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Poly (vinylidene fluoride) polymer electrolyte-based Supercapacitors

ABSTRACT

PVDF, or polyvinylidenefluoride, is a popular polymer in the fluoropolymer family because of its superior mechanical strength, thermal stability, and piezoelectric qualities. It is chemically resistant to various substances, including diverse acids, bases, organic solvents, oil, and fat, and it is also easily processed.Electrochemical devices with superior energy storage effectiveness are necessary because of the increasing electricity consumption in the modern world. Because of its great power density, extended lifespan, remarkable charge/discharge cycle stability, and inexpensive cost, supercapacitors are regarded as amazing energy-storing devices. Supercapacitors' electrochemical performance is entirely dependent on the selection of their basic components and their manufacturing process.Materials made from carbon with improved thermophysical characteristics and deformation strength are currently of great interest.These materials have various uses in numerous sectors because of their distinctive physical and chemical features.The abundance of research on the "structure-property," manufacturing, application, and ecology of composite polymers based on polyvinylidene fluoride (PVDF) can be attributed to the many opportunities for their use in science and technology.It is feasible to achieve a high degree of multi-disciplinarity and integration of polymer science by using innovative technologies to build an expanded conceptual picture regarding polymeric materials. This leads to the formation of fundamental problems in polymer science, the solution affecting a significant improvement to the natural scientific picture of the modern world.PVDF is arguably the most sought-after polymer nowadays due to its ability to self-polarize in the presence of an electric field. Researchers and experts involved in the development of energy harvesting and storage devices such as self-charging supercapacitors are drawn to the piezoelectric, ferroelectric, and pyroelectric capabilities of PVDF.The advanced qualities of PVDF and its possible uses in a variety of polymer forms are explained.

Keywords: *Polyvinylidenefluoride, charge carriers, supercapacitor, structural properties*

1. INTRODUCTION

There are several advantageous characteristics of polyvinylidene fluoride ($(CH_2$-$CF_2)n$[1]: a high mechanical strength even at elevated temperatures, a reasonably high melting point, resistance to hydrolysis and UV radiation, resistance to chemicals and radiation, strong wear resistance, extremely low electrical and thermal conductivity, and remarkable igniting susceptibility. PVDF, which at the time was thought to be the best synthetic polymer available.

More than 30 years of research have finally led to a significant improvement in the electro-mechanical and piezoelectric characteristics. The only commercially accessible piezoelectric polymer, this type of fluoropolymer exhibits exceptional electro-mechanical responses across a broad temperature range among all existing organic compounds. The β-phase of PVDF is particularly intriguing since it possesses ferroelectric and piezoelectric characteristics.As a result, PVDF is extensively utilized as a structural stability and packaging resource, in the production of solar cells and piezoelectric elements, and the fields of electronic devices, acoustics, medical science, medications, and the manufacturing components for petroleum-based, chemical-based, metallurgical, food, paper, apparel, textiles, and radioactivity industries.

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Energy production and storage face challenges due to the unpredictable nature of renewable energy sources.The answers to these issues lie in creating renewable energy sources that are both ecologically benign and environmentally friendly, as well as in their storage. One of the most oddly effective strategies for further advancement in the energy device industry is the implementation of renewable energy systems.Apart from meticulously gathering energy resources, the primary focus is maximizing the storage devices' recognizable reliability to achieve a primarily techno-financial scale and performance.

In light of the aforementioned information, a creative method for storing a significant quantity of electrically generated energy was cleverly put into practice. This method takes the shape of an electrochemical device known as a supercapacitor (SC)[2]. Since their inception, supercapacitors have been used in a wide range of applications, including electronic devices, medical instruments, transformer construction, and electric automobile equipment. The green revolution and rising energy prices made it possible for the supercapacitor to be developed and modernized, as well as affirmed its significance in the energy industry. Their efficiency in storing large amounts of electrical power, high electrical density, quick charge and discharge times, long-term cycling capabilities, wide potential window, and dependability allowed them to be replaced by other renowned subsequent energy storage devices like batteries, dye-sensitized solar cells, and fuel cells, etc.Supercapacitors differ greatly from second-generation devices in their energy storage technique. The electrical double-layer capacitance (EDLC) and the pseudo-capacitance were the two guiding concepts of the supercapacitor's energy storage mechanism, which set it apart from previous second-generation devices.These two mechanisms are linked to each other. These devices remarkable power management capabilities bridged the gap between traditional aluminum capacitors and batteries. Their unique operating principle allows them to handle and store significant quantities of power. Supercapacitors have a poor energy density, a high rate of self-discharge, and a slow voltage drop. These are the most difficult aspects of assembly, aside from its advantageous side. Supercapacitors with cutting-edge qualities like versatility, durability, and rechargeable. Qualities are the result of decades of research and development by scientists and researchers in the area. To minimize voltage loss and self-discharge rate, the majority of studies are conducted using supercapacitor components. Positive and negative electrodes, separators, binders, electrolytes, and current collectors are the main components of a supercapacitor. A supercapacitor's self-discharge rates may be efficiently decreased by making changes to the way these parts are prepared. This will also increase the densities of power and energy as well as the energy system's cycle stability. In terms of supercapacitor electrode preparation, is the ultimate goal of the researchers. The majority of a supercapacitor is made up of electrodes. The operation of supercapacitors also varies concerning the material of the electrodes. Electrode materials include graphene, carbon fiber, carbon nanotubes, graphite, and activated carbon as well as so-called electrical double-layer capacitors, generally showing electrical double-layer capacitance. However, conducting polymers such as polypyrene, polythiophene, polyaniline, etc, and metal oxides such as RuO_2, MnO_2, etc are exhibiting pseudo capacitance and exhibiting what are known as pseudo capacitors[3].The hybrid supercapacitor that results from the hybridization of a pseudocapacitor with an electrical double-layer capacitor has higher energy storage efficacy, potential width, and charging and discharging stability [4].

The carbon-based electrode materials received a lot of attention in the early phases of the advancement of electrical energy storage devices. The first isolated instance of polyaniline (PANI) in the middle of the 1900s marked a turning point in the research and fabrication of polymer-based electrochemical energy storage systems. Because of their potential pseudocapacitivebehaviorwith outstanding conductivity and charge-discharge stability, conducting polymers have attracted scientific attention. Subsequently, the production of secondary energy storage devices has steadily expanded the use of various conductive polymers, such as polyaniline [5], polythiophene [6], and polypyrene [7], whose development has started. Polymers were employed as separators in electrochemical devices even before conductive polymers were developed because of their low cost, durability, mechanical stability, and dielectric property dependability.However, the discovery of the lithium-ion polymer battery (LIP) in the 1980s, which used a polymer electrolyte rather than a liquid electrolyte, solidified the role of polymers in the creation of electrochemical energy storage devices [8]. Electroactive polymers are polymers that exhibit electroactive characteristics (EAP). When electrical fields are applied, electroactive polymers show significant strain. Electric stimulation can cause these materials to change in size and form. EAPs with substantial distortions in adaptation to relatively tiny inputs are the most desirable kind of properties. The lightweight, fracture-tolerance, and pliability of EAP materials are only a few of their many desirable qualities.

Ionic and electric materials are the general categories into which they fall. In contrast to electric EAPs, which are powered through an electric field, ionic EAPs employ the diffusion of ions[9].Electroactive polymers include polyvinylidene fluoride (PVDF) and its co-polymers, poly (vinyl alcohol) (PVA), poly (tetrafluoroethylene) (PTFE), polyethylene (PE), and poly(methyl-methacrylate) (PMMA). Ultimately, the layout, structure, and manufacturing process of super-capacitors, as well as the improvement of the energy system's efficiency and marketing, depend on the electroactive polymers with adjustable attributes. One kind of electric EAP with piezoelectric properties is PVDF. Supercapacitors are made using electroactive polymers as separators, electrolytes, and binders.An in-depth analysis of PVDF, its co-polymers, and their nanocomposites—an electrically active polymer containing fluorine—and its potential applications in the creation of supercapacitors is provided in this article [10].

PVDF is a synthetic polymer whose physical, chemical, mechanical, and thermal properties are the main topics.This investigation also aims to investigate and highlight the characteristics that affect the polymer's broader applicability in other fields. About the various fields of biomedical research, solar devices, sensors, battery electrolytes, molecular separation, conductive polymers, polymer viscosity, and polymer nanocomposite applications, this work summarizes the state of research and development on PVDF applications. As a result, this study might help researchers and industry professionals better comprehend polymers and gain a deeper grasp of them while also allowing them to enhance polymer science and technology.

PVDF is a linear hydrocarbon polymer that is semi-crystalline and contains approx 59.4% fluorine and 3% hydrogen. They have been known since the 1960s and are created with the polymerization of vinylidene fluoride monomer (VDF). They exhibit an elevated level of rigidity, and durability, because of their large amount of distinctive crystalline structure [11]. An emulsification or polymerization of suspended particles process was used to create PVDF on a commercial scale. The PVDF synthesis level falls between 1000 and 2500 VDF units [12].

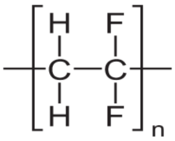

Figure 1. Structure of PVdF [13]

Many factors, including mechanical performance, lightweight, high impact resistance, flexibility, good dielectric constant, and electrochemical stability, have sparked interest in PVDF. Moreover, it possesses the unique ability to repel chemicals, temperature, UV light, and weather conditions. The structural characteristics, processing circumstances, and constituents of PVDF determined its processing method and subsequent application [14]. The primary crystalline variations identified by studies to address the intricacies of PVDF's structure are Alpha (α), Beta (β), Gamma (γ), Delta (δ), and Epsilon (ε) [15]. The mechanical, electrical, and thermal manufacturing conditions influence the proportion of these phases [16]. Changes in the condition or characteristics of matter without corresponding changes in its chemical makeup are referred to as physical changes. Understanding and modifying the characteristics of polymeric materials is a constant goal for engineers and researchers. Changing, modifying, or permanently transforming the qualities into different forms is possible, creating new substances with specific characteristics. The phrase "chemical properties" refers to these characteristics of a material or substance. Chemical property, then, defines how one sort of matter changes into another. Examples of chemical characteristics include heat of combustion, flammability, toxicity, acidity, and reactivity to other substances. As a result, PVDF is a macromolecule with both physical and chemical characteristics that will be covered in this current study.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.1. Different types of Poly(vinylidene fluoride) (PVDF) Phases

In PVDF, which exists commercially, alpha represents the most prevalent polymorph. Condensed PVDF cools down to create this phase, which is the most prevalent and thermodynamically stable state. Along the chain, it features a crankshaft formation (TGTG conformation: T-trans, G-gauche) with a monoclinic unit cell. The dipole moment of the C-F bonds is angled concerning the normal axis in the alpha phase conformation, which aids in reducing the steric hindrance between the fluorine atoms and the polymer skeleton in alpha phase [17]. While in the Beta phase, when the material of the polymer backbone undergoes expanding, straining, or annealing, the polar beta phase forms.The all-trans (TTTT) conformation, a planar zig-zag shape seen in the orthorhombic unit cell structure of the crystal β phase, stays in the same plane as the carbon backbone.When two beta-PVDFpolymer chains are in the TTTT conformation, their dipole moments are directed in the identical direction. When an electric field is applied, the polarisation of these molecular dipoles in a particular direction results in a permanent dipole in the beta phase and causes a spontaneous polarisation within the crystal's structure [18,19] and also in the gamma phase, a small amount of stress or an interaction with certain chemicals might cause the polymer to move into the gamma phase, which is characterized by a transitional polar structure with a TTTG conformation. Typically, the gamma phase of PVDF polymer materialwas produced by using molecules having high molecular weight [20].

According to some scientific findings, delta (δ) phase crystals are created through deformation that can take place in alpha or beta-crystalline forms [21,22]. Under certain crystallization temperatures and pressures, only the delta-phasematerial can crystallize [23,24]. There is ongoing discussion on two configurations, namely the delta and epsilon phases.

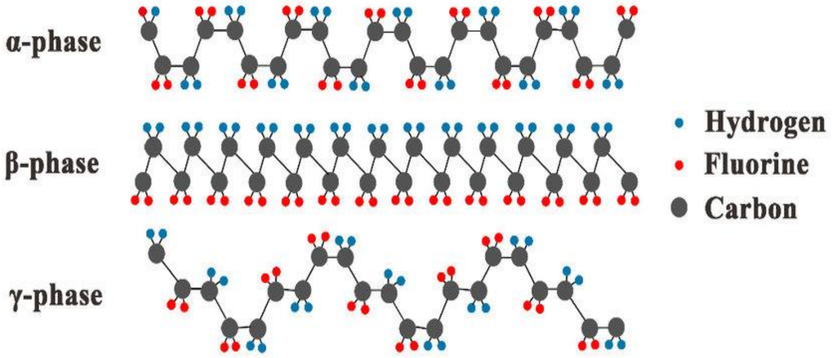

Figure 2. Structure of α,β and γ phase [25]

2.2. Physical Properties

PVDF has a spherulitic structure; on the other hand, because of its complex morphology in the variations, the spherulite characteristics are lost when the molten form is allowed to solidify close to its melting point [26]. As was already mentioned, the polymer is partially crystalline, suggesting some amorphous areas in the structure. It is discovered that the amorphous zone (1.68 g/cm^3) has a lower density than the crystalline region (1.93–1.97 g/cm^3).At high temperatures i.e. 230°C and pressure at 1 bar, the range for polymer chains based on hexafluoropropylene (HFP)-Poly(vinylidene fluoride-hexafluoropropylene) (PVDF-HFP) is 1.45–1.48 g/cm^3[27]. The melting point of PVDF was determined to be between 155 °C and 192 °C, whereas the glass transition temperature (T_g) ranges from – 40°C to − 30 °C concerningthe sample and test procedure.

Table 1. Physical Properties of PVdF

Property	Range	Reference
Colour	Colourless	[28]
Density	1.78g/cm^3	[28]
Melting Point	177^{o}C	[28]
Glass TransitionTempertaure	-35^{o}C	[28]
Tensile Stress	35-55 MPa	[28]
Temperature Range	200-300^{o}C	[28]
Dielectric Strength	260-950 kV/mm	[28]

Applications for PVDF are many and have nothing to do with its ferroelectric characteristics. It has a great mechanical strength and a very long lifespan. This material demonstrates remarkable mechanical strength in orientated fibres and films. ForPVDF tanks with rotational moulding, the greatest temperature ever measured is 100 °C. It has exceptional chemical resistance up to this temperature range against strong acids, liquid halogens, powerful oxidising agents, weak bases and salts, and aliphatic, aromatic, and halogenated solvents. It is suitable for usage at temperatures between -100 and 300 °C.It has a density of 1.76 g/cm3 and a dielectric constant of 5.6. It demonstrates remarkable resilience to repetitive flexure or fatigue, high resistance to deformation under load, and outstanding resistance to abrasion. PVDF is machineable, resistant to chemical attack, and almost unaffected by sunlight. It can be treated using almost all of the standard techniques used for thermoplastics.

Numerous applications have been made possible by this combination of features. It has a density of 1.76 g/cm^3 and a dielectric constant of 5.6. It demonstrates remarkable resilience to repetitive flexure or fatigue, high resistance to deformation under load, and outstanding resistance to abrasion. PVDF is machineable, resistant to chemical attack, and almost unaffected by sunlight. It can be treated using almost all of the standard techniques used for thermoplastics. Numerous applications have been made possible by this combination of features. Because it is resilient and unaffected by sunshine, it is used in long-lasting, long-lasting finishes for external metal siding. There are several uses for it as an electrical insulator, especially as a wire coating, due to its creep resistance and sufficient electrical qualities. Here are some important polymers with the glass transition temperature (t_g) and their Melting Point(t_m). Polyethylene(-120^{o}C), Polypropylene (-20^{o}C), PMMA (105^{o}C),PVdF (-35^{o}C), Polysulfone (185^{o}C), Polyamide (47-90^{o}C), Polycarbonate (145^{o}C) have respective glass transition temperature and alse their melting point Polyethylene (118-146^{o}C), Polypropylene (179^{o}C), PMMA (1470-170^{o}C), PVDF (140-170^{o}C), Polysulfone (185-190^{o}C), Polyamide (220^{o}C) respectively.

2.3. Chemical properties

PVDF contains around 0.05% water at normal temperature and is unappealing, odorless, environmentally friendly, and hardly water-soluble. PVDF has gained commercial prominence under its chemical resistance, which is attained by liberating hydrogen fluoride, which may react with the majority of nucleophiles.To produce its film, PVDFis soluble in polar solvents like acetone, Dimethyl sulfoxide (DMSO), N-methyl pyrrolidone (NMP), N, N-dimethyl formamide (DMF), and tetrahydrofuran (THF) is beneficial.However, these solvents have an issue since they pose a risk to the environment and the well-being of humans. Mixing different fluorinated co-monomers with PVDF increases the material's adaptability by diminishing its crystallinity, and increasing the industrial uses of PVDF copolymers.Trifluorethylene (TrFE) and Vinylidene fluoride (VDF) are the two co-monomers of PVDF that are primarily utilized[29]. Co-monomer inclusion has been reported to provide steric interference in the matrix of PVDF and ultimately raise the PVDF's beta concentration.

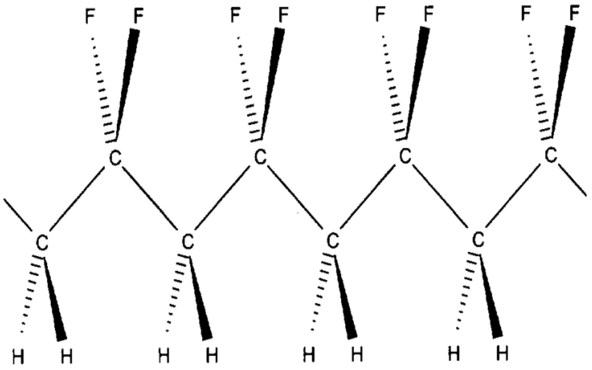

Figure 3. Molecular structure of PVdF[30]

Table 2.Electrolytes IL and Salt-based polymer electrolyte

Polymers	Salt/ Additives	Ionic Liquid	Tc (^{o}C)	Ionic Conductivity (S/cm)	Specific Capacitance (F g^{-1})	Efficiency (%)	Ref
PVDF	$TEABF_4$				28.46 F g^{-1}		[31]
PVDF	SiO_2	EMIFSI	25 °C		58.0 F g-1		[32]
PVDF	PVAc	$BMIMBF_4$	300 °C	2.42×10^{-3} S cm^{-1}	93.3 F g^{-1}		[33]
PVDF	(P_{4444})(Sac)		34 °C	2.5×10^{-4} S cm^{-1}	204 F g^{-1}		[34]
PVDF		[EMIM][FSI]	25-105 °C				[35]
PEO/PVdF	Zn $(CF_3SO_3)_2$	$EMIHSO_4$	298 -333 K	5.8×10^{-4} S cm^{-1}			[36]
PVDF	$LiMn_2O_4$:MESO Carbon black	EMITFSI			50.70 Fg^{-1}		[37]
PEG/ PVdF	TiO_2					5.5%	[38]
PMMA+PVdF	$AgNO_3$				9.13×10^{-4}		[39]

3. APPLICATION OF POLY(VINYLDENEFLUORIDE)’ IN SUPERCAPACITORS AREA

3.1. Binder Activity

During the electrode manufacturing of supercapacitors, PVDF's binding activity is more evident. The binder's job is to solidify the active material in the electrode's surface and increase the electrode's adherence to current collectors.The quality characteristics that were taken into account while choosing the right binders were adhesion strength, hydrophilic nature, thermal and electrochemical stability to tolerate extended charging and discharging cycles, and non-toxic nature. The binders have the potential to offer a condensed configuration for the electrodes, guaranteeing an effective electrical exchange between the active components. Physical factors that affect the formation of the electrodes and the overall electrochemical performance of a supercapacitor include the amount and purity of the binder, the solvent that is used to prepare the binder, and the temperature at which they dry off the electrodes.

A nanomaterial's optimal electrochemical efficiency or the acquisition of its optimum electrochemical characteristics can be ensured by paying excessive attention to certain physical factors. There is an ideal ratio between the active substance and the polymer binder, thus care must be used while adding a binder. If the amount of binder is less than what is needed, the active material's compacted strength decreases and a large amount of binder may clog its pores [40]. The ideal concentration of binder to active material can improve pseudocapacitive charging, the rapid passage of electrolyte ions into nanomaterial pores, and the prevention of adsorption. It can also decrease electron-transfer impedance at the interface between the electrode and the electrolyte. Numerous researchhas been published that demonstrate PVDF's binding influence on the creation of electrodes.One remarkable aspect of PVDF is its ability to function as an appropriate binder for nearly every kind of active material, including pseudocapacitive and EDLC materials. However, to prevent its detrimental conductivity impact on the active material, it is occasionally required to add a conductive agent such as Graphite, carbon black, acetylene black, etc.Parulekar et al. looked into the binding effect of PVDF on the electrochemical characteristics of the pseudo capacitor and the electrical double-layer capacitor (EDLC) [41].

The remarkable properties of PVDF are its resistance and great mechanical and thermal stability; these attributes are crucial when choosing a binder. To prepare the working electrode and ensure the supercapacitor operates properly, the binder's holding capacity is essential. They discovered that PVDF completely dissolves in DMSO, generating a dense polymeric solution that can bind activated carbon through the creation of chemical bonds. As a result, this adhesive power lowers the resistance within during the procedure of transfers of electrons. They concluded that PVDF can be used with both kinds of supercapacitors and that it may be able to lower the electrochemical series resistance (ESR) that forms inside of them as shown below Eq. (1).

$$PVDF = \frac{1}{40}x \tag{1}$$

The total quantity of PVDF and active material used during the study is denoted by x, and the multiplication factor is 1/40.

3.2. Electrolyte

Electrolytes will always play a part in the manufacturing of a supercapacitor. A supercapacitor's primary working processes are the charge transference and buildup at the interface between the electrode and the electrolyte.As a result, an electrolyte should have low volatility, low viscosity, low ion-pairing propensity, high density of free ions, low toxicity, and strong electrochemical stability across a wide potential window. Supercapacitors rely heavily on their electrolytes for performance, meaning that an electrolyte with the aforementioned qualities can produce an extremely efficient supercapacitor, that has low equivalent series resistance (ESR), and high specific power.Electrolytes that are often employed in the creation of electrochemical energy storage devices include ionic liquid, organic, polymer, aqueous, and non-aqueous electrolytes. However, the importance of polymer electrolytes unexpectedly rose with the development of the extensible supercapacitor idea.

Because of their capacity to produce thin films with superior flexibility and ionic conductivity, polymer-based electrolytes are thought to be a great candidate for the construction of lightweight supercapacitors.The capacity of polymers to construct various shapes and to modify these structures according to needs is another intriguing property of polymers. In comparison to other electrolytes, particularly organic electrolytes, they are safer and more environmentally friendly. Moreover, it aids in stopping the leaking of liquid electrolytes, which lowers the risk of electrode corrosion and short circuits in the supercapacitor and boosts its dependability [42].

Solid polymer electrolyte (SPE) and gel polymer electrolyte (GPE) are the two most common forms of polymer-based electrolytes utilized in the construction of electrochemical devices. As SPEs, high molecular weight polymers, such as PEO, and PPO, are often combined with anionic salts, such as KI,$LiCF_3SO_3$, $LiClO_4$, NaI,etc.Its anti-corrosive nature, mechanical durability, stability that can endure prolonged cycles, and ease of processing allow them to be used as both electrolytes and separators for supercapacitors, ensuring the device's safety. They are also compatible with metal current collectors, which perfectly prevents contacting directly between the electrodes [43]. The SPEs' ionic conductivity was somewhat enhanced by all of these methods, but in the end, the mechanical versatility and volume percentage of amorphous substance were reduced. The decrease in the amorphous content limits the movement of polymer chains, which in turn causes the chains' convoluted course to be restricted [44].

Since GPEs are quasisolid-state polymer electrolytes with significant liquid content, they differ greatly from SPE. The common salts and solvents used in liquid electrolytes are chosen for use in GPSs. The cohesive characteristics of solid polymers and the diffusive qualities of liquid electrolytes work together to give the GPEs their characteristic "gel" consistency.The trapping of liquid electrolytes lowers the glass melting point to below -40° C. It improves the polymer's amorphous material, which in turn enhances the mobility of ions which causes the GPEs' to increase ionic conductivity. This improved ionic conductivity at ambient temperature, which is nearly similar to liquid electrolytes (10^{-4} to 10^{-3}Scm^{-1}), led to a wide increase in the acceptability of GPEs as electrolytes or separators. The charge carrier mobility and concentration determine the ionic conductivity. The viscosity of gel electrolytes is negatively correlated with mobility [45].

3.3. Separator/Piezoelectric Generator

Every element that goes into making a supercapacitor significantly impacts how electrical charge is stored and released. One such essential part that prevents any direct contact between the electrodes and ensures a clear electrochemical channel for the movement of ions from the electrolyte to the electrodes is the separator. To keep the device durable, a separator needs to be both mechanically robust and adequately thin. It also needs to stop active materials from migrating so that the gadget doesn't short-circuit.Aside from these characteristics, the separator needs to remain steady over the operational potential spectrum. The right choice of separators is determined by several parameters, including low fragility, waterproofing, substantial porosity, isolating ability, and elevated ionic conductivity. Together with all of these requirements, the separator also needs to be stable in the presence of gases, air, and humidity as well as chemically resistant to the effects of the electrolytes to prevent corrosion [46].

4. CONCLUSION

Since their discovery in the 1930s, fluorinated polymers have been the most intriguing and difficult polymers. several studies have yielded really impressive results in a combination of useful and essential qualities in several technical applications. These polymers were a perfect choice for the researchers because of their exceptional qualities, which include chemical resistance, thermal stability, weather stability, and high durability.To replace or enhance the present conventional partners for supercapacitor reconciliation, we tried to stimulate four major applications of PVDF and its copolymers: a binder, separator, and electrolyte. Self-sustaining electronic gadgets are a new technology that scientists and researchers from all over the world are starting to take notice of. Energy storage systems with self-powering capabilities, high energy and power densities, and endurance will become increasingly necessary in the future due to the unpredictable nature of energy resources. When it comes to advancing the creation of self-powered supercapacitors, nanogenerators, sensors, and other energy-harvesting and storing devices, scientists, and researchers are drawn to PVDF because of its piezoelectric properties, which makes it one of the most complex polymers in the supercapacitor field.Even though they are a clever class of polymers with a lot of promise, more work has to be done to meet the new demands of dynamic research and to develop customized features that will enable the most difficult biomedical applications in the near future. As we wrap up our assessment, we offer our thoughts on the prospects and difficulties that PVDF's development and real-world applications are facing.

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IZVOD

SUPERKONDENZATORINABAZIPOLI (VINILIDENFLUORIDA) POLIMERNOGELEKTROLITA

PVDF, ili polivinilidenfluorid, je popularan polimer u porodici fluoropolimera zbog svoje superiorne mehaničke čvrstoće, termičke stabilnosti i piezoelektričnih svojstava. Hemijski je otporan na razne supstance, uključujući razne kiseline, baze, organske rastvarače, ulje i masti, a takođe se lako obrađuje. Elektrohemijski uređaji sa superiornom efikasnošću skladištenja energije su neophodni zbog sve veće potrošnje električne energije u savremenom svetu. Zbog velike gustine snage, produženog veka trajanja, izuzetne stabilnosti ciklusa punjenja/pražnjenja i pristupačne cene, superkondenzatori se smatraju neverovatnim uređajima za skladištenje energije. Elektrohemijske performanse superkondenzatora u potpunosti zavise od izbora njihovih osnovnih komponenti i njihovog procesa proizvodnje. Materijali napravljeni od ugljenika sa poboljšanim termofizičkim karakteristikama i čvrstoćom na deformaciju trenutno su od velikog interesa. Ovi materijali imaju različite primene u brojnim sektorima zbog svojih karakterističnih fizičkih i hemijskih karakteristika. Obilje istraživanja o „strukturi-svojstvu“, proizvodnji, primeni i ekologiji kompozitnih polimera na bazi poliviniliden fluorida (PVDF) može se pripisati mnogim mogućnostima za njihovu upotrebu u nauci i tehnologiji. Moguće je postići visok stepen multidisciplinarnosti i integracije polimerne nauke korišćenjem inovativnih tehnologija za izgradnju proširene konceptualne slike o polimernim materijalima. Ovo dovodi do formiranja fundamentalnih problema u polimernoj nauci, a rešenje utiče na značajno poboljšanje prirodno-naučne slike savremenog sveta. PVDF je verovatno najtraženiji polimer danas zbog svoje sposobnosti samopolarizacije u prisustvu električnog polja. Istraživači i stručnjaci koji se bave razvojem uređaja za prikupljanje i skladištenje energije, kao što su samopuneći superkondenzatori, privučeni su piezoelektričnim, feroelektričnim i piroelektričnim mogućnostima PVDF-a. Objašnjena su napredna svojstva PVDF-a i njegova moguća upotreba u različitim polimernim oblicima.

Ključne reči: *poliviniliden fluorid, nosioci naelektrisanja, superkondenzator, strukturna svojstva*

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