Montmorillonite (MMT)/Ethylene Vinyl Acetate (EVA) Nanocomposite as an Encapsulant in Photovoltaic Cell (PV)

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Abstract: Nowadays engineering in the manufacturing of *Photovoltaic (*PV) modules is being upgraded very fast *as the demand for cleaner energy worldwide increasing* day by day. *When the PV industry enlarges suitable material solutions must be accessible to meet the numerous desires including durability, performance, price, throughput and global accessibility. PV cells built of semiconductor materials convert sunlight directly to the electricity employing Photovoltaic (PV) systems. Photovoltaic cells can be made from either monocrystalline or polycrystalline elements, and consist of various layers. EVA (ethylene vinyl acetate) materials are well known to be one of the most suitable materials among rubber family for optical and optoelectronic applications, such as PV Encapsulants, EVA have also been noted as the best material for the encapsulation of PV cells as an Encapsulant. This is due to their high transparency in the UV-Visible wavelengths, good dielectric strength, a wide range of refractive indices, suitable glass transition temperature Tg (-40 °C), good thermal and environmental stability. This is flexible even at low temperatures. EVA transparency elevates with increasing vinyl acetate content. Also, when it is formulated with appropriate additives, they provide the required moisture protection. Main objectives of this survey would be increasing the shelf life of the PV cells with the formulation of EVA by increasing the properties and providing protection. It may be possible the formulation with the appropriate 1,2 or 3% of MMT can improve the properties of EVA as per the analytical observation.*

Key words: PV (*Photovoltaic)*, Encapsulant, Nanocomposite, EVA (Ethylene Vinyl Acetate), MMT (Montmorillonite), Bentonite.

1. INTRODUCTION

It is well known, among the polymers within the PV construction, the EVA Encapsulant works collectively of all much relevant materials. In PV components, Polymeric Encapsulant components are advanced to allow automatic insulation. Moreover, they're also accustomed to safeguard them from natural corrosion and mechanical harm [2]. The copolymer EVA is that the famous PV module Encapsulant worldwide and has been employed in the PV industry for quite 20 years. As it is depicted in the figure 1, that EVA is leading material within the PV industries. Thanks to the strong influence of the encapsulation material on efficiency and reliability, the choice of an appropriate material is a very important aspect in module design. Over this long period of time, the life stability of PV EVA, which is extremely influenced by the additive formulation used, has been improved tremendously, especially with having the degradation problem of discolorations (Browning) and delamination [1]. To eliminate these problems, the engineering research is going very fast. In front line with my research study there's specific nanofiller named MMT (Montmorillonite) may be a perfect material for fulfilling the needed properties with regard of having availability in cheap price.

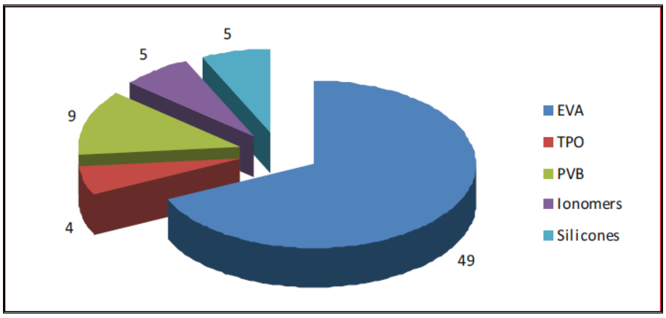


Fig-1: Number of products in the different materials [1].

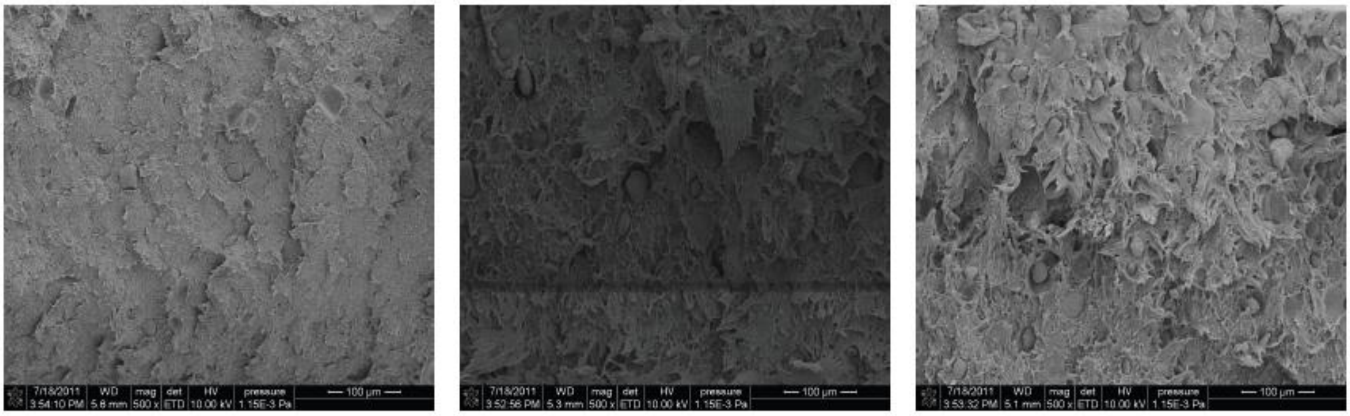
EVA continues because the dominant Encapsulant within the PV industry although it suffers from non-ideal mechanical and thermal properties, a high diffusivity for water, the requirement for vacuum lamination in an exceedingly semi-batch preparing process, and therefore the production of carboxylic acid. As next-generation crystalline silicon wafers are designed thinner, the mechanical characteristics of EVA might not be enough, especially at low service temperatures [2]. So, the improvement is much needed for PV Encapsulant EVA.

2. NANOFILLER BASED NANOCOMPOSITE POLYMERS

As per A.M. Alakrach et al, the performance of nanocomposites constituting EVA filled MMT Nano clay as applicant components of biomedical devices was studied is

incredibly much useful for environment sustainability which is discussed in his research paper entitled "Thermal properties of ethyl vinyl acetate (EVA)/Montmorillonite (MMT) nanocomposites for biomedical applications". As per this paper, MMT filled EVA nanocomposites are doped by assimilating the ratios 0, 1, 3 and 5% of the clay MMT to EVA copolymer [3]. It is a widely explored group of polymer nanocomposites within which a little number of nanostructured clay particle is well dispersed at a nanoscale within the polymeric matrix. Such well diffused composites have exclusive characteristics like mechanical strength, thermal stability, modulus, optical activity, chemical resistance, and some properties like rheology, intercalation, transparency, permeability, barrier properties, electrical conductivity, etc. than those of conventional engineering polymers. Various clay polymer nanocomposites are developed by fictionalizations of clays with natural and engineering polymers with enhanced properties thanks to the flexibility of clay filler present within the polymer matrix and therefore the strong intercalation chemistry is obtained by layered clay [4]. It is seen during study of this paper "Improved Electric Strength and Space Charge Characterization in LDPE Composites with Montmorillonite Fillers" by author Ruijin Liao et al. distribution (space charge) and breakdown strength were studied in composites of LDPE (low density polyethylene) and different contents of nanofilller MMT. It was noticed that the dispersion act of MMT in LDPE with scanning microscopy (SEM) and X-RD.
The greater intercalation of LDPE into MMT interlayer and also the tighter interface structure between polymer-filler were examined For MMT concentration of 1 wt%, and relative to MMT concentration of 3 and 5 wt%. In MMT doped samples the dielectric strength enhance up to a maximum at 1wt% loading, which decreases at 3 and 5wt%. For insulating dielectric elements, attempts have shown that the addition of an appropriate amount of MMT to synthetic rubber, PP (polypropylene), PE (polyethylene), and EVA forms the nanocomposite with improved ability to inhibit electrical tree development additionally as enhanced breakdown strength and thermal resistance. The MMT sheets were found to be increasing with the rise in filler content. It's worthwhile to notice that the mixing between MMT and LDPE are different. In Figure 2(a), at the addition content of 1 wt%, the MMT sheet is inset in the LDPE closely and hence the bond between them is incredibly good. With the rise of the number of MMT, the resin particle interfacial junction becomes weak because in the area of the interface, there are large amounts of gaps between them as shown in Figures 2(b) and 2(c).

The MMT sheet can inhibit charge carrier mobility within the polymer matrix. PEA test results show that LDPE blended with 1wt% MMT can effectively decrease in space charge (assembly and transfer). But in higher MMT concentration of 3 and 5wt%, because of ionization the large amounts of hetro charges were found. The breakdown electrical field increases of LDPE/MMT composites at a maximum 1 wt% loading, and so decreases with remaining percentage. Hence, the 1wt% is the optimum MMT content for LDPE/MMT system [5].



(a) (b) (c)

Fig-2: Analysis of doped LDPE with MMT by: (a) 1wt%, (b) 3wt%, and (c) 5 wt% [5].

The Ethyl Vinyl Acetate (EVA) along Montmorillonite (MMT) filled nanoclay as aspirant materials devices of biomedical are investigated.

EVA/MMT nanocomposites were performed with the ratios of 0, 1, 3 and 5 wt% of clay MMT to EVA copolymer. In this, bio-stability of the virgin EVA and EVA nanocomposites (nanofiller) was correlated and determined by exposing the weather to oxidizing and hydrolytic agents for 4 weeks at 37°C. The thermal properties of the virgin EVA and EVA nanocomposites (nano clay-filled) were studied by using Thermogravimetric analysis (TGA).

TGA experiments proved that the EVA nanocomposite sample with 1 wt% MMT exhibits the greater T_{onset} and drastic reduction within the mass loss rate as compared to the virgin EVA and other higher percentage nanocomposites [2].

The present experimental work by the author F. Guastavino et al. in his paper entitled, "Electrical Treeing in EVA-Boehmite and EVA Montmorillonite Nanocomposites" focuses on the expansion of electrical treeing inside different Ethylene-vinyl acetate (EVA) nanocomposites containing Bohemite (an alumina hydroxide) and Montmorillonite (a phyllosilicate clay mineral) nanoparticles. The MMT is doped within the Ethyl Vinyl Acetate (18% of vinyl acetate content) is 5% which was characterized using transmission microscopy (TEM) and wide-angle X-ray diffractography (XRD). Since Polymeric nanocomposites were introduced, they need captivated interest on the pattern, construction and profiteering of organic elements. Nanostructured organic/inorganic compounds can provide enhanced electrical, thermal and mechanical properties, which might make them attractive applicants to enhance specific power in voltage generation, transport and utilization. The existence of the clay platelets (intercalated) can generate blockade to the enlargement of the released channels. A reduction of the breakdown voltage has been recorded for EVA+5%MMT. However, the behavior of the EVA-Montmorillonite nanocomposite is incredibly good since the decline of the breakdown strength is slight while the rise of the duration during ageing tests noticed [6]. Montmorillonite-nylon-6 (nm) composite has been produced through melt blending or compounding technique followed by injection moulding using percent loading of organic-Montmorillonite (nm) composites ranging from 0–5 wt% content. The required properties of tensile and flexural properties were indicated optimum at 5 wt.% loading [7].

3. IDEAL PROPERTIES OF MMT FOR EVA

As we studied it is a widely investigated that the nanocomposites polymer in which a small amount of Nano clay (nanofiller) particles are well dispersed at a nanostructured scale in the matrix (polymer). These kinds of well-dispersed composites having major properties such as mechanical strength, modulus, thermal stability, optical, a chemical resistivity, and other properties like rheology, transparency, intercalation, permeability, electrical conductivity, etc. than those of virgin polymers.

The author Faheem Uddin, has described in his paper "Montmorillonite: An Introduction to Properties and Utilization" MMT having the plethora of properties which are much compatible or we can say these properties could be very beneficial in the reference of the ideal PV module Encapsulant requirements.

Previously when technology was not at the foundation of human civilization, clay minerals were used as relevant material to form a variety of products in regard the human need. Its softness, plasticity, porosity, pliability, tangibility and weather adaptability, all at a ambient price, were applicable properties to identify its practicality and introduce various products. Today, when nanotechnology is the trademark of the scientific world, the addition of clay mineral is significantly visible as highly useful fillers or additives in polymers for required effects. Nanoclays, based on MMT, is recently used to tweak the polymer performance. Bentonite is very important clay found in nature. It is a relevant source of MMT in nature. It is a rock made of highly colloidal and plastic clays mainly consisting of MMT. The numerous use of Bentonite is in the applications are the result of its comprising interesting chemical and physical properties.

This spectrum of characteristics includes rheology, sorbent effects, plasticity and lubricity, high shear, high dry bonding strength, and compressive strength, impermeability, and low compressibility. Natural Bentonite particles are identical from kaolin clay minerals noticed under the scanning electron microscope (SEM); however, the main difference marked was thickness. Sodium or potassium salts of Bentonite into thin plates that could be of 1 nm in thickness which exfoliated into it.

In general, the Bentonite clay minerals may exhibit the properties of thixotropic gel formation (with water), high water absorption, and high cation exchange capacity (CEC). It could be diverse characteristics in clay minerals depending upon the nature of interstitial water and convertible cations in the interlayer space. Sodium or calcium in Montmorillonite derived from Bentonite may be contained different percentage. The cation exchange capacity can be very much promising fulfilling by removing the acidic generation problem which been one of the major problematic reason for the degradation of the PV module.

In the clay- polymeric matrix, the clay nanoparticle could be intercalated or exfoliated. Where clay crystal is used as a nanoparticle, it can be referred as intercalated clay (in the phenomena, the polymer chains will be in between the clay platelets), and when the single-particle of clay is the adjacent unit, it is known as exfoliated (i.e., iso-tropically clay platelets are diffused in the polymer). The valuable or must noticeable properties include are particle size, surface area, and aspect ratio. Commercially, several desired effects obtained in PNC (polymeric nanocomposite) are resulting in enhancement in the consumption of Montmorillonite. In reference of the combination of improved properties, including weight reduction and low cost in the final product, resulted in important commercial applications in automotive and packaging, and so on. The important findings in the MMT- polymeric matrix nanocomposites are examined for material types: elastomers, thermosets, and polymers from essential resources or biopolymers as well.

Also, the author has shown that some of the functional properties which are conveying that the MMT is one of the best material to make PV module Encapsulant EVA in the industry. The properties like that *Cation Exchange Capacity* (CEC) properties, *Electrical properties*; the electrical ions distribution around clay pores are called membrane polarization. In membrane polarization, the negative ions are being oriented to one end of the pore under the impact of direct current potential within the clay pore, and this polarization help into restrict the current flow. *Thermal Resistance*; MMT is work as an acceptable thermal insulator, and thermal-resistant effects are attainable using it as a supplement in any substance (polymer etc.). This is a field of important research to produce thermal blockade effects in composite material structure which are very useful in today's era. Thermal resistance characteristics of clay minerals had been used in heat-resistant and flame-retardant operations. Nanoclay is recently used broadly and examined in polymer composite to get an increased thermal stability and flame retardancy as well. *Water sorption;* Water sorption is a relevant property of natural/synthetic clay particles. Clay particles can absorb or lose water in response to changes in humidity content in the ambient environment; when water is absorbed, it fills the spaces between the stacked silicate layers. *Resistance to Tooth Decay*; Results obtained for flexural strength, elasticity modulus, tensile strength, and thermal resistance on the applied dental adhesive with polymers, using Montmorillonite as an additive, with polymeric materials are encouraging and much favorable. Adhesive produced with dimethacrylate copolymer and MMT (0.2% concentration). *Adsorption of toxic heavy metals;* A relevant application of adsorption characteristics of MMT is seen in the discharge of toxic heavy metals from aqueous solution. *Properties enhancing in Biopolymers*; Biopolymer modification using Montmorillonite as nanofiller is found to improve the thermo-mechanical properties. Biopolymer produced from chitosan/MMT nanocomposite over diluted carboxylic acid used as a solvent for liquefying and diffusing chitosan and MMT. *The effect in fibber-forming polymer;* Important properties of fibre-forming polymers may be improved using Montmorillonite as a filler. In general, clay mineral (nm) showed flame–retardant effects as assessed by a reduction in the utmost thermal decreasing rate for several thermoplastic polymers also containing polystyrene, polyamide-6, polypropylene, PMMA (poly methyl methacrylate), polyamide-12, polyethylene (PE), and ethylene-vinyl acetate (EVA). Nanometer-sized particles of Montmorillonite may be made known in polymers/fibers, resulting in improve resistance to electricity, chemicals, thermal and flaming, and upgrade ability to stop or prevent *UV* light.

4. MMT FAVORS ELIMINATION AUTO-OXIDATION FROM EVA

As we tend to study in some papers the dominant encapsulation material for PV modules presently is ethylene vinyl acetate (EVA) polymer. The ageing behavior and degradation mechanism of EVA and particularly of formulated EVA (with additives) as a PV encapsulation material are well narrated in the literature. The introductory step of EVA degradation is the buildup of carboxylic acid (HAc) influenced by the chemical reaction and breakdown of the backbone chain (polymeric). The rate the degradation is larger in moisture or oxygen touch atmosphere. Other degradation reason merchandise reportable within the literature is lactones, generated by intramolecular reaction by the acetate group present in the EVA and hence the evolution of methane and therefore the production of ketones reported. Moreover, group of α,β-unsaturated carbonyl , hydroperoxides and anhydrides are occurs throughout the oxidation reaction. Generally, their rate of formation and decay follows typical auto-oxidation dynamics.

With increasing the content of vinyl acetate, the EVA degradation rate is increased. Coz of increasing of degree percentage of vinyl acetate content results in the higher polarity and so higher solubility of the carboxylic acid within the polymeric compound. Besides, the reduction in stability with increasing vinyl acetate content may be explained by the accumulated residual carboxylic acid content at intervals the compound arising from totally different process steps. Carboxylic acid Formation of happens at temperatures from 120 to 150°C. This temperature variation is sometimes reached throughout polymerisation and palletisation of the EVA polymer, film extrusion, and PV module lamination [8]. Because the percentage of MMT 1 or 3% nanofiller would be doped within the EVA Encapsulant the thermal properties can increase therefore the formation of carboxylic acid possibilities get decrease. More than that the MMT is a layered structure of intrinsic inorganic filler that offers Bronsted and Lewis acid chemical catalytic site which implies the ion exchanging capability of MMT will not let be the formation of acetic site within the EVA.

5. CONCLUSION

The review study gives a roadmap and general technical understanding of MMT along with various possible favorable outcomes which are applicable as of the ideal material for PV Encapsulant. The study almost proves as per the future aspect the EVA-MMT nanocomposite with appropriate formulation can be a substitute of conventional EVA Encapsulant which will be fulfilling of the low cost availably demand with of the best ideal properties. The MMT could be fast developing material for the PV industry and also as I reviewed, it is very important environment friendly material for PV Industries. Though the present article is review, it still gives a clear view of revolution in the world of EVA Encapsulant formation and development. If tested, it might be best results giving material among 1, 2 and 3wt% MMT with EVA.

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