Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Examining Effect Of Different Parameters On PVA/MMT By Different Characterization Techniques

Alak Das, Dr. Om Prakash Choudhary

Department of Physics, Dr. A.P.J. Abdul Kalam University, Indore, M.P., India.

The enhanced features and versatile applications that nanocomposites offer have piqued the curiosity of many. Nanoscale constituents are dispersed throughout a matrix to form a nanocomposites. Creating and characterizing Polyvinyl Alcohol/Na+-Montmorillonite (Na+-MMt) nanocomposites was the focus of this research. After being used as a charge for polyvinyl alcohol, the montmorillonite was put through a battery of tests, including X-ray diffraction (XRD) and thermogravimetric analysis (TGA). The results of a volumetric adsorption of carbon dioxide at room temperature (RT) indicated, through an isotherm, that the CO2 adsorption capacity of MMT-PVA may be enhanced by modification with PVA. These results prove that MMT intercalation is responsible for the formation of nanocomposites and that an increase in MMT concentration leads to a greater interlayer distance. When compared to Nanocomposite, Na-MMT has a reduced potential to absorb CO2.

Keywords: Thermogravimetric, Polyvinyl, Montmorillonite, Clay, Adsorption

1. Introduction

In material science and engineering, the constant quest for new and superior materials has been a driving factor in expanding the scope of what is conceivable. Polyvinyl Alcohol (PVA)/Na+-Montmorillonite (MMt) nanocomposites have captivated the scientific and engineering communities with their ground-breaking innovation. Nanocomposites are a synergistic mixture of two materials, with improved properties above each one used alone. The incorporation of nanoparticles such as Na+-MMt into polymer matrices has ushered in a new era of material development with enhanced mechanical, thermal, and barrier properties. Polyvinyl alcohol, or PVA, is a synthetic polymer that is biocompatible, water-soluble, and has excellent film-forming and adhesive capabilities. The textile, paper, adhesive, and pharmaceutical industries are just some of the many that make extensive use of it. To enhance its properties and expand its applications, scientists have started looking at incorporating nanoparticles into the PVA matrix. Amazing nanomaterial examples include Na+-Montmorillonite (or Na+-MMt). Montmorillonite, a member of the smectite family, is a layered silicate clay mineral known for its large surface area, great swelling ability, and large ion exchange capacity. Because of the synergistic effects of the Na+-MMt nanoparticles and the PVA matrix, the resulting composite material exhibits improved performance characteristics.

To manufacture PVA/Na+-MMt nanocomposites, one has to have a deep understanding of polymer chemistry and material interactions. In-situ polymerization and solution casting are two popular techniques. Polymerization of PVA monomers in the presence of dispersed Na+-MMt nanoparticles creates polymers with strong interfacial interactions to the clay surfaces. To make a composite film through solution casting, however, prefabricated Na+-MMt nanoparticles are first dispersed in a PVA solution before the solvent is evaporated. These methods need precise regulation of environmental factors including temperature, stirring rate, and concentration to prevent nanoparticle clumping. The structure of the resulting nanocomposite is influenced by a number of variables, such as the concentration of nanoparticles, the nature of interactions between polymer and nanoparticles, and the processing parameters. By manipulating these parameters, scientists may tailor the final characteristics of the nanocomposite for a wide range of applications.

When Na+-MMt is integrated into a PVA matrix, an exceptional nanocomposite is produced. The layered structure of Na+-MMt may be responsible for its increased tensile strength, modulus, and impact resistance by restricting the movement of polymer chains, which has a reinforcing effect. This reinforcement, which aids in stress distribution and prevents fractures from propagating, is the result of the formation of a three-dimensional network inside the polymer matrix. The high aspect ratio of the Na+-MMt nanoparticles reinforces the material and reduces the likelihood of fracture propagation. The enhanced mechanical properties of PVA/Na+-MMt nanocomposites position them favorably as alternatives to conventional materials for use in load-bearing applications in industries such as transportation, construction, and sports.

In addition to their mechanical properties, PVA/Na+-MMt nanocomposites exhibit remarkable thermal stability and flame-retardant properties. When added to a polymer matrix, Na+-MMt nanoparticles act as a barrier, reducing the rate of thermal degradation and blocking the movement of volatile degradation products. The clay particles' unique form acts as an insulator, reducing the rate of heat transfer and material diffusion. Therefore, the nanocomposites are preferable for applications where fire safety is critical, such as in building materials and electronics, since they are less flammable and more resistant to high temperatures.

2. Review Of Literature

Sirait, Makmur et al., (2018) In this study, poly(vinyl alcohol) (PVA)/bentonite nanocomposites were analyzed for their mechanical, morphological, and thermal characteristics. To make nanocomposites, the sol-gel method is used. Poly(vinyl alcohol) was combined with different concentrations of natural bentonite from North Sumatra, Indonesia (35.26 nm). The calculations used a weight range of 0% to 8%. The produced nanocomposites were characterized by means of tensile testing, scanning electron microscopy, and differential thermal analysis. Addition of bentonite at a weight percentage of 6 wt% enhanced mechanical characteristics and generated a more uniform surface, whereas additions at weight percentages of 2, 4, and 8 wt% lowered the elasticity modulus. However, zero-weight bentonite may be used to boost thermal characteristics.

Xu, Buqin et al., (2015) To make the nanocomposite emulsion, an exfoliated Na-MMT solution was employed for in situ emulsion polymerization. We investigated the relationship between Na-MMT concentration and emulsion polymerization and stability. Na-MMT/PVA composite polymer films were tested for water resistance, thermal stability, and anti-aging properties using the water absorption ratio, thermo-gravimetric analysis (TGA), and an anti-ultraviolet aging test. It is possible to generate a stable Na-MMT/PVA nanocomposite emulsion at concentrations below 2.0wt% Na-MMT. Transmission electron microscopy (TEM) analysis has shown a layered-sphere hybrid structure in the Na-MMT/PVA composite latex. The composite film outperformed a film made of pure PVA polymer in terms of its water resistance, thermal stability, and anti-aging capabilities.

Raheel, Muhammad et al., (2014) It has been shown that aqueous manufacturing of poly(vinyl alcohol) (PVA)-based graphene oxide-montmorillonite (GO-MMT) nanocomposites is straightforward, effective, and ecologically sound. The nanohybrid GO-MMT may arise when GO and MMT are mixed in water without the use of any additional reducing or stabilizing agents. The creation of the GO-MMT nanohybrid is due to hydrogen bonding and crosslinking activities. Na+ ions in MMT sheets act as crosslinkers, connecting successive layers of GO. As soon as the nanocomposites are ready for inspection, scientists apply a wide variety of techniques, such as mechanical testing, thermogravimetry, scanning electron microscopy, and differential scanning calorimetry. Because nanoadditives attach so strongly to the matrix's surfaces, PVA nanocomposites have greater thermal stability and mechanical characteristics than pure PVA. Tensile strength and modulus are improved even more by the strong contact between PVA chains and stacked GO-MMT compared to the PVA/GO and PVA/MMT nanocomposite.

Karimi, Ali & Daud, Wan. (2014) Polyvinyl alcohol (PVA) and natural sodium montmorillonite (Na+-MMT) were combined to create a nanocomposite hydrogel, which was subsequently chemically crosslinked and subjected to a Freezing-Thawing process to create a novel physicochemical crosslinked material. Nanocomposite hydrogels were analyzed for their structure, shape, and properties (thermal, mechanical, swelling, and deswelling) with and without physicochemical crosslinking. A number of techniques were utilized to learn more about the nanocomposites' internal structure and external appearance. These included X-ray diffraction, Field emission scanning electron microscopy, and Transmission electron microscopy. Thermogravimetric analysis, differential scanning calorimetry, dynamic mechanical analysis, a hardness test, and a water vapor transfer rate (WVTR) test were used to evaluate the nanocomposites' thermal and mechanical properties after they had undergone physical and physicochemical crosslinking. The findings demonstrated that after physicochemical crosslinking, the Hardness and WVTR of a PVA nanocomposite were enhanced while the crystallinity and melting temperature were reduced.

Using a gravimetric method, we determined that controlled crosslinking with glutaraldehyde improved the crosslinking ratio and overall amount of water loss in PVA nanocomposite hydrogel. For both physical and physicochemical crosslinking of nanocomposite hydrogels, a fickian model was employed to match swelling (sorption) and deswelling (desorption) kinetics data. Therefore, it may be possible to create hydrogels with increased swelling capacity by means of controlled crosslinking of PVA nanocomposites.

Sirousazar, M. et al., (2011) In order to create a series of polyvinyl alcohol nanocomposite hydrogels that are stable throughout repeated freezing and thawing cycles, the loading amount of hydrophilic natural Na-montmorillonite nanoclay was adjusted from 0% to 15%. Nanocomposite hydrogels' gelation process and the effect of Na-montmorillonite on it were investigated throughout a temperature range. The shape of the synthesized nanocomposite hydrogels was quite similar to that of exfoliation. Gel fraction values were found to rise when nanoclay content in nanocomposite hydrogels was raised. Experiments in a controlled environment demonstrated that the dehydration rates of nanocomposite hydrogels were proportional to the dehydration temperature and inversely proportional to the nanoclay loading amount. All specimens showed non-Fickian behavior during drying at 20 °C1, but Fickian behavior at 37 °C and 55 °C.

Ip, Kin Hong et al., (2011) We prepared and studied poly(vinyl alcohol) and montmorillonite composites with increased clay loading. The intercalation levels of various composites were investigated using X-ray diffraction and scanning electron microscopy with energy dispersive spectroscopy. The acidity and subsequent washing of the clay creates a uniform polymer-clay layer. The morphology of the clay in the composite was found to vary with the origin of the montmorillonite. Results from making composites of poly(vinyl alcohol) with two kinds of montmorillonite demonstrated that the clay structures inside the composites differed depending on the polymer type.

3. Research Methodology

Preparation of Na+ -MMt

The ion exchange method was used to manufacture Na+ -MMt using NaCl as the cation source. Using the same crushing and drying conditions and time frame as our previously reported study, we exposed 20 grams of MMt to 105 degrees Celsius for 20 minutes. To treat the powder, 500 ml of NaCl solution (1 M) is added, and the mixture is stirred magnetically at room temperature for 3 hours, or until saturation is reached. The mineral is dried at 105 degrees Celsius, and then washed in distilled water to remove any remaining Cl.

Preparation of polyvinyl alcohol/Na-MMt

The precursors for the synthesis of the MMT-PVA nanocomposites were a MMT/water suspension, and the reactants were dissolved PVA. To begin, we sonicated a suspension of Na-MMT in distilled water for about 2 hours after dissolving it in water at a 25% weight concentration. The mixture was then sonicated for an additional 24 hours after polyvinyl alcohol was added, heated to 90 degrees Celsius to dissolve the PVA, and then sonicated for an additional hour. After the castings cooled to normal temperature after being heated to 60 degrees Celsius for a day, they were stored and further analyzed. Sodium montmorillonite was added to the compositions at varying percentages of 1, 3, 5, 7, 10, and 15% by weight, while the polymer content remained unchanged.

Characterization

Using a Bruker D8 Advance X-Ray Diffractometer (40 kV, 30 mA) and CuK radiation (k=0.154 nm) at a rate of 2 min-1 for 2 hours, X-ray diffraction measurements were made across a temperature range of 2.0-80°C at room temperature. In addition, 51 pieces of Shimadzu Thermogravimetric Analysis (TGA) equipment were used to perform thermogravimetry (TG) at temperatures ranging from 0 to 900 degrees Celsius at a rate of 10 degrees Celsius per minute in an atmosphere containing 50 milliliters of air per minute. The sample's total size was 5.0 0.5 mg.

CO2 adsorption isotherms were created at 0 °C using ASAP 2020 V4.01 (Micromeritics) apparatus. One hundred milligrams of the nanocomposite sorbent were weighed out and deposited in the sample cell. The pollutants attached to the adsorbate were removed by outgassing the nanocomposites at 170 degrees Celsius in a vacuum. Very pure CO2 (99.999%) was used in the adsorption process, which took place at low pressures (5-760 mmHg).

4. Data Analysis and Interpretation

X-ray diffraction was used to examine the atomic structure of a nanocomposite with varied MMT concentrations in a PVA matrix (Figure 1). The DRX spectrum of Na+-exchanged MMT shows that the base peak, d001=11.87 (d001, calculated by Bragg's rule, d001=/2 sin), has been shifted to a lower diffraction angle compared to the unmodified clay. Because of the water molecules in the interlayer region, the basal spacing has shifted. This is caused by the hydrated galleries.

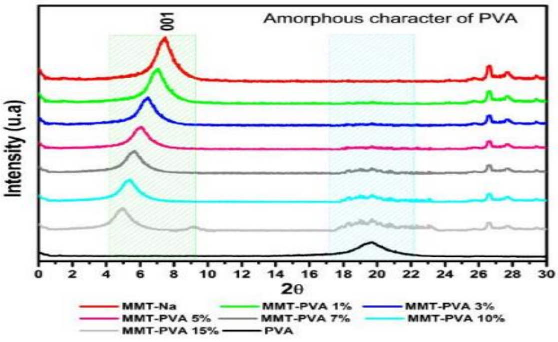

Figure 1: Nanocomposite MMT-PVA using XRD patterns

In contrast to Na-MMT, the base peak 001 in the XRD pattern of MMT-PVA nanocomposites is located out to the side. The interlayer distance of MMT-PVA nanocomposites with 1, 3, 5, 7, 10, and 15% by weight is 12.54 nm, 13.73 nm, 14.58 nm, 15.78 nm, 16.64 nm, and 17.77 nm, respectively. As a result of polymer chains intercalating between the clay layers, the interlayer gap has narrowed.

The nanocomposite with a lower MMT content (10% wt) yielded a bigger volume, but the peak for this sample (MMT-PVA (15%)) was different due to the altered crystal structure of the clay particles. The generated MMT-PVA nanocomposites all showed different intensities at 2=19.54°C due to the amorphous nature of PVA.

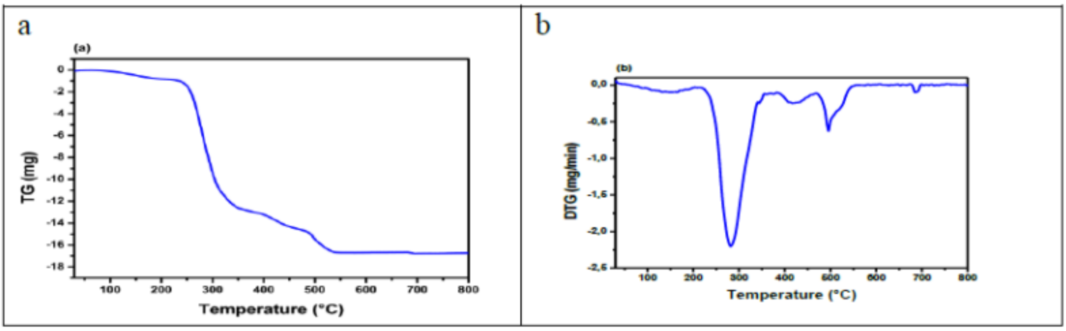

Figure 4: TGA/DTG analysis curves for MMT-PVA

The thermal stability window of the nanocomposite MMT-PVA (15%) was calculated using thermogravimetric analysis (TGA). Figure 4a and b demonstrate this. The TGA curve of MMT-PVA nanocomposite (15%) exhibits three distinct phases of mass loss, which is in agreement with previous findings. Consistent with DRX and FTIR results, the findings demonstrate that physisorbed water degrades at temperatures between 30 and 200 degrees Celsius, while PVA degrades at temperatures between 220 and 390 degrees Celsius, leading to net mass loss at both of these temperatures. This behavior was also seen by Strawhecker and Manias.

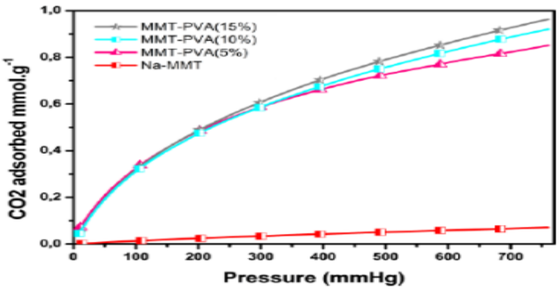

Figure 5: Sorption isotherms of CO2 on the nanocomposite MMT-PVA at 0°C.

Figure 5 depicts the Na-MMT and MMT-PVA CO2 adsorption isotherms at 5, 10, and 15% saturation. When compared to layered materials (such Kanemite or Smectite), the clay modified by cation exchange (Na+) clearly demonstrates a weak CO2 adsorption capability, at 0.07 mmolg-1. CO2 adsorption behavior is consistent across surfaces because of the low surface basicity of these materials. There is some evidence that utilizing nanocomposites may improve CO2 adsorption; increasing CO2 adsorption by 0.85, 0.92, and 0.96 mmol.g1 for Na-MMT when using MMT-PVA at concentrations of 5%, 10%, and 15%, respectively. The presence of OH groups in the structure is considered to be active locations for collecting the CO2 molecules, making the chemical and structural features of the nanocomposite utilized vital to the success of this transition. Water molecules that have been physisorbed into the nanocomposite structure may also be supported by weak interactions with CO2 and OH groups. Adsorption of carbon dioxide (CO2) is sensitive to several factors, one of which is interlayer distance. More CO2 may be adsorbed into nanocomposite structures if the interlayer gap between the material layers is larger.

5. Conclusion

Significant progress has been made in the field of nanomaterials and their prospective applications thanks to the synthesis and characterization of Polyvinyl Alcohol/Na+-MMt nanocomposites. The extraordinary potential of nanotechnology to change material design and engineering is shown by the synthesis and characterisation of Polyvinyl Alcohol/Na+-MMt nanocomposites. This study paves the way for future breakthroughs in a variety of disciplines by combining the benefits of PVA and Na+-MMt, two materials that each have their own set of advantages.

References

1. Sirait, Makmur & Gea, Saharman & Siregar, N. & Bukit, Nurdin & Ginting, E.M. & Zega, R.F.. (2018). Fabrication of Poly(vinyl alcohol)/Bentonite Nanocomposites Using Sol-Gel Method. Asian Journal of Chemistry. 30. 2210-2214. 10.14233/ajchem.2018.21388.

2. Naderizadeh, Sara & Shakeri, Alireza & Mahdavi, Hossein & Nikfarjam, Nasser & Taheri Qazvini, Nader. (2018). Hybrid Nanocomposite Films of Starch, Poly(vinyl alcohol) (PVA), Starch Nanocrystals (SNCs), and Montmorillonite (Na-MMT): Structure-Properties Relationship. Starch - Starke. 71. 10.1002/star.201800027.

3. Chikh, Karim & Larbi, Bouhadjar & Kherroub, Djamal & Meghabar, Rachid & Belbachir, Mohammed. (2017). Synthesis and Characterization of Polyvinyl Alcohol/Na +-MMt Nanocomposite: Effect of Charge Content and CO 2 Adsorption Properties. Der Pharma Chemica. 9. 90.

4. Xu, Buqin & Yang, Jin & Xu, Guilong & Jiang, Honggang. (2015). Preparation and Properties of Na-MMT/PVA Nanocomposite Emulsion. 10.2991/cmfe-15.2015.65.

5. Karimi, Ali & Daud, Wan. (2015). Materials, preparation, and characterization of PVA/MMT nanocomposite hydrogels: A review. Polymer Composites. 38. 10.1002/pc.23671.

6. Raheel, Muhammad & Yao, Kun & Chen, Xuecheng & Liu, Dongtao & Yichao, Lin & Cui, Dongmei & Siddiq, Muhammad & Tang, Tao. (2014). Polyvinyl alcohol/GO-MMT nanocomposites: Preparation, structure and properties. Chinese Journal of Polymer Science. 33. 329-338. 10.1007/s10118-015-1586-2.

7. Karimi, Ali & Daud, Wan. (2014). Comparison the properties of PVA/Na+-MMT nanocomposite hydrogels prepared by physical and physicochemical cross-linking. Polymer Composites. 37. 10.1002/pc.23248.

8. Sirousazar, M. & Kokabi, Mehrdad & Hassan, Zuhair Mohammad & Bahramian, A.. (2011). Dehydration kinetics of polyvinyl alcohol nanocomposite hydrogels containing Na-montmorillonite nanoclay. Scientia Iranica. 18. 780-784. 10.1016/j.scient.2011.06.002.

9. Ip, Kin Hong & Stuart, Barbara & Thomas, Paul & Ray, Abhi. (2011). Characterisation of poly(vinyl alcohol)–montmorillonite composites with higher clay contents. Polymer Testing - POLYM TEST. 30. 732-736. 10.1016/j.polymertesting.2011.06.004.

10. Yeum, Jeong. (2011). Novel Poly(vinyl alcohol)/Clay Nanocomposite Microspheres via Suspension Polymerization and Saponification. Polymer-Plastics Technology and Engineering. 50. 1149-1154. 10.1080/03602559.2011.566302.