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PVA/GO BASED POLYMER ELECTROLYTES FOR FUEL CELL APPLICATION

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Abstract: Polyvinyl alcohol (PVA)/graphene oxide (GO)-based polymer electrolytes have gained considerable attention for fuel cell applications due to their promising combination of mechanical strength, flexibility, and enhanced ionic conductivity. PVA, a hydrophilic polymer with excellent film-forming ability and chemical stability, serves as an ideal host matrix. The incorporation of GO, with its high surface area and oxygen-containing functional groups, improves proton transport pathways, increases water retention, and enhances the overall conductivity of the composite electrolyte. These characteristics are critical for effective proton exchange membrane fuel cells (PEMFCs), where efficient ion transport and thermal stability are essential for high performance and durability. Various synthesis techniques, including solution casting and crosslinking, are employed to optimize the PVA/GO membrane structure. Experimental results have demonstrated that increasing GO content up to an optimal level leads to significant improvements in ionic conductivity, thermal stability, and mechanical properties without compromising membrane integrity. Additionally, PVA/GO membranes exhibit good chemical resistance and low fuel permeability, making them a viable alternative to conventional Nafion-based membranes. The development of cost-effective, environmentally friendly PVA/GO polymer electrolytes holds significant potential for advancing next-generation fuel cell technologies aimed at sustainable energy solutions.

Fuel Cell Fuel cells are devices that convert chemical energy directly into electrical energy through an electrochemical reaction—without combustion. The most common fuel used is hydrogen, which reacts with oxygen (typically from air) to produce electricity, water, and a small amount of heat

Keywords:

1. Anode – Where hydrogen gas is introduced and split into protons and electrons.

2. Electrolyte – Allows only protons to pass through, forcing electrons to travel through an external circuit, generating electricity.

3. Cathode – Where protons and electrons recombine with oxygen to form water.

I.APPLICATION:

Transportation – Fuel cell vehicles (cars, buses, trucks, trains).

Backup and off-grid power – For hospitals, data centers, and remote areas.

Portable power – Military, camping, and small electronics.

Industrial uses – Combined heat and power (CHP) systems.

PVA (Polyvinyl Alcohol)

Polyvinyl Alcohol (PVA) is a synthetic, water-soluble polymer widely used in various industrial and consumer applications due to its excellent film-forming, emulsifying, and adhesive properties. It is typically produced through the hydrolysis of polyvinyl acetate, where the acetate groups are replaced by hydroxyl groups.

Key Features of PVA:

Chemical Formula: $(C_2H_4O)x$

Appearance: White or cream-colored powder or granules, odorless

Solubility: Soluble in water; insoluble in most organic solvents

Biodegradability: Biodegradable under specific environmental conditions

Non-toxic: Considered safe for many applications, including food packaging and pharmaceuticals.

Advantages:

Good mechanical strength and flexibility Excellent film-forming and barrier properties Environmentally friendly compared to ther synthetic polymers Non-toxic and safe for use in sensitive applications

II.LIMITATION:

Moisture sensitivity due to its hydrophilic nature

Requires proper storage to prevent degradation

Graphene Oxide

Graphene oxide (GO) is a single-atomic layered material derived from graphite, which is composed of carbon, oxygen, and hydrogen atoms. It is considered an oxidized form of graphene, distinguished by the presence of various oxygen-containing functional groups such as hydroxyl (-OH), epoxy (-O-), and carboxyl (-COOH) groups. These functional groups make graphene oxide hydrophilic and allow it to disperse well in water and other solvents, unlike pristine graphene.

Key Features of Graphene Oxide:

1. **Structure**: GO has a two-dimensional sheet-like structure similar to graphene but with disruptions in its hexagonal lattice due to oxidation.
2. **Synthesis:** The most common method of synthesizing graphene oxide is the Hummers' method, which involves treating graphite with strong oxidizing agents (e.g., $KMnO_4$ in concentrated H_2SO_4).
3. **Properties:**
   Electrical: GO is an electrical insulator due to the disruption of the π-conjugated system by oxygen groups.Mechanical: It retains significant mechanical strength, though lower than that of pristine graphene.Chemical Reactivity: The presence of functional groups allows GO to be easily modified or functionalized for various applications.Thermal Stability: Lower than graphene due to the decomposition of oxygen groups at elevated temperatures.
4. **Applications:**Graphene oxide is widely studied and used in various fields due to its unique properties:

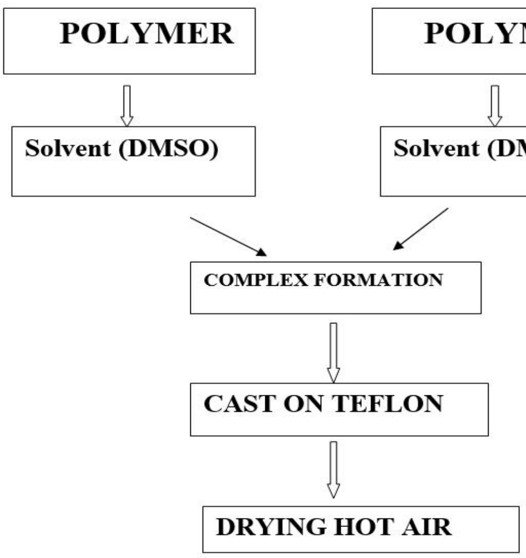
Energy Storage: As an electrode material in batteries and supercapacitors.

Water Purification: For filtration and desalination, thanks to its layered structure and hydrophilicity.Biomedical: In drug delivery, biosensors, and imaging, due to its biocompatibility and functionalizability.Composites: As a filler to enhance the mechanical and thermal properties of polymers.Electronics: Reduced graphene oxide (rGO), obtained by reducing GO, can be used in flexible electronics.

Dimethyl Sulfoxide (DMSO)
Dimethyl Sulfoxide (DMSO) is an organosulfur compound with the chemical formula $(CH_3)_2SO$. It is a colorless, hygroscopic liquid that is miscible with water and many organic solvents. DMSO is characterized by its distinctive garlic-like odor and is widely used in chemical, pharmaceutical, and biological research. DMSO is a versatile chemical with a unique combination of chemical stability, solvency power, and biological activity. Its broad utility in science and industry, coupled with its controversial medical potential.

Chemical and Physical Properties
Molecular Formula: C_2H_6OS
Molecular Weight: 78.13 g/mol
Boiling Point: 189°C (372°F)
Melting Point: 18.5°C (65°F)
Polarity: Highly polar aprotic solvent
Solubility: Miscible with water, ethanol, acetone, and other organic solvents

Applications
1. **Solvent**: Widely used in organic synthesis, polymer chemistry, and pharmaceutical formulations due to its ability to dissolve both polar and non-polar compounds.
2. Cryoprotectant: Commonly used to protect cells and tissues from damage during freezing and thawing in cryopreservation.
3. Drug Delivery: Known for enhancing the permeability of skin and mucous membranes, which has led to its use (and controversy) in topical drug formulations.
4. Medical Research: Investigated for anti-inflammatory, analgesic, and antioxidant properties.
5. Industrial Uses: Solvent for paints, coatings, and adhesives, and used in microelectronics and cleaning agents.



Flow chat of the preparation of PEM for fuel cell application by solution casting technique.

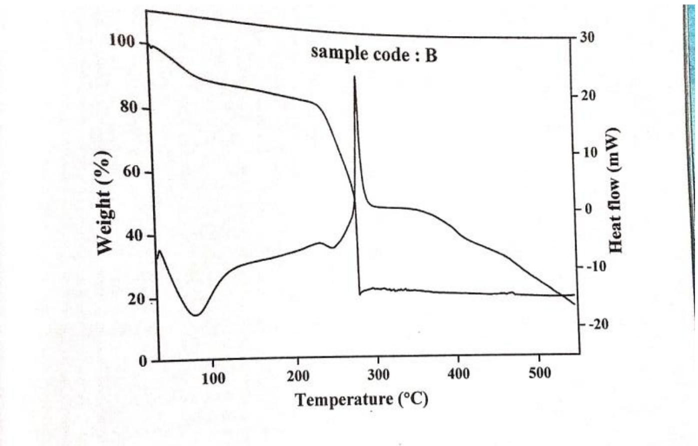
Electro chemical impedance spectroscopy.
Impedance spectroscopy is a method to characterize the electrical properties of materials and their interfaces with electrically conducting electrodes. It is used to study the dynamics of mobile changes in bulk ionic, electronic-ionic and dielectric materials. This consists of applying an electrical pulse across the electrode and studying the response. Unlike DC technique uses small pulse in the range of 5-10mV peak to peak. This cause only is reduced. This method provides data on both electrode capacitance and charge kinetics. The objective of the ac impedance experiment is to determine the values of the various reference electrodes, Rp polarization resistance at the electrode and cell the double layer in the equivalent circuit. This is done by studying the response to an AC excitation over a wide range of frequencies. The data obtained are represented either by the nyquist plot which is also known as cole-cole plot or impedance phase diagram. In this the imaginary component of impedance is plotted against the real component for the different frequencies. From the plot one can compute R_Ω, R_p and C_{dl}. The bode plot permits examination of the absolute impedance and the phase angle as a function of frequency. The log (Z) vs log (F) curve yields the value of R_Ω and R_p. The Bode plot is a useful alternative with low frequency determination.

Electrical Conductivity
To avoid cell polarization ac impedance analysis was carried out using stainless steel as ion-blocking electrodes. Electric conductivity measurements are normally carried out under ac condition because under these conditions polarization effects are minimized. Many electrochemical parameters including alternating current is out of phase with the applied ac voltage, perturbing the various processes within the cell (single crystal or polycrystalline pellets or thin films) such as surface interface. Measurement of accurate and meaningful conductivity values is the most useful characterization of fast ion conductors, but often such measurements are associated with interfacial problem.
Conductivity experiments are often carried out by using complex impedance or admittance techniques, which permit bulk conduction to be distinguished from grain boundary or surface contribution; because ion polarization is very rapid unless ion-reversible electrodes are available, simple dc conductivity measurements are less common for these materials.

Thermal Analysis
TG provides the analyst with a quantitative measurement of any weight change associated with a transition. For example TG can directly record the loss in weight with time or temperature due to dehydration or decomposition. Thermo gravimetric curves are characteristic for a given compound or system because of the unique dequence of physio-chemical reactions which occur over definite temperature ranges and at rates that are a function of the molecular structure. Thermal analysis involves the measurement of thermal characteristics when the changes occur. These changes are sensed through" thermograms" . Thermo analytical techniques can be classified as TGA differential scanning calorimetry, Differential thermal analysis, Thermo mechanical analysis and dynamic mechanical analysis TGA measures changes in weight during the thermal stability and determination of thermal decomposition kinetics.DSC/DTA measures the temperature and heat flow during any transition and material

undergoes.

SAMPLE CODE	DECOMPOSITION TEMPERATURE (°C)			% WEIGHT LOSS		
	I	II	III	I	II	III
B3	68.16	231.56	276.3	3.04	57.72	24.04



III.CONCLUSION

TG/DTA analysis.

The thermal stability of the polymer membranes plays a vital role in deciding the performance of fuel cells. TG/DTA is a versatile tool to probe the thermal properties such as the thermal stability and the transition behavior of the polymer electrolytes. TG/DTA thermograms of polymer electrolyte. The data obtained from the TG/DTA curves for the prepared samples have been summarized. From the TG/DTA curve, it is found that the membranes start decomposing at 68.16 degree C with a weight loss of 31 %.This is due to the presence of moisture at the time of loading the samples.The second decomposition is observed at 231.56 degree C with a weight loss of 58%.This indicates the gradual decomposition of the polymer and GO,followed by the evaporation of the electrolytes of the varies concentrations of plasticizer are said to be thermally stable up to the temperature pointed above.Then sudden decrease in the wt% is observed,which signifies that the polymer gel electrolytes are thermally stable up to the temperature at which the decomposition of the film starts . Thus the thermal stability of the film is found to be around degree C. The sharp exothermic peak in the DTA curve of the sample is accordance with the TG result. Thus the prepared sample with 6 wt% of GO can be used in the fuel cell and the cell can be operated till the temperature of 231.56 % C.In the point view of thermal stability,it is conclude that the prepared polymer electrolyte membrane can serve as a promising candidate for fuel cell application.