Ac)\}X100$, where Ac and Aa are the area under the crystalline and amorphous diffraction peaks respectively. The X-ray radiation is being scattered by atoms regularly arranged in the lattice possessing inter atomic distance of a magnitude comparable to the wavelength of the incident radiation is said to be a diffraction phenomenon X-rays diffracted from different atoms interfere with each other. The X-ray diffraction data was collected by using the transmittance or reflection geometry In the case of the reflection mode, X-rays reflected from the material are detected and the reflected X-rays interfere with each other in the diffractogram, intense peaks are obtained.

4.2 Field Emission Scanning Electron Microscopy

The surface morphology of material is studied using the most widely used technique Field emission scanning electron microscope (FESEM). This technique is used to scan on the solid surface of the material and gives clear image of the specimen in the range down from micrometer to nano metre scale. The electrons interact with atoms that produces various signals which gives information about the shape and size of the grain, surface topography, and produce a highly magnified image instead of light it uses electrons. FESEM instrumental diagram were shown in figure. A beam of an electron is produced at top of the microscope by an electron gun and the beam follows a vertical path through the microscope which held within the vacuum. The beam travels through electromagnetic fields and lens which focus the beam towards the sample. Once the beam hit the sample, electrons and Xrays are ejected from the sample.

Figure:4 Photography diagram of field emission scanning electron microscope.

The detectors collect the x-rays, backscattered electrons, and secondary electrons then convert them into a signal and sent to a screen similar to the television screen to produce the final image of the sample. The surface images of polymer samples were obtained by SIGMA ZEISS 500 FE scanning electron microscopes at room Temperature.

4.3 Transmission Electron Microscopy

Transmission electron microscopy is widely used to characterize for imaging nanomaterials in the sub-nano metres resolution. In this technique, an electron beam of uniform current density is irradiated on a thin specimen. The instrument is usually accelerating in the voltage range at 80-120 kV. The medium-voltage instrument works at acceleration voltage of 200- 500 kV to achieve a better transmission and resolution. The high voltage electron microscopy instrument works at the acceleration voltage range 500 kV – 3 MV. The model of the instrument is JOEL-JEM 2100 with a LaB6 is an electron source This instrument works at an operating voltage of 200 keV with point resolution of 0.23 nm and lattice resolution of 0.14 nm. In all the cases, the electrons are emitted in the electron gun by thermionic (tungsten or lanthanum hexaboride filaments), Schottky or field emission (tungsten filaments). The illumination aperture and area of specimen illuminated can be controlled by the two stage condenser lens used in the instrument. The main function of the objective lens is to take image of diffraction pattern formed because of the specimen. The electron diffraction patterns are used to identify the crystallographic structure of the samples. The image can be recorded by the photographic plate inside the digital fluorescence screen coupled by a fibre-optic plate to a CCD camera. In recent days, the integration of other advanced techniques in to the instruments is to improve the performance of TEM analysis, for example, energy dispersive X-ray analysis (EDX) and electron energy loss spectroscopy (EELS).

Figure:5 HR-TEM transmission electron microscope instrument.

In recent years the researchers produce the images in atomic resolution, which helps us to observe the arrangements of lattice structures with the crystalline materials. In order to get high resolution atomic image it is required for very high magnification in addition to high voltage magnification. The crystalline lattice images are obtained by increasing acceleration voltage and 0.1 nm resolution has been achieved with a 1 MV instrument. There are several factors must be controlled in order to acquire a good quality of HR-TEM image. It consists of electron gun which is a source of electrons, the alignment of condenser lens, astigmatism correction of condenser lens, scanning coils, specimen holder and detector.

4.4 TG/DTA Thermal Analyser

Thermogravimetric analysis (TGA) and differential thermal analysis (DTA) techniques are used to determine the thermal properties of materials like metals, glass, polymers, composite materials, inorganic materials and ceramics, etc. the weight loss of the material can be change and measured as a function of temperature at a controlled nitrogen atmosphere n the vacuum. Thermal behaviour of the polymer samples was studied with the help of SDT Q600 TG/DTA thermal analyzer as shown in the figure.

Figure:6 SDT Q600 Thermogravimetric Analyzer.

4.5 Preparation of Graphite

Large-scale preparation of Graphite with controllable size still represents a key challenge in the development of Graphite technology. The first successful preparation of Graphite was by using the scotch-tape method to peel off Graphite via a layer-by-layer technique from a highly oriented pyrolitic graphite (HOPG), followed by depositing on a silicon substrate assisted by an organic solvent. This method allows one to obtain high quality Graphite with sizes of about 10 mm. However, the yield and efficiency of the scotch-type method are low.

The melting enthalpy and melting point were recorded by the differential scanning calorimetry (DSC) in the temperature range from 30 – 120 °C. The variation in the crystalline phase of the conducting polymer materials was studied by the relative degree of crystallinity using the area under the curves In general, the temperature program for a DSC analysis is designed to ensure that the temperature of the sample holder increases linearly as a function of time This technique is highly efficient to study the properties like phase diagrams, polymer phase changes, phase transition enthalpies, phase transition temperature, melting temperature (Tm), glass transition temperatures (Tg), crystallization temperature (Tc)

4.6 Synthetic Strategies of Conducting polymer composites

Conducting Polymers are strategically synthesized through oxidative coupling of monomers. In the case of polymerization, the first stage is the oxidation of the monomer, which yield a radical cation, which then reacts with another radical cation, to form dimer Hence, an obvious classification is the initiation process of polymerization, which includes three major steps: oxidation, coupling and propagation. These three steps serve as integrated and key components which determine the physical and chemical properties of CPs. The oxidation stage can be activated through several methods which includes chemical, electrochemical, and photo-induced oxidation, with each having its own merits and demerits as shown in Figure In the first method, chemical oxidants (such as ferric chloride or ammonium persulfate) are applied to oxidize the monomer. In the second method, the monomers are oxidized electrochemically, and in the third method, light is required to oxidize the monomer with a photo initiator.

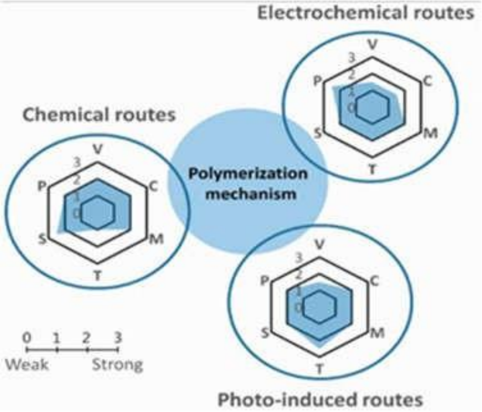
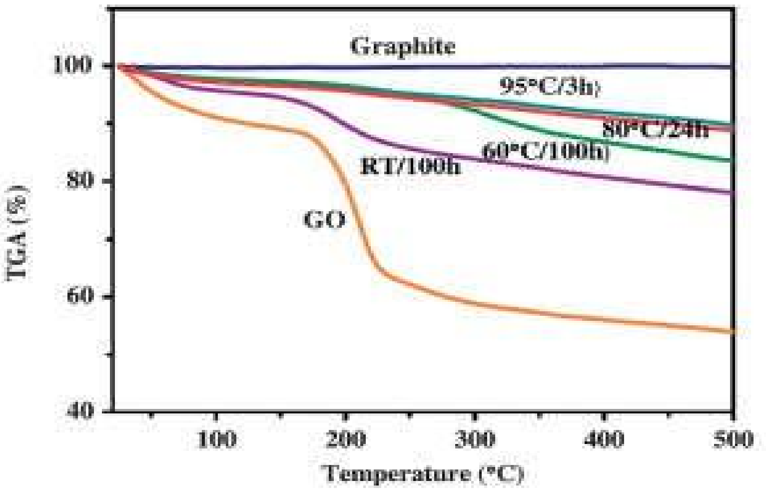


Figure:7 Schematic comparing the chemical, electrochemical, and photopolymerization mechanisms. Each method has been evaluated in term of variables

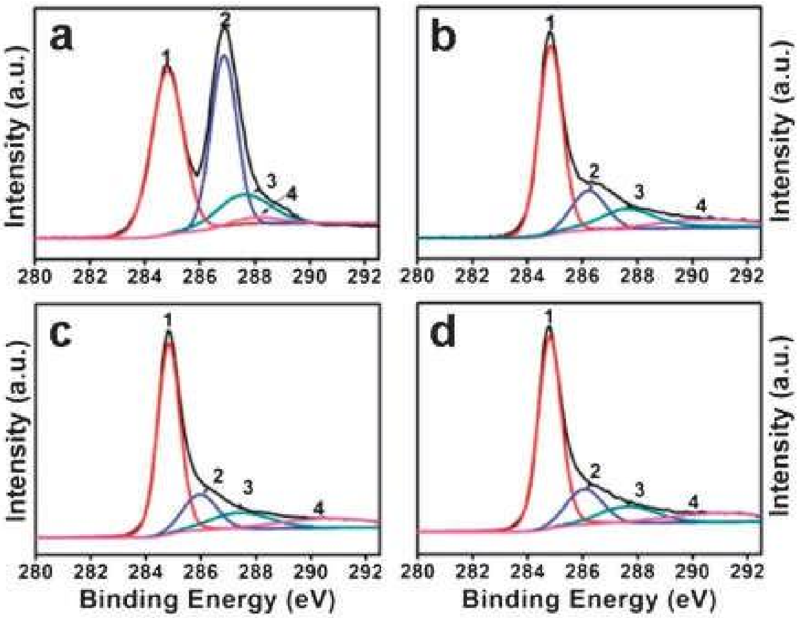
4.7 Thermogravimetric analysis (TGA):

Thermogravimetric analysis (TGA) can be used to investigate the impact of particle size on degradation It has also been used to discriminate between various forms of graphite (graphite, graphene, and graphene oxide) and thus characterize the purity and uniformity of samples TGA is a thermal analysis technique that measures weight changes in a sample subjected to a heating program in a furnace. It is a straightforward and reliable analytical tool that is used in both quality control and research settings. One of the mechanisms of weight change is sample decomposition. Due to the kinetic nature of decomposition, the temperature at which weight changes occur is sensitive to numerous parameters including temperature ramp rate, sample mass, sample morphology, and particle size.

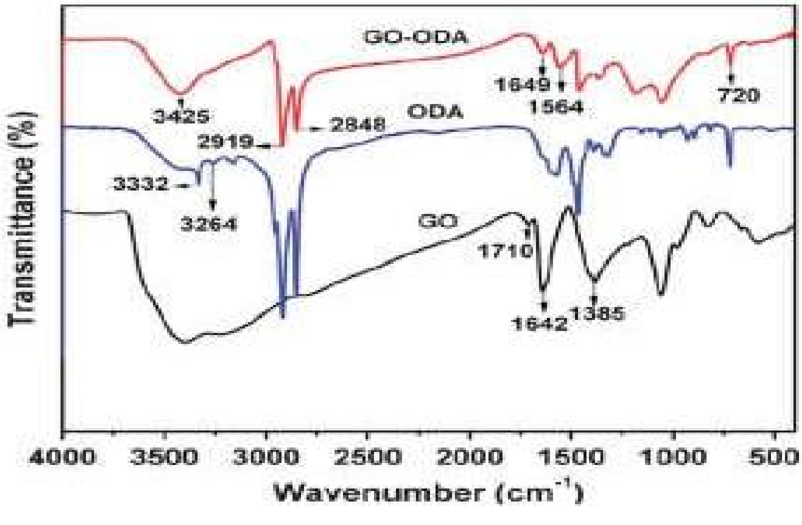


Graph :4.1 Thermogravimetric analysis (TGA) curves of graphite, GO, and RGO.

The presence of hydrophilic or hydrophobic functionalities on the foreign stabilizer prevents restacking during reduction. Ongoing research on graphene revealed that primary alkyl amines, organic isocyanates, polymeric surfactants, and aromatic polyatomic molecules can be used to modify the surface of GO. These stabilizing molecules (macromolecules) either formed direct bonds (covalent interactions) with GO or adsorbed on the surface of GO and helped it to be dispersed in different solvents



Graph:4.2 C 1s XPS spectra of GO before (a) and after reduction for 30 min (b), 1 h (c), and 12 h (d). Peaks 1, 2, 3, and 4 correspond to C]C/C–C in aromatic rings, C–O O, and COOH groups, respectively. Efficient synthesis of processable graphene sheets using pyrrole as a reducing and surface modifying agent has also been reported. Reduction occurred through the exchange of electrons between pyrrole monomers and GO dispersed in water. During the reduction process, the pyrrole monomers reduced GO to RGO sheets and were themselves oxidized to form an oxidized product of pyrroles (OPy). OPy, which are possibly oligomers of pyrrole, facilitated the dispersion of graphene in organic solvents (ethanol, isopropanol, DMF, DMSO, NMP, THF, and acetone) through their adsorption to GO by p–p interactions. The formation of crystalline RGO sheets as compared to amorphous GO was demonstrated by transmission electron microscopy (TEM) analysis. Simultaneous surface functionalization and reduction of GO with octadecylamine (ODA) can also be used to obtain RGO sheets. FT-IR spectra shows that the carboxyl functionality at 1710 cm1 is absent in the ODA functionalized RGO. The appearance of a new band at 1564 cm1 indicates the formation of –C–NH–C– bonds due to the reactions between epoxide and amine groups. Fan et al. were the First to describe an environmentally friendly and efficient route for the reduction of GO by aluminum powder (Al)/hydrochloric acid (HCl) within 30 min.28 The bulk conductivity of the RGO was 2000 S m1 at room temperature. They also studied the reduction of GO using iron (Fe)/HCl at room temperature.29 The appearance of a broad peak centered at 24.5 confirmed the stacking of graphene sheets during reduction. In comparison to Fe and Al, zinc (Zn) powder has been used extensively for the reduction of GO to graphene.30,94,95 According to these authors, reduction was completed within 1 minute after ultrasonication.



Graph:4.3 FT-IR spectra of GO, ODA and GO–ODA (20 h)

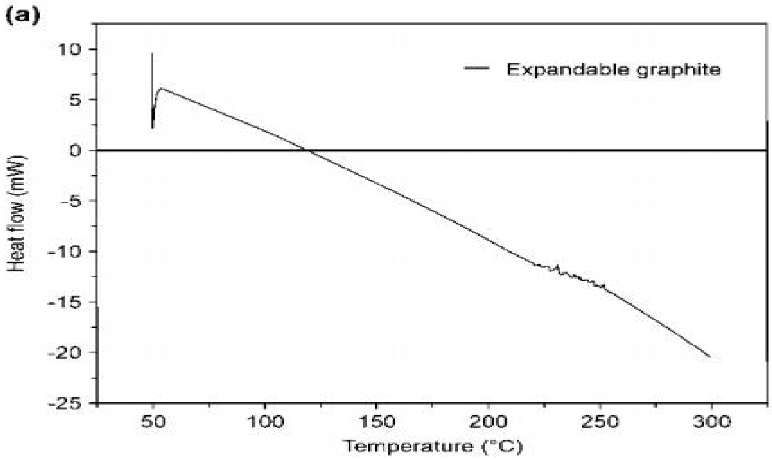
4.8 DSC and XRD Analyses

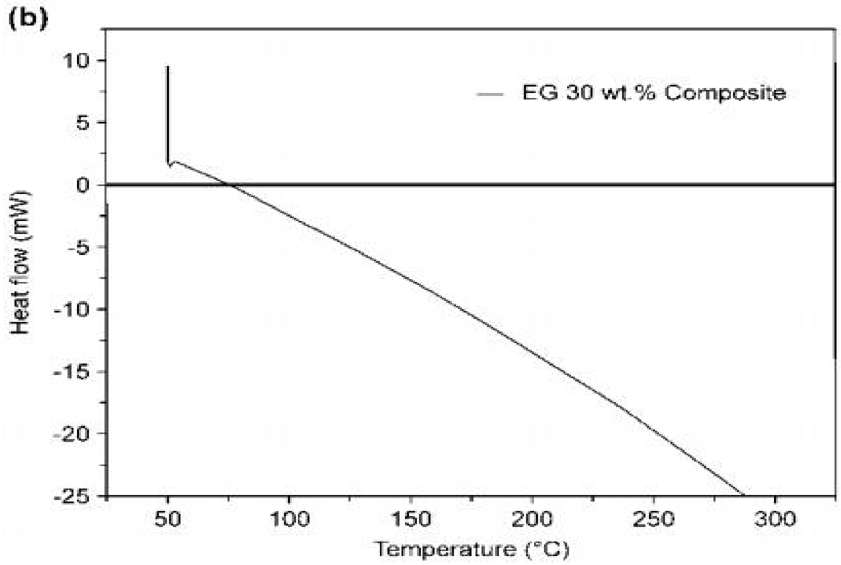
DSC is the most popular thermal technique for characterization. It is easy to use, requires small samples (~20 mg), operates from–180 to 1200 °C and measures heat flow associated with sample transitions as a function of temperature (or time) under controlled-atmospheric conditions. Differential scanning calorimetry has been used to study thermodynamic processes (glass transition, heat capacity) and kinetic events such as cure and enthalpic relaxations associated with physical aging or stress. [26] Differential scanning calorimetry measures the energy absorbed (endotherm) or produced (exotherm) as a function of time or temperature. It is used to characterize melting, crystallization, resin curing, loss of solvents, and other processes involving an energy change. Differential scanning calorimetry may also be applied to processes involving a change in heat capacity, such as the glass transition. X-ray diffraction (XRD) and differential scanning calorimetry (DSC) analysis are two important techniques in materials science and chemistry used to characterize the physical and chemical properties of materials. In the pharmaceutical industry, it is used to identify and determine the purity, crystalline form, structure, and stability of raw materials, APIs, excipients, and other ingredients in pharmaceutical formulations, thereby ensuring the quality and effectiveness of drugs.

XRD analysis is a technique used to determine crystal structure. When a sample is exposed to X-rays, the X-rays are diffracted by the crystal lattice, producing a diffraction pattern that can be used to determine the arrangement of atoms within the crystal, thereby identifying the type of crystal structure present in the sample, as well as the orientation, size, and strain of the grains.

DSC analysis is a technique used to measure the heat flux into or out of a sample as a function of temperature. This technique is used to determine the melting point, crystallization temperature, glass transition temperature and other thermal properties of a sample through controlled heating of the sample.

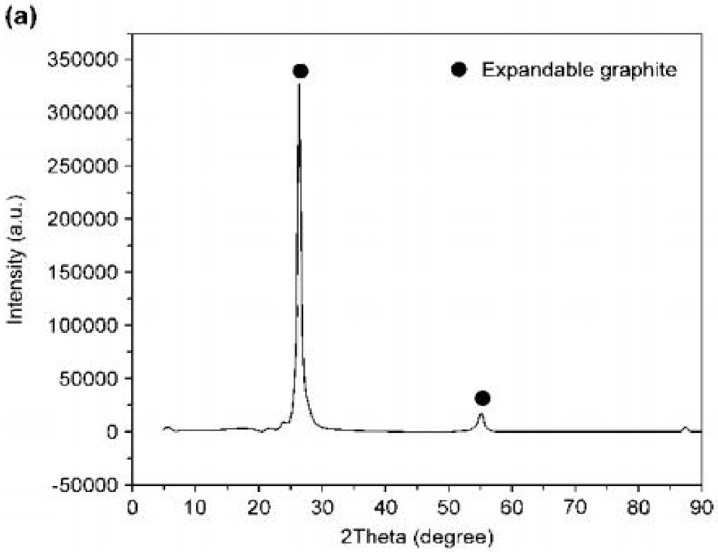
Figure shows the differential scanning calorimetry (DSC) analysis of the expandable graphite (a) and EG 30 wt.% composite specimen (b). The DSC analysis was conducted at a heating rate of 10 °C/min in an Ar Inert gas atmosphere. In Figure 2a, the expandable gas absorbed heat at approximately 54 °C, and the heat flow reached −20 mW at 300 °C. At this period, the heat absorption rate was 1.04 mW/min. In Figure b, the EG 30 wt.% composite absorbed heat at approximately 54 °C, and the heat flow reached −25 mW at 285 °C. At this period, the heat absorption rate was 1.174 mW/min. It was considered that the EG 30 wt.% composite had a faster heat absorption rate than that of the pure expandable graphite because it absorbed a large amount of heat to carbonize the wood particles in the specimen.

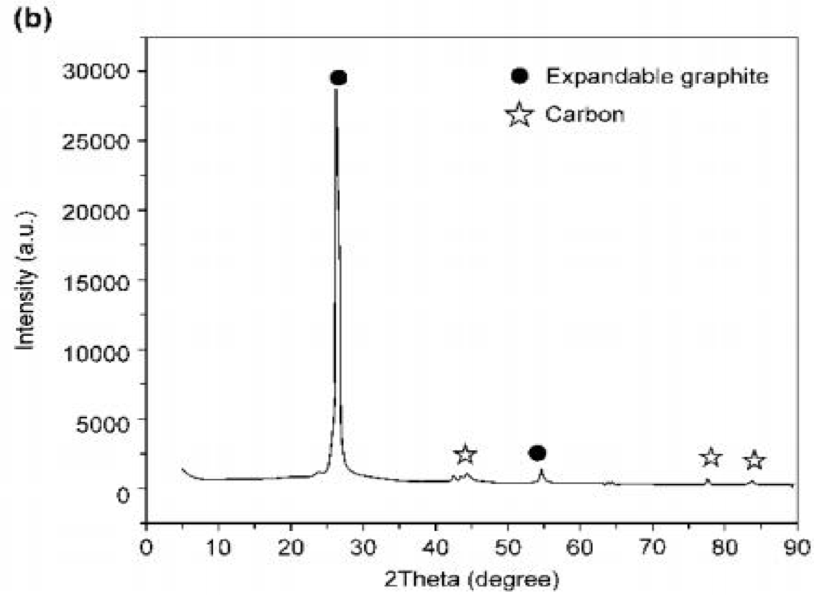




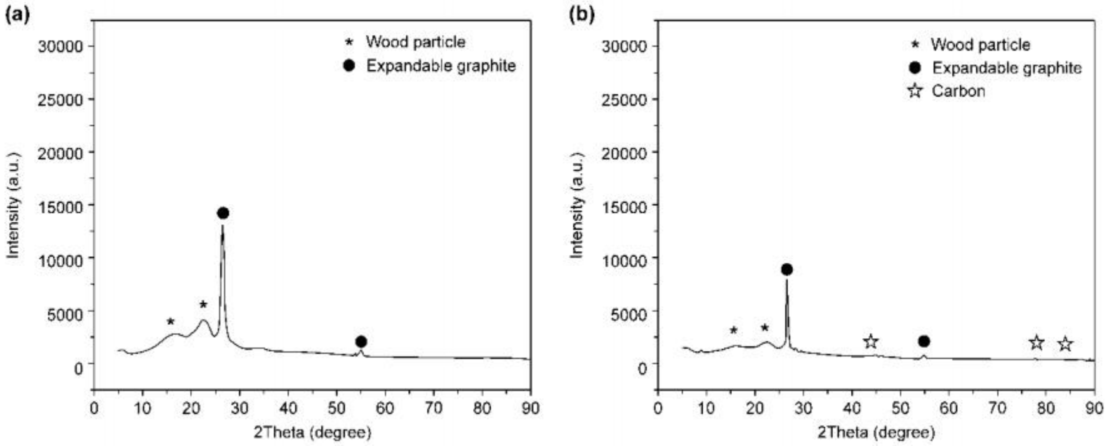
Graph:4.4 DSC analysis of the expandable graphite (a) and EG 30 wt.% composite (b).

Figure shows the X-ray diffraction (XRD) analysis before (a) and after (b) combustion of pure expandable graphite. In Figure 3a, the main peaks are at 27° and 55°, which were reflected by graphite. In Figure 3b, the peaks at 45°, 78°, and 83° confirmed that the expandable graphite was decomposed by heat to form carbon. Figure 4 shows the XRD analysis before (a) and after (b) combustion for the EG 30 wt.% composite. In Figure 4a, the diffraction peaks can be observed at 16°and 23° due to the effect of wood particles in the composite. Furthermore, Figure 4b shows that the diffraction peak of the wood particles lowered after the combustion of the sample, and that carbonwas detected as a result of the combustion of the wood particles and thermal decomposition of expandable graphite.

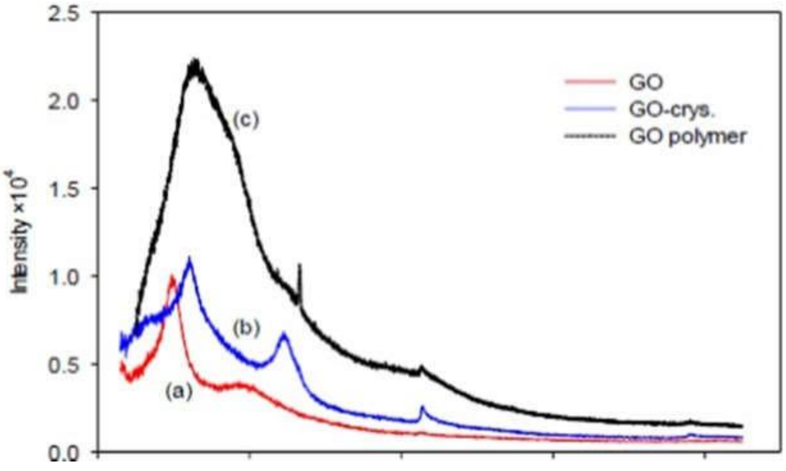


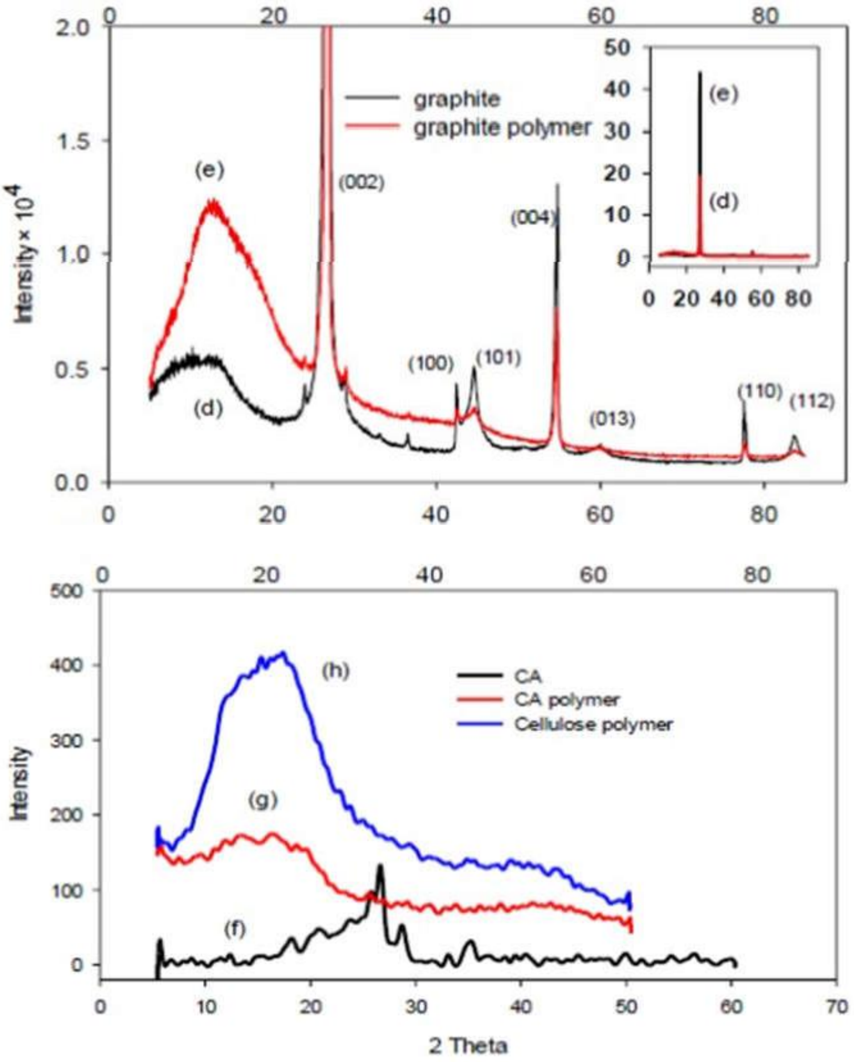


Graph:4.5 XRD analysis of the expandable graphite (a) before and (b) after combustion.



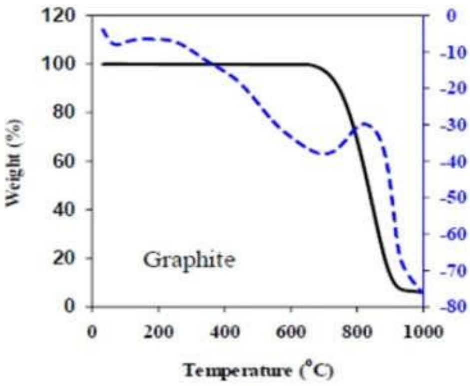
Graph:4.6 XRD analysis of the EG 30 wt.% composite specimen (a) before and (b) after combustion.

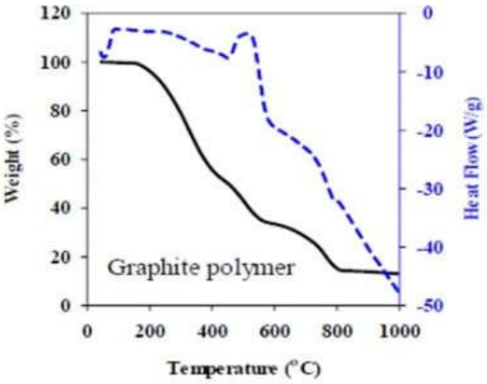




XRD Patterns graphite

Based on the XRD graph pattern for CA, small peaks appeared with a maximum at 2θ = 27.43°, with d =0.32 nm corresponding to the diffraction of (002), which can be related to the impurity of graphite CA polymer and cellulose polymer exhibit very broad diffraction peaks under 2θ = 20°. The absence of a sharp peak reveals a predominantly amorphous structure such as bitumen The polymerizations effect on storage and thermal stability of the graphite, CA and GO were investigated using thermogravimetric analysis (TGA) and differential scanning calorimetric (DSC). The TGA is the easiest method of thermal analysis, which is based on the measurement of the sample weight in the heating. This method provides valuable information when the materials decompose in the heating or react with the gaseous surroundings. In the DSC method, the unknown and control samples are kept at the same temperature. The difference in the energy required for being at the same temperature is plotted based on the temperature change. In other words, the unknown and control samples use some energy to stay under the same thermal conditions. Figure shows the combination of TGA and DSC curves for each sample. A sample weighing between 3-5 mg was sealed in an aluminum pan and heated from current temperature to 1000 °C at a rate of 20 °C/min, in air, and 50 minutes.





According to the results of the TGA test, the graphite loses about 94.02% of weight in the temperature range from 700 to 900 °C. The change in weight of CA, such as graphite, occurs in a step at a temperature range of 400 to 600 °C. CA loses 75.61% weight. Similarly, the GO has been found to degrade in three stages with 97.16% weightless. It seems that water is removed at temperatures below 100 °C. The weight loss that occurs between 100 and 300 °C is related to the removal of oxygen functional groups, and the weight loss at 360 to1000 °C can be linked to the oxidative pyrolysis of carbon framework

V. CONCLUSIONS

In conclusion, it is evident that the need for furthering Graphite's capabilities for application is strong and that there are many approaches one can take to fabricate Graphite as a fiexible electrode. The incredible interest in Graphite can be linked to its ballistic transport at room temperature combined with chemical and mechanical stability. The advancement of portable, wearable, and implantable sensing devices with electrodes can shape the future. This was done so that they could be learned from and manipulatable for researchers to fabricate ideal Graphite as fiexible electrodes. A modified Hummers' method, chemical vapor deposition, and exfoliation of graphite oxide proved as critical methods to use to obtain the desired electrode

The experimental investigations into Nano- Graphite- coated electrodes on ceramic materials reveal promising advancements in the field of high-performance materials. In conclusion, experimental and modeling methods were used to examine the effects of graphite coating on the aluminum substrate and the subsequent annealing process. To create a graphite-coated AL substrate (AL-Graphite) with a robust interface, the AL substrates used in the studies had their surfaces annealed at 1026 K. Prior to annealing, the surface of an aluminum plate substrate is made up of several micron-sized flakes. This surface is rough, contains numerous faults and voids, and fails to provide a sufficient protective layer for the Aluminium substrate. These hybrid materials demonstrate considerable potential in both super capacitors and lithium-ion batteries, offering improvements in energy density, power density, and long-term stability.Structural and electro chemical characterization are indispensable tools for understanding the properties and performance of Al/Graphite composites. By combining these techniques, researchers can optimize the micro structure and composition of the composite to achieve desired properties for various applications, such as batteries, super capacitors, and structural materials. Future research should focus on optimizing the synthesis techniques and exploring the scalability of these materials for commercial energy storage devices.

The main problems associated with conducting polymer electrodes includes poor rate and cyclic stability. These problems can be reduced by effective combination of conducting polymers with other materials to form composite electrodes materials. Combination of these composite nanostructures in forming the conducting polymer composites ensures the composite electrodes have a largely improved energy density and excellent cycling stability. Nevertheless, at the present stage, the capacitances of the conducting polymer composites achieved are insignificant compared to their theoretical values. Although the boosted performance after the composition of conducting polymers with metal oxides/hydroxides/ sulfides, there is still plenty of room to further improve the capacitance features. Also, while some reports have been studied, the design and production of ternary conducting polymer composite electrodes for use in supercapacitors and batteries has not being thoroughly explored. Such hybrid nanostructures in a multiphase system could be more reliable for better-working supercapacitors and batteries. In order to take full advantage of both energy storage mechanisms of electrochemical double layer capacitance and pseudocapacitance, other carbon materials, for example cheap carbon materials, can be used to ultimately improve the specific capacitance, energy density and power density.

Also, the nature of the CPs provides them with excellent structural diversity, high flexibility and great durability. Additionally, the electrochromic characteristics of conducting polymers may probable be a superior advantage for their potential use in smart supercapacitors. With vigorous and high research interest and developments in conducting polymer composites for the last decade, conducting polymer composite electrodes are expected to play a leading role in flexible, smart and economical energy storage utilization in the future.

REFERENCES

1. A. Benosman, M. Mouli, and D. Houivet, (2012),"Mineralogical Study of Polymer-Mortar Composites with PET Polymer by Means of Spectroscopic Analyses," Materials Sciences and Applications, Vol. 3 No. 3, pp. 139-150.
2. A. Bhattacharjee, R.K. Mohanty, A. Ghosh,(2020), Design of an optimized thermal management system for li-ion batteries under different discharging conditions, Energies. 13 .
3. A. Tang, J. Li, L. Lou, C. Shan, X. Yuan, (2019),Optimization design and numerical study on water cooling structure for power lithium battery pack, Appl. Therm. Eng. 159 113760.
4. Adaikalam, K.; Teli, A.M.; Marimuthu, K.P.; Ramesh, S.; Lee, H.; Kim, H.S.; Kim, H.-S.(2024), Energy Storage Application of CaO/Graphite Nanocomposite Powder Obtained from Waste Eggshells and Used Lithium-Ion Batteries as a Sustainable Development Approach. Nanomaterials, 14, 1129. https://doi.org/10.3390/nano14131129.
5. Ahmed H. El-Wahy (2014),"Preparation and Properties of a New Carbon Paste Iron Selective Electrodes and Their Applications",American Journal of Analytical Chemistry,ISSNno:2156-8278,Vol.5,No.2,Pages.140-148.
6. Aina, O. (2024), “Energy Storage Systems Technologies, Evolution and Applications”. Energy and Power Engineering, Vol.16 No.2, 97-119.
7. Akira Todoroki (2016),"Effect of Degree of Cure on Sandwich Structural Capacitor Using Ion-Conductive Polymer with Carbon Fabric Skins",Open Journal of Composite Materials,ISSNno:2164-5655,Vol.6,No.4,Pages.112-120.
8. Al-Sehemi, A. ,and Atanasova, G. (2018), “Complex Permittivity and Permeability Studies Viewing Antenna Applications of NBR-Based Composites Comprising Conductive Fillers”. Materials Sciences and Applications, Vol.9 No.11, 883-899.
9. Anju Yadav (2023),"A Decisive Study on Dielectric Response of Bi2O3/Polystyrene & Bi2O3/PVDF Composite as Flexible Electrodes for Energy Storage",Open Journal of Composite Materials,ISSNno:2164-5655, Vol.13,No.1,Pages.1-11.
10. Anwar (2020),"An Amazingly Simple, Fast and Green Synthesis Route to Polyaniline Nanofibers for Efficient Energy Storage",Polymers,ISSNno:1349-0540,Vol.12(10), Pages.2212.DOI:10.3390/polym12102212
11. Ashik, K. and Sharma, R. (2015), “A Review on Mechanical Properties of Natural Fiber Reinforced Hybrid Polymer Composites”. Journal of Minerals and Materials Characterization and Engineering, Vol.3 No.5, 420-426.