# "A review on thermoplastic polymer Nanocomposites for Automobile applications"

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## Abstract:

Thermoplastic polymer nanocomposites have emerged as a transformative class of materials in the automotive industry, offering unparalleled improvements in performance, durability, and functionality. This review provides a comprehensive overview of the current state and advancements in thermoplastic polymer nanocomposites for automotive applications. The integration of nanoscale fillers such as carbon nanotubes, graphene, nanoclays, and metallic nanoparticles into thermoplastic matrices significantly enhances mechanical, thermal, and electrical properties. These enhancements lead to superior structural components, improved thermal stability, enhanced electrical conductivity, and reduced weight, contributing to overall vehicle efficiency and performance. The review delves into the synthesis methods, including melt compounding, solution blending, and in-situ polymerization, highlighting their impact on the dispersion of nanofillers and resultant composite properties. Additionally, it discusses the application-specific benefits of these nanocomposites in areas such as body panels, interior components, and electrical systems. The challenges related to the processing, scalability, and cost of these advanced materials are also examined, alongside potential solutions and future research directions. This review aims to elucidate the potential of thermoplastic polymer nanocomposites to revolutionize automotive materials, paving the way for the next generation of lightweight, high-performance, and sustainable vehicles.

## 1.0 INTRODUCTION

Polymer based products are used for large consumption applications (automotive industry, domestic and electric applications, toys, etc.) but also for sophisticated high technology products (MEMS devices, biomedical implants, etc.) as they are easy to process and form and also due to their functionality. Wide range of polymer properties results from a great variety of chemical structure and supermolecular structure complexity that can be relatively easy modified by tuning conditions of phase transitions such as crystallization and phase separation. These material properties are mainly determined by the structure, at a nanoscale; during forming, stretching or shearing of a semi-crystalline polymer melt followed by rapid cooling the specific morphologies of thin crystalline lamellae interspersed with thin amorphous layers are generated. Also other higher

hierarchical structures arise such as deformed spherulites, or more complex crystalline macrostructure with a high anisotropy of molecular orientation. For engineering applications, there is an industrial need for the prediction of those induced mechanical properties in order to determine many functional properties, for example the strength of blown bottles or the shrinkage and the warpage of injected parts. Despite extensive research the prediction of those macroscopic mechanical properties of nanostructured polymers is still a bottle neck. Four main problems remain very tough to solve:

a) The precise knowledge and description of the topology of the microstructure,

b) The multiscale modelling,

c) The modelling of the interfaces between constituents or interphases between phases,

d) The determination of the mechanical properties of confined phases.

The objective of my research is to go deeper into the all previous points. As technological trends tend to master systems of nanometer size, it becomes imperative to gain a complete understanding of how the properties of such small material systems might differ from those of bulk systems. An example of such an area where the properties at the nanometer length scale exhibit significant deviations from bulk properties is the study of thin polymer films with at least one free surface . But these studies are not sufficient to understand the behavior of nanostructured materials, nanocomposites and semi crystalline materials, which can be also considered as nanocomposites from a mechanical point of view, because interfaces and interphases play a major role. The idea is to determine the properties of a nanostructured model material: a single layer film in which one material could be confined in a large number of nanolayers. This technique has been developed for years by Baer who gave us the opportunity to manufacture these specific films for the study.


## 1.1 COMPOSITE MATERIALS

It is evident that the material advances have been the key to significant breakthroughs throughout the history. The Stone Age, the Iron Age, the Industrial Revolution, the Nuclear Age, the Electronic Revolution, the aerospace of today; all has critically resulted from breakthroughs in material technology.

A composite material is a combined material created from two or more components, selected filler or reinforcing agent and a compatible matrix, binder (i.e. resin) in order to obtain specific characteristics or properties that were not there before.

The matrix is the continuous phase, and the reinforcement constitutes the dispersed phase. It is the behavior and properties of the interface that generally control the properties of the composite.

## 1.2 THE REASON FOR CONSUMPTION OF COMPOSITES

The increases in consumption of composite materials were primarily due to the need for nonconductive electrical components, noncorroding and noncorrosive storage containers and transfer lines, and sporting goods.

Designers of structures have been quick to capitalize on the high strength-to-weight or modulus-to-weight ratios of composites. The advantages include,

➢ Weight reduction (high strength- or stiffness-to-weight ratio)
➢ Tailor able properties (strength or stiffness can be tailored to be in the load direction)
➢ Redundant load paths (fiber to fiber)
➢ Longer life (no corrosion)
➢ Lower manufacturing costs because of lower part count
➢ Inherent damping
➢ Increased (or decreased) thermal or electric conductivity.

## 1.3 BASIC CONCEPTS OF COMPOSITES

The combination of dissimilar materials can have unique and very advantageous properties if the materials have appropriate characteristics, and result in a material that is better in certain key properties than either of the materials alone. The reinforcements and the matrix are usually very distinct types of materials with widely different properties.

It is probably true to say that all polymers contain some form of additives ranging from small fractions of catalyst residue to large-scale incorporation of mineral filler. The most important additives are these introduced for some specific purpose and would therefore include fillers, plasticizers, colorants, reinforcing fibers, blowing agents, stabilizers, flame retardants, processing aids, and final group of miscellaneous additives. Because of low specific gravities, the strength-to-weight and the modulus-to-weight ratios, and also fatigue strength-to-weight ratios of these materials are superior to those of metallic materials.

Most low-density material would be weak, but in the case of composites, the reinforcement provides the structural attributes.

In general, the properties of a fiber-reinforced composite depend strongly on the direction of measurement, whereas the traditional structural materials have weaker dependence.

**Heterogeneous nature** of composites provides mechanisms for high-energy absorption on a microscopic scale comparable to the yield process, exhibiting gradual deterioration in properties, but they do not usually fail in catastrophic manner.

**Coefficients of thermal expansion (CTE)** for many fiber-reinforced composites are much lower than that of metals, exhibiting a better dimensional stability over a wide temperature range.

**High internal damping** leads to better vibrational energy absorption within the composite material, resulting in reduced transmission of noise and vibrations to neighboring structures.

## 1.4 REINFORCEMENT-MATRIX INTERFACE

The load acting on the matrix has to be transferred to the reinforcement via the interface. Thus reinforcements must be strongly bonded to the matrix, if their high strength and stiffness are to be imparted to the composite. The fracture behavior is also dependent on the strength of the interface. A weak interface results in low stiffness and strength, but high resistance to fracture, whereas a strong interface produces high stiffness and strength but often a low resistance to fracture, i.e., brittle behavior. The exact role of interface may differ with the type of reinforcement. The interface can be viewed as a planar region of only a few atoms in thickness across in which there is a change in properties from those of the matrix to those of the reinforcement. Thus, the interface is usually a discontinuity in chemical nature, crystal and molecular structure, mechanical and other properties.

## 1.5 WETTABILITY

Interfacial bonding is due to adhesion between the reinforcement and the matrix and mechanical keying. For adhesion to occur during the manufacture of a composite, the reinforcement and the matrix must be brought into intimate contact. Wettability defines the extent to which a liquid will spread over a solid surface. Covering every bump and dip of the rough surface of the reinforcement and displacing with air carries out good wettability.

### 1.5.1 Interfacial Bonding

Once the matrix has wet the reinforcement, therefore in intimate contact with it, bonding will occur. For a given system more than one bonding mechanism may be operative at the same time.

### 1.5.2 Mechanical Bonding

A mechanical interlocking or keying of two surfaces can lead to a reasonable bond. The rougher the interface, the greater the interlocking, Figure 1 shows mechanical bonding



Fig 1: Mechanical bonding

### 1.5.3 Electrostatic bonding

Bonding occurs between the matrix and the reinforcement when one surface is positively charged and the other negatively charged, Figure 2, leading to an electrostatic attraction between the components of the composite depending on the difference in charge on their surfaces. Electrostatic interactions are short range and are only effective over small distances.



Fig 2: Electrostatic bonding

### 1.5.4 Chemical bonding

Chemical bonding is the bond formed between chemical groups on the reinforcement surface, marked X in Figure 3 and the compatible groups (R) in the matrix. Strength depends on the type of bond and the number of bonds.



Fig 3: Chemical bonding

### 1.5.5 Reaction or interdiffusion bonding

The atoms or molecules of two components of the composite may interdiffuse at the interface to give this type of bonding, Figure 4, considered as due to the intertwining of molecules. The strength of this type of bonding depends on the distance over which the molecules have entwined, the extent of the entanglement of the molecules and the number of molecules per unit area of interface.



Fig 4: Interdiffusion bonding

## 2.0 BASIC RESIN CONCEPTS

Resins are of the general class of materials called polymers. The length of the chain determines a basic polymer property known as the molecular weight. As the chains get larger, the mechanical properties (such as tensile strength and toughness) improve. The improvement in properties is thought to result from interchain forces, including entanglements of chains. Therefore, the entanglement of nearby polymer chains is a key characteristic in determining the nature of polymeric materials. Both polymer molecular weight and crystallinity affect mechanical and thermal properties like another key feature of polymers; this is stiffness of the polymer chain. As a chain stiffened, both mechanical and thermal properties increase.

## 2.1 THERMOPLASTIC RESIN PROPERTIES

**Chemical Structures**

The matrix in a fiber-reinforced resin-matrix composite has several functions. It transfers the imposed loads to the fibers, so it must have a good bond with the reinforcing agents. It gives the shape to the part, so must be readily formable, and it must retain that shape and mechanical properties throughout the temperature range of use. In order to protect the reinforcing agents from environmental damage, the matrix should have toughness and impact resistance.

**Mechanical Properties**

The discussion of mechanical properties of resins used for matrix materials in composites must consider the effect of reinforcement material. Domination of composite properties by the reinforcement is true for many properties such as tensile strength, flexural strength, and thermal expansion.

**Thermal Properties**

As the temperature of the composite is increased, more and more energy is imparted to the polymer, converting into molecular motion. At lower temperatures, the motion is largely vibration which relatively unrestricted motion is. When temperatures become higher, the molecules gain sufficient energy to flex and rotate and at even higher temperatures they begin to translate. In highly crystalline polymers the crystal lattice energies are strong resulting in tightly held molecules with very little rotation and almost no translation till the imposed energy is to overcome the lattice energies. This phenomenon is called the crystalline melting point for the polymer. In totally amorphous polymers there is no crystalline structure and therefore no crystal lattice energy. The transition from solid to melt is more gradual with only small indications of the increased mobility of the molecules. The temperature at which this transition occurs is called the glass transition temperature, $T_g$, for the polymer. The $T_g$, crystalline melting point, $T_m$, and the heat distortion temperature, HDT, the maximum use temperature for the polymer for continuous service, define general thermal characteristics of a given polymer to be used.

## 3.0 POLYMER COMPOSITES

A polymer electrolyte (PE) is defined as a solvent–free system whereby the ionically conducting pathway is generated by dissolving the low lattice energy metal salts

in a high molecular weight polar polymer matrix with aprotic solvent. The fundamental of ionic conduction in the polymer electrolytes is the covalent bonding between the polymer backbones with the ionizing groups. Initially, the electron donor group in the polymer forms solvation to the cation component in the dopant salt and then facilitates ion separation, leading to ionic hopping mechanism. Hence, it generates the ionic conductivity. In other words, the ionic conduction of PE arises from rapid segmental motion of polymer matrix combined with strong Lewis–type acid–base interaction between the cation and donor atom However, the well separated ions might be poor conductors if the ions are immobile and unable for the migration. Therefore, the host polymer must be sufficiently flexible to provide enough space for the migration of these two ions.

Progress to date in solid state ionic's is largely the result of developments in two categories of materials: insertion compounds and fast ionic conductors. Polymer electrolytes represent the newest class of solid state ionic conductors. They contrast sharply with the usual solid ionic materials based on ceramics, glasses, or inorganic compounds with respect to the mode of charge transport (polymer electrolytes only conduct well above their glass transition temperatures) and the value of the ionic conductivity, which is of the order of 100 to 1000 times lower than for the inorganic materials. This drawback is compensated primarily by the greater flexibility of the polymeric materials which allows polymer electrolytes to be made into very thin films of large surface areas to maintain high power levels. Flexible polymer electrolytes can better accommodate the volume changes in the cell during cycling without the physical degradation of interfacial contacts, which is often observed in crystalline or vitreous solid electrolytes.

Although conductivity of the order of $10^{-5}$ S/cm may be obtained for a number of polymer electrolytes at various temperatures, this is not as high as may be desired. Polymer electrolytes therefore have to be configured as very thin, large-area elements, in order to keep the internal resistance of the cell within an acceptable range. A solid state polymer electrolyte (SPE) for dye sensitized solar cell applications must posses the following attributes:

1. It is an ion (usually cation) carrier that can be fabricated as thin films to improve the energy density.

2. It acts as an electrode spacer, which eliminates the need to incorporate an inert porous battery separator.

3. It is a binder, which ensures good electrical contact with the electrodes at all times during charging and discharging.

The substitution of conventional liquid electrolytes by a plastic material eradicates corrosion problems arising from the use of aggressive solvent systems that may attack the seals or the containers. A liquid-free configuration ensures no gas formation and low vapor pressure throughout the applications, and the battery can be packaged in low-pressure containers. The cells can be fabricated into almost any shapes and sizes. The production of solid polymer electrolyte batteries is simplified by the elimination of the need for liquid handling. The manufacturing process can be highly automated and based on existing production technologies of the plastics industry.

## 3.1 Types of polymer composites used as electrolyte:

The polymer composites systems could be classified into three categories, namely, i) Polyelectrolyte, ii) Solvent swollen polymer electrolyte and iii) solvent free polymer electrolytes.

**Solvent free polymer electrolytes**

The polymer –salt complexes are formed by complexes between salts of alkali metals and polymer containing solvating heteroatoms such as O, N, S, etc. The most common examples are complexation between poly (ethylene oxide) (PEO) and alkali metal salts. The polymer salt complexes are further classified into: i) Solid polymer electrolytes ii) Blend polymer electrolytes iii) Gel polymer electrolytes iv) Composite polymer electrolytes. Among the various polymer electrolytes which are used in Li-ion batteries, solvent free polymer electrolytes are the most favourable for device fabrications. The solvent free polymer salt complexes are further classified into: i) Solid polymer electrolytes ii) Gel polymer electrolytes iii) Composite polymer electrolytes.

**a) Solid polymer electrolytes**

Solid polymer electrolytes (SPEs) have an ionic conductivity when modified by dissolving alkali salts in suitable polymer matrix. SPEs are typically thin films, which have a wide range of electrochemical applications such as batteries and electrochromic devices. They have several advantages when used in a battery and can be formed into thin

films of large surface area giving high power levels. The flexibility of the films allows space-efficient batteries to be constructed [Quartarone et al., 1998].

**b) Gel polymer electrolytes**

Plasticizers incorporated polymer- salt complex is called gel polymer electrolytes. The addition of plasticizers into the polymer matrix softens the polymers and they increase free volumes which are used for ion migration. Addition of plasticizer also increases the chain flexibility, reduces crystallinity, decreases the glass transition temperature and hence increases the ionic conductivity. The conductivity of PEO: $LiBF_4$ is of the order of $1x10^{-6}Scm^{-1}$ which has been increased to the order of $1x10^{-4}Scm^{-1}$ when the complex is plasticized at 25ºC [Chiodelli et al., 1988] this is mainly due to the specific nature of the plasticizers and the prepared gels has both the cohesive properties of solids and the diffusive property of liquids. Even though the gel polymer electrolyte exhibits high ionic conductivity, its thermal and mechanical stability are poor and it has higher reactivity towards the electrode. Gel electrolytes may undergo solvent exudation upon long storage, especially under open atmosphere conditions. This phenomenon is known as 'Synerisis effect', and has been encountered in many systems such as PAN: EC: PC: $LiClO_4$, PAN: EC: PC: $LiAsF_6$ [Groce et al., 1994 and Slane & Salomon et al., 1995].

**c) Composite polymer electrolytes**

This is another approach in which both the ionic conductivity and the mechanical stability of the electrolytes were considerably enhanced simultaneously. Composite polymer electrolytes are prepared by the addition of high surface inorganic fillers such as $Al_2O_3$, $SiO_2$, MgO, $LiAlO_2$, $TiO_2$, ZnO, ZnO and Zeolite powders. The mechanical strength and stiffness of the complex systems were improved appreciably when the fillers are incorporated into the polymer matrix. However the main advantages of the composite electrolyte is the enhancement of room temperature ionic conductivity and an improved stability at the electrode electrolyte interface. The inert fillers due to its large surface area prevent the local chain reorganization with the result of locking in at ambient temperature, a high degree of disorder characteristic of the amorphous phase, which is more favour for the high ionic transport [G. Nagasubramanian and S. Di Stefano, 1990, Peter P Chu,P.P. Reddy, M.J., 2003]. The nano sized ZnO incorporated PEO composite

electrolytes exhibits ionic conductivity of the order of $x10^{-3}$ Scm$^{-1}$ and good electrochemical stability (4.0V).

## 4.0 Materials for Polymer composites

Polymer composites or electrolytes are solutions of salts dissociable in the polymer host. As polymer electrolytes must function as both a separator and an electrolyte in a solid-state configuration, it must possess a number of essential electrochemical characteristics as listed below:

1. Conductivity: the electrolyte must have sufficient ionic conductivity to support a reasonable current density. $10^{-2}$-$10^{-5}$ S/cm would be ideal at room temperature although a lower value may be acceptable.

2. Electrochemical stability: the electrolyte should be electrochemically stable in a voltage window that is as wide as the voltage window defined by the electrode reactions (it should preferably be wider, to accommodate overcharge and discharge reactions).

3. Compatibility: the polymer electrolyte must be chemically and electrochemically compatible with the electrode materials.

4. Thermal stability: the electrolyte must have good thermal stability to maintain close contact with the electrode.

5. Mechanical stability: mechanical stability becomes an important consideration when a polymer electrolyte moves from laboratory into process development, pilot production and, finally, full production.

6. Availability: the polymer electrolytes must be made from readily available and inexpensive raw materials. Exotic materials have many uses as model compounds but may be impractical at a production level.

In order to perform satisfactorily as a solvent for the salt, the polymer host or the active part of the copolymer should have a minimum of the following three essential attributes:

1. Atoms or groups of atoms with sufficient electron donor power to form coordinate bonds with cations.

2. Low barriers to bond rotation so that segmental motion of the polymer chain can take place readily.

3. A suitable distance between the coordinating centers because the formation of multiple intrapolymer ion bonds appears to be important.

## 5.0 POLYMER NANOCOMPOSITES

Composite solid electrolytes, also referred to as 'dispersed solid electrolytes', are high ion conducting multiphase solid systems attracted great technological attentions after 1973 as potential candidates for all-solid-state electrochemical device fabrication. They are mostly two-phase mixture, containing a moderately conducting ionic solid such as AgI, CuI etc. as Ist– phase host salt and a IInd - phase material, which may be either an inert insulating compound such as $ZnO$, $Al_2O_3$, $SiO_2$, $ZrO_2$, $Fe_2O_3$ etc. or another low conducting ionic solid such as AgBr, AgCl, KCl etc. As a consequence of dispersal of submicron size particles of IInd-phase in a small fraction into Ist-phase host salt, a substantial improvement in various physical properties of the host is usually achieved without altering the structural/chemical nature of the constituent compounds. Both the phases coexist together separately in the composite system. In two phase composite electrolytes, an enhancement of 1-3 orders of magnitudes could be obtained in the conductivity at room temperature. Liang [1973], for the first time, reported a remarkable enhancement (~ 50) of Li+ conductivity in: a 2-phase composite electrolyte system: LiI-$Al_2O_3$ Since then, a very large number of 2-phase composite electrolytes involving different mobile ions viz. Ag+, Cu+, Li+ etc., has been investigated.

The size of particles of IInd-phase dispersoid play significant role in improving the physical properties of Ist-phase host salt viz. the conductivity. Hence, the dispersal of nanosize particles would result into a substantial enhancement in the conductivity. On the basis of physical / chemical nature of the constituent phases, 2-phase composite electrolyte systems have been grouped into following two broad categories:

• Inorganic Composite Electrolytes: They are either crystal-crystal composite electrolytes viz. moderately ion conducting alkali/ silver halide salts dispersed with insulating / inert materials such as $Al_2O_3$, $SiO_2$, $ZrO_2$, fly-ash etc. or crystal-glass composite electrolytes viz. ion conducting glass dispersed with above mentioned insulating / inert materials.

• Organic Composite Polymer Electrolytes: They are either crystal-polymer electrolyte composites viz. conventional solid polymer electrolytes (SPEs).

Polymer systems are widely used because of their light weight, design flexibility, and process ability. These systems, however, generally exhibit less attractive mechanical properties such as low strength and low elastic modulus as compared to metals and ceramics. One way to improve the mechanical properties of these systems while

maintaining their desirable properties is by adding high-modulus reinforcing filler to make polymer composites. Adding micro-sized inorganic filler particles to reinforce the polymeric materials has been standard practice in the composite industry for decades. Composite design efforts to achieve the optimal mechanical properties have focused on maximizing the interaction between the polymer matrix and the filler. Commonly, smaller fillers are used to increase the surface area available for interaction with the matrix. However, in the case of micron sized fillers, content above 20% volume fraction is required to optimally impact mechanical properties. At these high concentrations the filler can detrimentally impact other benefits of polymers such as process ability and appearance.

With the advent of nanomaterials research, synthesis of inorganic nanoparticles, that is, particles with one dimension in the nano-sized regime, is readily achievable. Because of their small size, nanoparticles have an extremely high surface to volume ratio providing significantly more surface area for bonding with the matrix than micro-sized fillers. Polymer nanocomposites, consisting of a polymer matrix with nanoparticles filler, have been predicted to be one of the most beneficial applications of nanotechnology. Much research has focused on the preparation and thermal and mechanical characterization of nanocomposites. Although some research has shown great improvement of mechanical properties from nanocomposites over those of micro-filled composites results have not been consistent. Additionally, the varying polymer matrix/filler systems and varying preparation techniques do not support establishing clear trends in polymer nanoparticles performance.

Current polymer models have not been able to consistently predict the properties of nanocomposites. Polymer composite theories in the past have relied on the idea that the modulus of a composite is a function of the mismatch of properties of constituents, volume fraction, shape and arrangement of inclusions, and matrix-inclusion interface. These theories, therefore, predict that the effect on the composite system is independent of the size of the inclusion. Recent theories have included the size of the filler particulate to predict the properties of composites.

## 6.0 LITERATURE SURVEY

Polymer electrolyte is a relatively latecomer to the broader field of solid state ionics. Fast ionic conductors with excellent transport properties and stability are mostly inorganic materials but they lack the flexibility of a polymeric material to be used as battery

electrolyte cum electrode separator. Material flexibility is an important design consideration as a soft material can better accommodate the volume change in cell charging and discharging that a rigid electrolyte cannot. For this reason, it has been recognized as early as 1973 that thin film polymer based batteries would become a forerunner of all solid state electrochemical cells in the years to come.

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In recent years water solution polymers such as PVP, PVA, etc. have been found to be more significant because of their possessing different applications. Interactions between metal ions and water soluble polymers such as polypeptides have been displaying significant influence on the behaviors of macromolecules. Polyvinylpyrrolidone (PVP) has drawn a special attention amongst the conjugated polymers because of its good environmental stability.

PVP is a potential material having a good charge storage capacity and dopant dependent electrical and optical properties. Chemically PVP has been bound to be inert, nontoxic and it displays a strong tendency for complex formation with a wide variety of smaller molecules. Current there is a trend in the researches in polymeric materials of enhancing the mechanical, optical, electrical and various functional properties depending on their fields of application by introducing organic, inorganic or hybrid fillers into different polymer matrices.

## 6.1 SYNTHESIS OF CONDUCTIVE POLYMER NANOCOMPOSITE

**U. Sasikala et al., [1]** carried out a study on the ion transport property studies on plasticized Na+ ion conducting PEO/PVP blended solid polymer electrolyte (SPE) membranes, 95[35PEO:35PVP:30NaF] : 5x, where x = PEG200 , PEG400 , PEG600 were reported. SPE films were prepared using solution cast technique. The solid polymer electrolyte film, (35PEO:35PVP:30NaF), also prepared and identified as the highest conducting composition at room temperature. Complexation of the prepared electrolytes was studied by X-ray diffraction (XRD) analysis. Frequency dependent conductivity ($\sigma_{ac}$) values were obtained from complex impedance (cole-cole) plots. It was observed that the magnitude of conductivity increased with the decrease of molecular weight of the plasticizer at room temperature. The charge transport mechanism in this SPE is mainly due to ions which were confirmed by the transference number experiment.

**Angesh Chandra et al., [2]** carried out a study on the ion transport property studies on Ag+ ion conducting PEO–PVP blended solid polymer electrolyte (SPE) membranes, $(1 - x)$[90PEO : 10AgNO$_3$] : $x$PVP, where $x$ = 0, 1, 2, 3, 5, 7, 10 (wt%), are reported. SPE films were caste using a novel hot-press technique instead of the traditional solution cast method. The conventional solid polymeric electrolyte (SPE) film, (90PEO : 10AgNO$_3$), also prepared by the hot-press method and identified as the highest conducting composition at room temperature on the basis of PEO–AgNO$_3$-salt concentration dependent conductivity studies, was used as the first-phase polymer electrolyte host into which PVP were dispersed as second-phase dispersoid. A two-fold conductivity enhancement from that of the PEO host could be achieved at room temperature for PVP blended SPE film composition: 98(90PEO : 10AgNO$_3$) : 2PVP. This has been referred to as optimum conducting composition (OCC). The formation of SPE membranes and material characterizations were done with the help of the XRD and DSC techniques. The ion transport mechanism in this SPE OCC has been characterized with the help of basic ionic parameters, namely ionic conductivity ($\sigma$), ionic mobility ($\mu$), mobile ion concentration ($n$) and ionic transference number ($t_{ion}$).

**M Ravi et al., [3]** carried out a study on the solid polymer electrolyte is based on poly (vinyl pyrrolidone) PVP complexed with different weight per cent ratio ratios of KCIO$_4$ salt was prepared using solution cast technique. The complexation of the salt with polymer was performed by Fourier transform infrared (FT-IR) spectroscopy studies. Electrical conductivity was measured with ac impedance analyzer in the frequency and temperature range 1 Hz-1 MHz and 303 K -373 K, respectively. It was observed that the magnitude of conductivity has increased with increase in the salt concentration as well as temperature. The variation of ac conductivity with frequency obeys Jonscher power law. The dynamical aspects of electrical transport process in polymer electrolyte were analyzed using complex electric modulus.

**S K Tripathi et al.,[4]** carried out a study on the Polymer blend electrolytes composed of poly (vinylidene fluoride-co-hexafluoro-propylene), poly (methylmethacrylate) and 1·0 M NaI as salt have been synthesized using solution caste technique by varying the PVdF(HFP)–PMMA blend concentration ratio systematically. A.c. impedance studies were performed to evaluate the ionic conductivity of the polymer electrolyte films. The highest ionic conductivity at room temperature for [PVdF (HFP)–PMMA (4:1)](20 wt%) – [NaI(1·0M)](80 wt%) system is found to be 1· 67 × 10−2 S cm−1. XRD studies reveal

complete complexation of the salt in the polymeric blend systems. The temperature dependence conductivity has been performed in the range of 303–373 K and it is observed that it obeys the Arrhenius behavior. It has been observed that the dielectric constant, $\varepsilon_r$ and dielectric loss, $\varepsilon_i$, increases with temperature in the lower frequency region and is almost negligible in the higher frequency region. This behaviour can be explained on the basis of electrode polarization effects.

**Shingo Tachikawa et al., [5]**carried out a study on the Optical properties of ZnO nanoparticles capped with polymers were investigated. Polyethylene glycol (PEG) and polyvinyl pyrrolidone (PVP) were used as capping reagents. ZnO nanoparticles were synthesized by the sol-gel method. Fluorescence and absorption spectra were measured. When we varied the timing of the addition of the polymer to the ZnO nanoparticles solution, the optical properties were drastically changed. When PEG was added to the solution before the synthesis of ZnO nanoparticles, the fluorescence intensity increased. At the same time, the total particle size increased, which indicated that PEG molecules had capped the ZnO nanoparticles. The capping led to surface passivation, which increased fluorescence intensity. However, when PEG was added to the solution after the synthesis of ZnO nanoparticles, the fluorescence and particle size did not change. When PVP was added to the solution before the synthesis of ZnO nanoparticles, aggregation of nanoparticles occurred. When PVP was added to the solution after the synthesis of ZnO nanoparticles, fluorescence and particle size increased. This improvement of optical properties is advantageous to the practical usage of ZnO nanoparticles, such as bioimaging.

**Andres bernal, et al.,[6]** carried out a study on the Poly(vinyl alcohol) and poly(vinyl pyrrolidone) were blended and films were obtained by casting method. Glutaraldehyde, hydrochloric acid and lactic acid were added to investigate their effect on mechanical properties, swelling and solubility of the blends with the aim to find a possible material candidate for medium or long term implants. Combination of all three additives (lactic acid, glutaraldehyde and hydrochloric acid) proved as the best choice for poly(vinyl alcohol)/poly(vinyl pyrrolidone) films production with respect to examined properties important for any indwelling medical application.

**Z L S Seowet al., [7]** carried out a study on Several important synthetic parameters such as precursor concentration, rate of evaporation and reaction time are found to determine

the growth of ZnO nanostructures. These reaction parameters can be tailored and tuned to produce a variety of nanostructures ranging from nanoparticles, nanorods and nanospheres. The nanorods are structurally uniform made up of crystallographically oriented attached nanoparticles while the nanospheres are made up of several closely packed and randomly aligned nanocrystallites. XRD spectra of both the nanoparticles and nanorods exhibit typical diffraction peaks of a well-crystalline wurtzite ZnO structure. Finally, solar cells made up of ZnO nanoparticles and nanorods electrodes with absorbed ruthenium dye ($N_3$) were measured to have a power conversion efficiency of 0.87% and 1.32%, respectively.

**Chun-Yi Chiu et al., [8]** carried out a study on the interactions that occur within complexes of poly- (vinylpyrrolidone-co-methyl methacrylate) (PVP-co-PMMA) and lithium perchlorate ($LiClO_4$) as well as these systems' phase behavior and ionic Conductivities using DSC, FTIR spectroscopy, and ac impedance techniques. The presence of MMA moieties in the PVP-co-PMMA random copolymer has an inert diluents effect that reduces the degree of self-association of the PVP molecules and causes a negative deviation in the glass transition temperature (Tg). In the binary LiClO4/PVP blends, the presence of a small amount of $LiClO_4$ reduces the strong dipole dipole interactions within PVP and leads to a lower Tg. Further addition of $LiClO_4$ increases Tg as a result of ionedipole interactions between $LiClO_4$ and PVP. In $LiClO_4$/PVP-co-PMMA blend systems, for which the three individual systemsdthe PVP-co-PMMA copolymer and the $LiClO_4$/PVP and LiClO4/PMMA blends dare miscible at all compositional ratios, a phase-separated loop exists at certain compositions due to a complicated series of interactions among the $LiClO_4$, PVP and PMMA units. The PMMA-rich component in the PVP-co-PMMA copolymer tends to be excluded, and this phenomenon results in phase separation. At a $LiClO_4$ content of 20 wt% salt, the maximum ionic conductivity occurred for a $LiClO_4$/VP57 blend (i.e., 57 mol% VP units in the PVP-co-PMMA copolymer).

**P.M. Sirimanne et al.,[9]** carried out a study on the ZnO films with different morphologies were synthesized electrochemically. The characteristics of ZnO films were studied. Addition of selected precursors into the electrolyte changes the morphology of ZnO films and yields hybrid organic-ZnO films.

Highly porous ZnO films were obtained by extracting eosin Y from hybrid ZnO|epoxy films. Different organic dyes were used to sensitize ZnO films by means of utilization as light harvesting electrodes in dye sensitized photovoltaic cells. Photo-effects of sensitized ZnO electrodes were studied in $I^-|I_3^-$ redox- electrolyte. Among tested dyes an indoline dye D149 produced better performance.

**Jong Hak Kim et al., [10]** carried out a study on the Solid polymer electrolytes consisting of NaI and $I_2$ dissolved in poly(butyl acrylate) (PBA, Mw=99,000 g/mol) were prepared and applied to dye-sensitized solar cells (DSSC). Upon incorporation of salt, the free ester carbonyl stretching bands of PBA in FT-IR spectra shift to a lower wave number, confirming the complex formation between sodium ions and carbonyl oxygen's. Coordinative interactions and structural changes of the PBA/NaI/$I_2$ electrolytes have been also characterized by X-ray photoelectron spectroscopy (XPS), wide angle X-ray scattering (WAXS) and differential scanning calorimetry (DSC). The conversion efficiency of DSSC employing PBA/NaI/$I_2$ electrolytes (1.66% at 10 mW/cm$^2$) is unexpectedly much higher than that employing poly (ethylene oxide) (PEO, Mw=1,000,000 g/mol)/NaI/I2 (0.07%), although the ionic conductivity of the former ($2.1*10^{-6}$ S/cm at room temperature) is not greatly different from that of the latter ($1.6*10^{-6}$ S/cm). The significantly improved solar cell performance is mostly attributed to (1) the easier penetration of PBA through TiO$_2$ nanoporous layer due to its lower molecular weight, and (2) the sticky property of PBA to allow a better adhesion with the electrodes.

**Varij Panwar, et al [31]** carried out on the research work on polymer metal composite for the biomedical application. The Young's modulus, tensile strength, and tensile strain of the ionic membranes were determined using a HIMADZU AGS-500 D tensile tester. The test speed was set to 10 mm/min. The samples are hydrated by immersing them in deionized water for at least one day. The cross-sectional area of the membrane samples was measured before testing with a micrometer. The gauge length between the grips was 10 mm. All the tested samples were of a regular rectangular strip shape.

**Noorhanim Ahad et al., 11]** carried out a study on the Structural, thermal, and electrical properties of solid composite polymer electrolytes based on poly (vinyl alcohol) complexed with sodium salicylate were studied. The polymer electrolytes at different weight percent ratios were prepared by solution casting technique. The changes in the structures of the electrolytes were characterized by XRD, which revealed the amorphous domains of the polymer which increased with increase of sodium salicylate concentration.. Thermal gravimetric analysis (TGA) was used to study the thermal stability of the polymer below 523 K. The decomposition decreases with increasing sodium salicylate concentration. The conductivity and dielectric properties were measured using an impedance analyzer in frequency range of 20Hz to 1MHz and narrow temperature range of 303 to 343 K. The conductivity increased with increase of sodium salicylate concentration and temperature. The dielectric constant and dielectric loss increased with the increase in temperature and decreased with the increase in sodium salicylate concentration. The synthesis of conductive polymer electrolyte based on the glassy transparent host PVA polymer (Mw = 88,000 g/mol) at 88% hydrolyzed and sodium salicylate salt ($HOC_6H_4COONa$) were purchased (product of Acros, US) and used directly without further purification. The PVA was dissolved in deionized water at 90∘C before adding SS salt which acts as an ionic dopant for the SCPEs. The SCPE films were prepared by solvent casting technique on the glass plates. Thick films of SCPEs between 80 to 220 $\mu$m of PVA-SS composite were prepared at different weight percent PVA-SS ratios (90: 0, 80: 20, 70: 30, 60: 40, and 50: 50).

**P. Chandra Sekhar et al., [12]** carried out a study on the effect of a plasticizer dimethyl formamide (DMF) on the properties of a sodium ion conducting electrolyte based on poly(methyl-methacrylate) (PMMA) complexed with sodium perchlorate ($NaClO_4$) prepared using solution cast technique was investigated. The features of complexation of the electrolytes were studied by X-ray diffraction. Film morphology was examined by Scanning Electron Microscopy (SEM). Various experimental techniques, such as electrical conductivity (temperature dependence) and transference number measurements were used to characterize these polymer electrolyte films. Transference number data show

that the charge transference in this polymer electrolyte system is predominantly due to ions. Electrochemical cells of configuration Na/PMMA+NaClO$_4$/ (I$_2$+C+electrolyte) and Na/PMMA+NaClO$_4$+plasticizer/ (I$_2$+C+electrolyte) were fabricated. The discharge characteristics of the cells were studied under a constant load of 100 k$\Omega$. The open-circuit voltage, short-circuit current and discharge time for the plateau region were measured. The PMMA+NaClO$_4$ polymer electrolyte system with added plasticizer showed an increased discharge time with respect to pure PMMA+NaClO$_4$ electrolyte system. The synthesis of conductive polymer electrolyte based Films (thickness, 150 μm) of pure PMMA, PMMA+ NaClO$_4$ and PMMA+ NaClO$_4$+plasticizer were prepared in weight percent ratio of 80:20 with tetrahydrofuran as solvent using solution cast technique. DMF was used in small quantities (2 ml) as a plasticizer in these films. The solutions were thoroughly stirred for 10– 12 h and, then, cast onto polypropylene dishes and evaporated slowly at room temperature. The final product was vacuum dried thoroughly at 10$^{-3}$ m bar.

**P. Chandra Sekhar et al., [13]** carried out a study on the   Solid polymer electrolyte films based on PMMA were prepared in different NaClO$_4$ salt concentrations by solution cast technique. The features of complexion of these electrolytes were studied by X-ray diffraction (XRD). Film morphology was examined by Scanning Electron Microscopy (SEM). The electrical conductivity of pure and NaClO$_4$ doped polymer electrolyte films was studied in the temperature range 303-393K. The electrical conductivity increased with increasing dopant concentration and exhibited Arrhenius type dependent with temperature. The increase in conductivity with dopant concentration may be attributed to the formation of charge transfer complexes. Transport number data showed that  the charge transport in this electrolyte system is predominately due to ions. Using this polymer electrolyte, solid state electro chemical cell have been fabricated, and their discharge profiles were studied under a constant load of 100 k$\Omega$. The synthesis of conductive polymer electrolyte based Films (thickness, $\sim$150 μm) of pure PMMA+NaClO$_4$ in the wt.% ratios (95:05), (90:10), (85:15), and (80:20) for conductivity measurements and battery discharge profiles were prepared by the solution-cast technique using tetrahydrofuran (THF) as solvent. The mixture of these solutions was stirred for 10– 12 h, cast onto polypropylene dishes, and evaporated slowly at room temperature. The final product was vacuum dried thoroughly at 10$^{-3}$ mbar.

**U. Sasikala et al., [14]** carried out a study on the Ion conducting polymer electrolyte films based on Polyethylene oxide (PEO) complexed with sodium fluoride (NaF) have been prepared by solution cast technique for solid state battery applications. Miscibility studies were performed using X-ray diffraction (XRD) and Frequency dependent conductivity ($\alpha_{ac}$) values were obtained from complex impedance (Cole-Cole) plots. It was observed that the magnitude of conductivity increased both with the increase in the salt concentration and the temperature. The activation energy values showed a decreasing trend with increasing ionic conductivity. Optical constants like absorption edge, direct band gap and indirect band gap were investigated in pure and doped PEO films from their UV-VIS absorption spectra in the 200-600 nm wavelength region. It was observed that these optical constants shifted to lower energies on doping with NaF salt. The charge transport of these electrolytes is mainly due to ions which were confirmed by the transference number experiment. Using this electrolyte, cells were fabricated and their discharge profiles were studied under constant load. Several cell parameters associated with the cells were evaluated and compared with earlier reports. The experimental data reveals that the conductivity of pure PEO is about 3.24 $X10^{-8}$ Scm-1 at room temperature and increases to 1.53 $X 10^{-7}$ $Scm^{-1}$ for 10 wt% NaF. The increase in conductivity becomes flatter on further addition of NaF to the polymer. The increase in conductivity at lower dopant concentrations of NaF is attributed to the formation of charge transfer complexes or decrease in the crystallinity.

**Abdelhameed Ahmed ElBellihi et al., [15]** carried out a study on Nano ZnO with an average size of 8 nm was prepared by thermal decomposition of zinc oxalate at 450 °C. A series of based composite polymer electrolyte PEO-LiClO$_4$ and nano ZnO as filler have been synthesized using solution cast technique, with varying the filler ratio systematically. XRD, DSC and FTIR studies have been conducted to investigate the structure and interaction of different groups in the composite polymer electrolyte. Effect of nano ZnO ceramic filler concentration on the structure of composites and their electrical properties (DC-conductivity, AC-conductivity, dielectric constant, dielectric loss and impedance) at different frequencies and temperatures was studied. Melting temperature (Tm) of PEO decreased with the addition of both LiClO$_4$ salt and nano ZnO filler due to increasing the amorphous state of polymer. All composite samples showed an

ionic conductivity. The maximum room temperature ionic conductivity is found for $(ZnO)_{0.5}(PEO)_{12}(LiClO_4)$ composite sample. All the results are correlated and discussed. The synthesis of nano ZnO was prepared by using 300 mL of 0.15 M oxalic acid solution was added slowly (drop by drop) to 300 ml of 0.1 M zinc acetate solution under stirring for 18hrs. A white precipitate of zinc-oxalate was obtained, which was filtered and washed with acetone several times to remove impurities. The precursor was then dried at 120 °C for 30 minutes and finally heated for 30 minutes at 450 °C to get nano ZnO. Then the Preparation of Polymer Nano Composite Electrolytes was synthesized by the conventional solution cast technique. PEO and $LiClO_4$ were dissolved in acetonitrile and magnetically stirred to get a homogeneous solution. An appropriate weight of nano zinc oxide was then added to the solution and stirred for 6 hrs getting a white viscous solution with high homogeneity. After that, the viscous solution was poured on peter dish and left to dry at room temperature for two days to allow the solvent to be evaporated slowly. All the films obtained with different concentrations of filler were then dried under vacuum for 10 hrs and kept in desiccators.

**Kothapalle Sivaiah et al., [16]** carried out a study on PVP polymers containing $Li^+$ or $Ag^+$ Ions have been synthesized in good stability and transparency by using the solution casting method. Their structural, optical, thermal and electrical properties have been investigated from the measurement of XRD, FTIR, SEM, EDAX, optical absorption spectra, TG-DTA profiles and impedance spectral features in order to evaluate their potentialities for their use in electrochemical display device applications.

PVP (Polyvinylpyrrolidone) $(C_6H_9ON)_n$, chemical with a molecular weight [MW] of 1,300,000) and also two other salts of $LiNO_3$ and $AgNO_3$ salts were purchased from M/S Sigma-Aldrich Company, Hyderabad. PVP was dissolved in a small beaker of 50 cc containing double distilled water and it was then thoroughly mixed by using a magnetic stirrer in a warmer condition for homogeneous mixing. Later, this solution was cast into polymer films in flat based Petri dishes under a slow evaporation method. Thus clearer and highly transparent host PVP film was successfully obtained. Lithium Nitrate $(LiNO_3)$ and Silver Nitrate $(AgNO_3)$ salts were separately dissolved in beakers containing double distilled water, PVP was mixed in double distilled water in an-other beaker. In 1:9 ratio; *i.e.*, solutions in 1 part of $LiNO_3$ or $AgNO_3$, 9 parts of PVP solutions were thoroughly mixed using a magnetic stirrer. All the polymer films were found to be 6 cm in diameter

and from such big sized films; required sizes of films were appropriately cut for carrying out the measurements.

**K. Vijay kumar et al., [17]** carried out a study on the solid polymer electrolyte system, polyethylene oxide (PEO) complexed with potassium bicarbonate (KHCO$_3$) salt was prepared by solution-cast technique. Several experimental techniques such as infrared radiation (IR), differential scanning calorimeter (DSC), and composition dependence conductivity, temperature dependence conductivity in the temperature range of 308–368 K and transport number measurements were employed to characterize this polymer electrolyte system. The conductivity of the (PEO+KHCO$_3$) electrolyte was found to be about 3 times larger than that of pure PEO at room temperature. The transference data indicated that the charge transport in these polymer electrolyte systems is predominantly due to K+ ions. Using this polymer electrolyte an electrochemical cell with configuration K+/ (PEO+KHCO$_3$)/ (I$_2$+C+electrolyte) was fabricated and its discharge characteristics are studied. A number of other cell parameters associated with the cell were evaluated and are reported in this paper.

**Moon-Sung Kang et al., [18]** carried out a study on The ionic conductivity of polymer electrolytes and their interfacial contact with dye-attached TiO2 particles were enhanced markedly by the addition of amorphous oligomer into polymer electrolytes, resulting in very high overall energy conversion efficiency. Dye-sensitized solar cells (DSSCs) have been under investigation for the past decade due to their attractive features such as high energy conversion efficiency and low production costs. Regenerable redox couples (e.g. I$^-$/I$_3^-$) are usually dissolved in an organic solvent, which results in high energy conversion efficiency but some drawbacks such as leakage and evaporation of the solvent. Poly(ethylene oxide) (PEO) has been most intensively studied as a polymer solvent for SPEs because it is both chemically stable and polar, which means that it can readily dissolve salts. However, its ionic conductivity is not satisfactory for solar cell applications primarily because of its high crystallinity. There have thus been many attempts to modify PEO to increase its ionic conductivity by incorporating comonomers or nanoparticle fillers. Nogueira et al. reported that the ionic conductivity of a polymer electrolyte comprising poly(epichlorohydrin-co-ethylene oxide), 9% NaI, and 0.9% (w/w) I$_2$ was found to be 1.5 $*10^{-5}$ S cm$^{-1}$.

**Kuei-Fu Chen et al., [19]** carried out a study on the Polyvinyl butyral (PVB), a polymer used world-wide in laminated glass, has been incorporated into dye-sensitized solar cells (DSSCs) as a quasi-solid polymeric electrolyte (SPE) thin film. SPE thin films soaked with different amounts of liquid electrolyte were prepared. The surface morphologies, the diffusion coefficients, and the ionic conductivities of the SPE thin films were analyzed as a function of the liquid electrolyte content (in weight percent). The optimal ionic conductivity was measured to be approximately $1.1 \times 10^{-3}$ S/cm, which is approximately six orders of magnitude higher than that of the original PVB thin film. The effective resistance of DSSC devices incorporating these thin films was measured using electrochemical impedance spectroscopy (EIS). The EIS spectra show a unique pattern consisting of four semi-circles, which is different from the three-semi-circle pattern observed for DSSCs with a liquid electrolyte. The SPE devices exhibited a high conversion efficiency of 5.46% at 100 mW/cm$^2$, approximately 94% that of corresponding liquid-electrolyte cells. The devices' long-term durability was tested to be over 3000 hrs.

**Manish M. Kulkarni et al., [20]** carried out a study on the silica–polyethylene-block-polyethylene glycol (PEPEG) nanocomposites xerogels and investigated therole of addition of the elastic PEPEG oligomer in a brittle porous silica matrix by relating microstructure to mechanical properties. For PEPEG < 7 wt.%, the oligomer fills smaller pores in the silica matrix; but, as evidenced by atomic force microscopy and Fourier transform infrared spectroscopy, PEPEG partially disrupts matrix formation at higher concentrations. Consequently the pore size distribution shifts towards larger sizes and the specific surface area of the composite decreases. The toughness increases continuously with PEPEG addition. The elastic modulus of the composite increases twofold for 7 wt.% PEPEG, but decreases on further addition of PEPEG. Microhardness and structural loss factor also show a similar optimum for PEPEG at around 5–7 wt.%. The analytical and empirical models agree with the experimental modulus values for lower PEPEG addition, but fail to explain the maximum because of their inability to capture the observed microstructural changes in the composite structure.

**Cephas E. Small et al., [21]** carried out a study on the Inverted polymer bulk heterojunction solar cells have received a great deal of attention because of their

compatibility with large-scale roll-to-roll processing. The inverted cell geometry has the following structure: substrate (rigid or flexible)/indium tin oxide/electron-transporting layer/photoactive layer/hole-transporting layer/top anode. Solution processed metal-oxide films, based on materials such as ZnO and $TiO_2$, are typically used as the electron-transporting layers. Here, we demonstrate enhanced charge collection in inverted polymer solar cells using a surface-modified ZnO–polymer nanocomposite electron-transporting layer. Using this approach, we demonstrate inverted polymer solar cells based on a low-bandgap polymer with an alternating dithienogermole–thienopyrrolodione repeat unit (PDTG–TPD) with certified power conversion efficiencies of 7.4%. To our knowledge, this is the highest efficiency reported to date for polymer solar cells with device architecture compatible with the roll-to-roll process.

**Seung Hyeon Yeon et al., [22]** carried out a study on the Mesoporous titanium dioxide ($TiO_2$) thin films were prepared using poly(vinyl chloride)- graft-poly(N-vinyl pyrrolidone) (PVC-g-PVP) as a templating agent via sol-gel process. Grafting of PVC chains from PVC backbone was done by atom transfer radical polymerization (ATRP) technique.. The porous morphologies of the $TiO_2$ films genereated after calcinations at 450°C was characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). The mesoporous $TiO_2$ films with 580 nm in thickness were used as a photo electrode for solid state dye sensitized solar cell (DSSC) and showed an energy conversion efficiency of 1.05% at 100 mW/cm$^2$.

**Jo-Lin Lan et al., [23]** carried out a study on a post heat treatment is developed to improve the "two-step dip coating process" in which poly-N-vinyl-2-pyrrolidone (PVP)-capped Pt nanoclusters are deposited with the aid of appropriate conditioner on transparent conductive oxide (TCO) glass as counter electrode for dye-sensitized solar cell (DSSC). Charge transfer resistance (*RCT*) is found only 0.56 Ω-cm$^2$ for this annealed counter electrode. The improvement of *RCT* is attributed to the removal of conditioner by the post heat treatment at 270°C, which enhances the electrical contact between the Pt nanoclusters and the TCO glass, and thereby accelerates the charge transfer. The DSSC employing this annealed counter electrode achieves high energy conversion efficiency over 8%.

**Ravichandran.S et al., [24]** carried out a study on the Zinc Oxide nanoparticles were synthesized by simple and efficient method in aqueous media from zinc nitrate and

sodium hydroxide. Zinc oxide is an important chemical substance that is widely used in the production of various industrial products. But, the production of nano particle ZnO remains a challenge. In this study, ZnO nanoparticles were prepared by chemical solution and precipitation methods. The size of the particles was measured by scanning electron microscope and particles size analyzer. SEM analyses revealed that single crystal ZnO nanoparticles were achieved with different crystal size. Experimental results have shown that the prepared zinc oxide nanoparticles by this method are higher in size. Zinc oxide nano particles in small size may be obtained by addition of any reducing agents, which was added to optimize the particle size. The size and density of the particles depends on the temperature, rotation of the magnetic stirrer and reducing agent.

**Ch.V. Subba Reddy et al., [25]** carried out a study on the cathode films of $V_2O_5$ xerogel modified with polyvinyl pyrrolidone (PVP) were prepared using sol-gel method. Investigations were conducted by X-ray diffractometry, Fourier transformation infrared spectroscopy, X-ray photoelectron spectroscopy and cyclic voltammetry. The results show that the H atoms in PVP are hydrogen-bonded with the O atoms of the V=O bonds of the $V_2O_5$ xerogel, which effectively shielded against electrostatic interactions between the $V_2O_5$ interlayer and Li+ ions when the $V_2O_5$ xerogel is modified by the intercalation of PVP. The reversibility of insertion/extraction of Li+ ions is greatly improved by modification of the $V_2O_5$ xerogel with PVP.

## 6.2 MECHANICAL CHARACTERIZATION OF POLYMER NANOCOMPOSITES

**Y. Prakash et al., [26]** carried out a study on the Microstructural Parameters of HPMC/PVP Polymer Blends. Mechanical properties were measured using Universal testing machine. Lloyd's instrument U.K. LRX Plug Model 5 KN. Tensile strength of the films was calculated by dividing the maximum load for break the film by cross sectional area. Young's Modulus is the slope of the linear portion of the curve of the stress strain. Elongation at break was calculated by the ratio of the film elongation at rupture to initial gauge length and multiplied by 100. It was observed that changing the concentration of PVP in HPMC matrix modifies the mechanical properties of the blend films. Results reveal that as the concentration of PVP increases, Tensile strength, strain at break decrease up to (5:4) Blend and then increases. Young's modulus, increases up to

(5:3) and then decreases. For (5:4) all measured values are minimum. The wide variation in Tensile strength from 42.21MPa to 10.09 MPa, Strain at break from 3.70 % to 0.88%, Young's Modulus from 1480.31 to 891 MPa.

**Natarajan Rajeswari, et al [27]** carried out a research on biodegradable polymers like PVA and PVP with lithium salt. Tensile strength (TS) and elongation (%E) have been evaluated for each film using an INSTRON 4240 testing machine. Two plate-shaped specimens (ASTM-638) were cut from each film. Specimens had a width of 6·5mm and ~1mm thickness. The gauge length is 25mm. The composition of 70 PVA: 30 PVP bear maximum load compared to other compositions. This composition could bear a maximum load 30·0625N with an extension 375·938% and tensile strength 5·64024MPa.

**L. Tsou, J. A. Sauer et al., [28]** carried out on the development of melt-process able molecular composites. Molecular composites have been prepared by dispersing rigid-rod molecules of ionically-modified poly (p-phenylene terephthalamide) (PPTA anion) in a polar poly (4- vinylpyridine) (PVP) matrix. For concentrations up to 5 wt % of the rigid-rod reinforcement, the resulting composites are transparent and possess a single glass transition temperature that increases with concentration of the PPTA anion. The mechanical properties of the molecular composites are found to increase with concentration and to attain maximum values at about 5 wt % of the PPTA anion. The enhancement in properties, and the miscibility induced between the two component polymers, is attributed to the development of specific interactions between the ionic groups of the PPTA anion and the polar units of the PVP matrix.

These are prepared by dispersing rigid-rod molecules, such as ionic versions of Kevlar®, poly (p-phenylene terephthalamide) (PPTA), in a matrix of a flexible coil polymer, such as poly (4-vinylpyridine) (PVP) and the preparation of specimen was done by solution casting method. The molecular composites were prepared by mixing for 8 h with stirring the PPTA anion solution and the PVP solution, which were made separately in DMSO. For every 50 ml of composite solution, 1,000 ml of anhydrous ether (a non-solvent) was used to precipitate the molecular composite. The resulting precipitate was dried under vacuum at 80°C for 48 h and then freeze milled to a fine powder, followed by vacuum drying at 80°C for another 48 h.

**S R C Vivekchand et al., [29]** carried out a study on the mechanical properties of poly(vinyl alcohol) matrix composites incorporating SiC and $Al_2O_3$ nanowires (NWs) have been investigated. A marked increase in the elastic modulus (up to 90%) has been observed even with the addition of a small quantity (0.8 vol%) of nanowires. This observation cannot be explained by iso-stress analysis, which is appropriate for describing the variation of properties with the reinforcement volume fraction in discontinuously reinforced composites. Crystallization of the polymer induced by the NWs, the high aspect ratio and the surface-to-volume ratio of the NWs as well as the possible in-plane alignment of the NWs during processing are considered to be responsible for the increase in the stiffness. A significant increase in the strength of the composite with the addition of NWs is also observed. This is due to the significant pull-out of the NWs and the corresponding stretching of the matrix due to the complete wetting of the NW surface by the polymer. The increase in tensile strength is found to saturate at higher vol% of NW addition due to the reduced propensity for shear-band induced plastic deformation.

The present study establishes the occurrence of a significant enhancement of the stiffness and the strength of semi-crystalline PVA due to the incorporation of SiC and $Al_2O_3$ nanowires. Experimental results show that enhancements of these mechanical properties occur even with a small vol% addition of NWs. Thus, the elastic modulus $E$ of the composites increases linearly with the volume fraction $V_f$, in accordance with the iso-strain rule-of-mixtures for predicting the composite $E$.

**S. Bahram Bahrami, et al, [30]** in the journal have reported studies on mechanical behavior of PVA-Chitosan blends. All the samples were prepared as thin films and their tensile strength and tensile strain in the dry and wet states were carried out using an Instron (model 5566, V=5 mm/min and d=10 mm). For testing in wet state, all the films were placed in phosphate buffer saline (PBS) solution (pH = 7.2 -7.4) for 30 min and then their tensile strength and tensile strain were measured. Specimens were held between two clamps positioned at a distance 10 mm. During measurement, the sample was pulled by top clamp at a rate 5 mm/min. The thickness of the film sample was measured using a micrometer at five locations (center and four corners), and the mean thickness was calculated.

## 7.0 SUMMARY

By going through the literature survey we can see that very less work has been done in improving the mechanical and electrical properties of the PVP polymer composite, So we have selected to addition of nanomaterials like ceramic nano-powders to improve the mechanical strength. Solution casting method was widely adopted and has given satisfactory results. PVP polymer has gained more attention in current research works, as it is non toxic, Bio-compatible and cheap.

Thermoplastic polymer nanocomposites are revolutionizing the automotive industry by offering significant enhancements in material performance, durability, and multifunctionality. This review explores the advancements and current state of thermoplastic polymer nanocomposites, focusing on their application in automobiles.

Thermoplastic polymer nanocomposites are revolutionizing the automotive industry by offering significant improvements in material performance. This review explores the advancements in these nanocomposites, focusing on their synthesis, properties, and applications within automotive contexts. Key nanoscale fillers such as carbon nanotubes, graphene, nanoclays, and metallic nanoparticles are incorporated into thermoplastic matrices, resulting in materials with enhanced mechanical strength, thermal stability, and electrical conductivity. These properties make thermoplastic polymer nanocomposites ideal for use in structural components, interior parts, and electrical systems of vehicles, contributing to weight reduction and overall vehicle efficiency.

The review covers various synthesis methods like melt compounding, solution blending, and in-situ polymerization, emphasizing how these techniques affect the dispersion of nanofillers and the properties of the final composites. It highlights the specific benefits of these nanocomposites in automotive applications, including improved durability, performance, and thermal management.

Challenges such as processing difficulties, scalability, and cost are discussed, along with potential solutions and future research directions. The review underscores the transformative potential of thermoplastic polymer nanocomposites in creating the next generation of lightweight, high-performance, and sustainable vehicles, suggesting that ongoing research and development could address current limitations and further enhance their applicability in the automotive sector.

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