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Nanocomposites of Polyethylene-Closite 20A: Preparation and Characteristics

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Abstract

Low-density polyethylene/closite 20A nanocomposites with different organoclay contents were made in the current study by a melt mixing technique with two different compatibilizers of varying contents: low molecular weight oxidized polyethylene and low molecular weight trimethoxysilyl modified polybutadiene. The inclusion of compatibilizers and concentrations of organoclay were analyzed in relation to the mechanical and thermal properties of the nanocomposites. The dispersibility of the silicate clay in the nanocomposites was investigated using transmission electron microscopy. It was discovered that organosilane created a more exfoliated structure and increased clay dispersion in comparison to the low molecular weight oxidized polyethylene. "A dynamic oscillatory rheometer" was used to analyze the samples' rheological behavior in the linear viscoelastic zone. Tensile strength, yield strength, and tensile modulus were all higher in the organosilane compatibilized system than in the uncompatibilized system, and much higher in the low molecular weight oxidized polyethylene compatibilized case. The crystallization characteristics of compatibilized and uncompatibilized nanocomposites were investigated using differential scanning calorimetry. The inclusion of compatibilizers raised the crystallization temperature due to the heterogeneous nucleation impact of organoclay on low-density polyethylene, according to the results of differential scanning calorimetry.

Keywords: Films, organoclay, crystallization behavior, mechanical properties, polyethylene.

INTRODUCTION

A novel class of composite materials, polymer nanocomposites have garnered a lot of attention lately due to their superior mechanical performance as fillers and improved physical characteristics, such as resistance to heat and flammability when compared to conventional micro-composites or base polymers [1–3]. Natural clays are typically utilized in the creation of polymer nanocomposites because of their structure and affordability. The most popular natural clay is montmorillonite, which is made up of layers of alumina-silicate that are extremely hydrophilic and only 1 nm thick. These layers are separated by exchangeable cations (Na^+, K^+, and Ca^{2+}). The structural characteristics of clays, including their layered structure, huge surface area (700–800 m^2g^{-1}), strength, and extremely high stiffness (150–250 GPa), may offer a stronger reinforcing effect than polymer materials. When clay platelets or other nanofillers are fully incorporated into a polymer matrix, the increased surface area between the clay platelets and the polymer matrix frequently results in a notable improvement in the material's characteristics. Both solution intercalation and melting intercalation, which involves mixing

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silicate with the polymer matrix while it is molten, can be used to prepare them. Compared to the solution intercalation method, this process has many advantages because direct melt intercalation is highly particular for the polymer and mixing tools, like a twin-screw extruder, are frequently easily accessible for the creation of polymer/organoclay nanocomposites.

The enhanced performance of polyolefin nanocomposites in engineering and packaging applications has sparked interest in them. One of the most popular polyolefin polymers is polyethylene (PE), which is inexpensive, lightweight, durable at low temperatures, absorbs little moisture, has good optical qualities, and is simple to produce and recycle. A common packaging material, low-density polyethylene (LDPE), appears to be particularly appealing for the creation of nanocomposite materials, primarily because of the anticipated enhancement of barrier properties [4–6]. LDPE still has a lot of issues, including low weather resistance, poor temperature capability, and difficulty bonding, despite its immense technical and commercial significance. In certain applications, the usage of LDPE and its composites is restricted by these intrinsic drawbacks. Therefore, to expand the uses of LDPE, new LDPE products with excellent qualities and qualities must be developed. Due to clay’s exceptional ability to enhance nanocomposite characteristics, clay-based PE nanocomposites have garnered a lot of interest from researchers studying a variety of applications in recent years. However, because LDPE lacks polar groups in the backbone of its chain, hydrophobic polymers of this type find it extremely difficult to intercalate into clay layers. This is mostly due to the polar groups in the changed clay layers, which make them compatible with only polar functional groups in polymers. For the clay to disperse at the nanoscale scale, the matrix must be changed with polar moieties before the modified clay is introduced [7]. Therefore, compatibilizers or interfacial agents-modified polymers with polar groups must be added to the nanocomposite formulations to improve the interfacial interactions between the clay layers and the polyolefin matrix [8]. Because the initial clay materials are readily available and their intercalation chemistry has been thoroughly explored for a long time, polymer/organoclay nanocomposites have been the subject of increasing research [9]. Both unmodified and modified LDPE have been used as the basis for the characterization of LDPE/organic-montmorillonite nanocomposites by numerous publications [10−14]. The efficiency of low molecular weight trimethoxysilyl modified polybutadiene (Organosilane) and low molecular weight oxidized PE (OxPE) as compatibilizers was investigated in this work. The intercalation of the polyolefin chains has been found to benefit from the addition of organosilane as a compatibilizer, which influences morphology and keeps the mechanical characteristics at a satisfactory level [15, 16]. The polar interactions between the amine groups in the modified clay and the organosilane in the resin may be the cause of the exfoliation seen in these systems. OxPE is a low molecular weight, modified PE with a variety of functions, primarily carboxylic acids, esters, and ketones. It has been utilized as a compatibilizer, in coating formulations, and as a processing aid in some polymer blends. Additionally, oxidized polyolefins have been employed as compatibilizers in certain polymer blends [17, 18].

To the best of the authors’ knowledge, no literature has been written about how specific compatibilizers affect the morphology, mechanical characteristics, and thermal properties of LDPE/organoclay nanocomposites made by melt mixing. This work aims to investigate in further detail LDPE)/organoclay nanocomposites with varied quantities of clay that were made by melt compounding both with and without the use of two different compatibilizers. The current study examined in detail how clay concentrations and two different compatibilizer types affected the nanocomposites’ morphology, and mechanical characteristics, such as their tensile strength (TS), yield strength (YS), and tensile modulus (TM), as well as their thermal characteristics.

EXPERIMENTAL

Ingredients

Hyundai Petrochemical Co., Kye Dong, Chongro-Gu, South Korea, provided the LDPE [MFI (ASTM D 1238) = 3.0 g/10 min], which is suitable for packaging use. Low molecular weight oxidized polyethylene (OxPE) and low molecular weight trimethoxysilyl modified polybutadiene were the two compatibilizers used in this investigation. In Shanghai 201203, China, Honeywell (AC 330), located at 430-Li Bing Road, Zhangjiang Hi-Tech Zone, donated low molecular weight OxPE. According to reports, AC 330's melt viscosity was 3600 cps at 150°C. The compatibilizer was subsequently identified as OxPE for the AC 330. Kettlitz-Chemie GmbH & Co. KG, located in Rennertshofen, Germany, supplied the low molecular weight trimethoxysilyl modified polybutadiene (Organosilane). With a cation exchange capacity value of roughly 95 meq/100 g, the organophilic clay (Organo-montmorillonite (OMMT), Closite 20A) was provided by Southern Clay Products, Inc., Gonzales, Texas, USA. A dimethyl dihydrogenated tallow quaternary ammonium chloride modification of Cloisite 20A was utilized to create LDPE-clay nanocomposites. According to the manufacturer, 38% of Cloisite 20A is organic [17]. The supplier of the crosslinking agent, Dicumyl Peroxide (DCP), was Akzo Nobel N.V. Co., located at Strawinskylaan 2555, Amsterdam, Noord-Holland, 1077 ZZ, Germany.

Procedures

Melt Processing

To eliminate the absorbed moisture, all the raw materials were dried in a vacuum oven set at 80°C to constant weigh for at least 12 hours before being allowed to cool to room temperature before compounding. Using a preweighed amount of LDPE with and without compatibilizers, and four different weight percentages of clay (1 wt%, 3 wt%, 5 wt%, and 7 wt%), LDPE/clay hybrids were created using the melt compounding technique. Table 1 lists the formulas of the synthesized nanocomposites. A co-rotating twin-screw extruder (Brabender DSK 42/7), warmed to 120°C, was used to perform melt intercalation. During polymer and organoclay loading, the rotor speed was kept at 60 rpm for roughly two and a half minutes. After that, it progressively increased to 60 rpm at 30-second intervals. Ten minutes was the whole kneading time. These premixes were then allowed to come to room temperature before being individually compression-molded between two steel plates at 190°C for five minutes while being under 10 MPa of pressure. At last, the mold was extracted from the plates and the pressure was released. After that, two thick metal blocks were placed at room temperature and allowed to cool to room temperature. To examine the mechanical qualities, the samples were chopped into typical sizes and shapes. To comparing mechanical qualities, virgin LDPE compression molded at comparable temperatures. After that, the samples were placed in plastic bags to await processing and examination.

Table 1. LDPE/organoclay nanocomposites' compositions.

Sample code	LDPE (wt%)	Organoclay (wt%)	Organosilane (wt%)	OxPE (wt%)	DCP (wt%)
LDPE	100	–	–	–	–
LC1	99	1	–	–	–
LC3	97	3	–	–	–
LC5	95	5	–	–	–
LC7	93	7	–	–	–
S1	93.5	5	0.5	–	1
S2	93.0	5	1	–	1
S3	92.0	5	2	–	1
P1	94	5	–	1	–
P2	93	5	–	2	–
P3	92	5	–	3	–

Assessment of Mechanical Properties

Using a Shimadzu (Model: AG–1) universal tensile testing machine equipped with a 5 kN load cell and running at a crosshead speed of 10 mm/min, mechanical test measurements were performed at room temperature (25 ± 1°C). Films were used to cut the specimens in the machine's direction. Tensile tests were performed on virgin LDPE and compatibilized nanocomposite specimens with dimensions of $100 \times 15 \times 3$ mm^3 in accordance with ASTM-D 638-01 [19]. The provided values for tensile strength, YS, and TM are the averages of five tests per sample conducted in machine direction for all films with a gauge length of 10 mm.

Measurements of Rheology

The sophisticated rheometric expansion apparatus was used to investigate the viscoelastic behavior of the nanocomposites. Nanocomposites were compression molded at 160°C in a hot press to create disc samples. In dry nitrogen, frequency sweeps between 0.01 and 100 rad/s were carried out. The linear viscoelastic strain range was used to test nanocomposite materials for rheological measurements.

Microstructure of Nanocomposite

A transmission electron microscope (TEM) (JEOL JEM-2010) operating at an accelerating voltage of 120 kV was used to examine the microstructure of the nanocomposite. A cryomicrotome with a glass knife (Reichert Ultracut S Ultramicrotome, Model FC-S Cryo) microtomed extruded samples into extremely thin slices (<200 nm) in liquid nitrogen before being photographed in a TEM.

Differential Scanning Calorimetry

Using differential scanning electron microscopy [differential scanning calorimetry (DSC) electron microscopy], the samples' thermal behavior was examined. Using a Perkin Elmer DSC-7 (Perkin Elmer, Inc., Wellesley, MA, USA), DSC tests were performed for LDPE, LC5, LDPE/1 weight percent OxPE/5 weight percent clay (designated as P1), LDPE/2 weight percent OxPE/5 weight percent clay (designated as P2), LDPE/0.5 weight percent organosilane/5 weight percent clay (designated as S1), and LDPE/1 weight percent organosilane/5 weight percent clay (designated as S2). The degree of crystallinity (X_c), melting temperature ($\mathrm{T_m}$), and crystallization temperature ($\mathrm{T_c}$) were all measured using DSC. DSC studies were carried out using 8–10 mg samples that were enclosed in aluminum pans in a nitrogen environment. To prevent the impact of moisture, all test items were pre-dried in a vacuum oven set at 90°C before measurements were taken. The samples were first heated at a rate of 10°C per minute from 25°C to 180°C, maintained at that temperature for one minute, and then cooled to 25°C at a rate of 10°C per minute. The thermal history was then erased by a second heating that was identical to the previous heating. The melting scans of high-purity indium and zinc samples at the same heating rate were used to calibrate the temperature and heat capacity scales. During the second heating, the DSC thermograms were captured. Equation (1) can be used to calculate the degree of crystallinity in the samples mentioned above:

$$X_c = \frac{\Delta H_c}{\Delta H_m^0} \times 100\% \quad , \tag{1}$$

where:
X_c = degree of crystallinity.
ΔH_c = crystalline enthalpy of the sample.
ΔH^o_m = enthalpy of 100 % crystalline melting virgin LDPE.
(ΔH^o_m for LDPE = 279 J g^{-1}) [20].

RESULTS AND DISCUSSION

Assessment of Mechanical Properties

A tensile test was conducted to examine the mechanical characteristics of the nanocomposites, including their TS, YS, and TM.

Nanoclay Loading's Impact

Mechanical tests were conducted on nanocomposites and virgin LDPE with clay loadings ranging from 1 to 7 weight percent. Figure 1 illustrates the differences in the YS and TS of the nanocomposites with the clay contents. As the amount of clay in the nanocomposites increased, their mechanical qualities improved considerably. It is evident that compared to virgin LDPE, the nanocomposites exhibit higher yield and TS values. The LDPE/clay hybrid's TS and YS increased up to 5% clay loading (2.5% and 3.9% increment in TS and YS, respectively, for 1% and 12.7% and 19.4% increment in TS and YS, respectively, for 5%). Afterward, when the clay loading was increased further to 7% (8.9% and 13.6% increment in TS and YS, respectively), the TS and YS decreased. Dispersed nanolayers with a high aspect ratio have reinforcing properties, which are responsible for the strength increase. Numerous reinforcing nanoclay platelets that are found in the polymer matrix cause plastic deformation in the host polymer. These platelets function as effective stress transmission agents in nanocomposites.

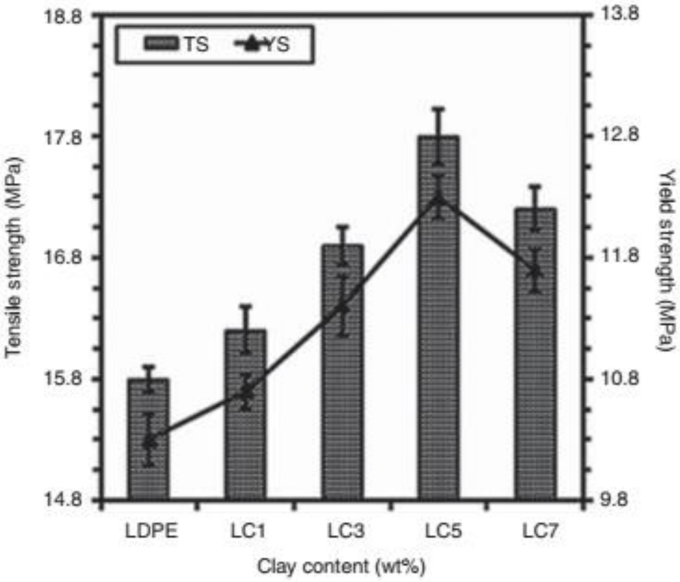

Figure 1. Impact of nanoclay content on the nanocomposites' TS and YS.

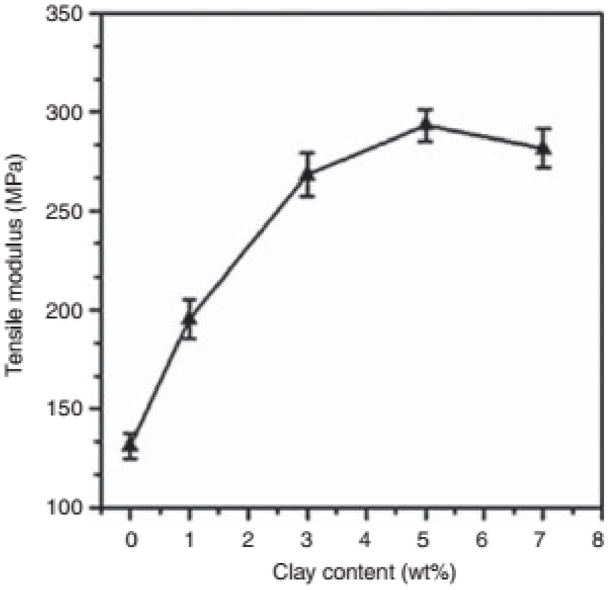

Figure 2. Impact of nanoclay content on the nanocomposites' TM.

As a function of clay content, Figure 2 displays comparable patterns in the TM of LDPE-based nanocomposites. In composites, the TM is typically associated with the filler dispersion and matrix–filler interaction. Fillers that are evenly distributed and have a high degree of contact with the matrix increase the composites' modulus [12, 14]. It is evident that the addition of OMMT raised the nanocomposites' TM. Between 0 weight percent clay (virgin LDPE) and 5 weight percent clay nanocomposites, the TM increased significantly, from 131 MPa to 293 MPa, which is a 124% increase in TM when compared with virgin LDPE. After that, the TM decreased when 7-weight percent clay was added to the nanocomposite. Both polymer chain orientation and nanocomposite orientation contribute to the increase in TM of nanocomposite films [21]. The expansion of the bubble in the hoop direction, which has a strong correlation with the improvement of mechanical characteristics, is what causes the orientation of the polymer chain [22].

Impact of Loading Compatibilizers

The performance of both compatibilizers in terms of mechanical features is intriguing. As shown in Figures 3 and 5, compatibilizer loading has an impact on the nanocomposites' TS, YS, and TM. The nanocomposites' YS and TS rose up to 1 weight percent of organosilane (S2) and 2 weight percent of OxPE (P2) addition, as shown in Figures 3 and 4. Above 2 weight percent P2 and 1 weight percent S2, these characteristics remained unaltered. Additionally, out of all the cases examined, the strength of nanocomposites containing S2 was the highest at 5% clay concentration. Comparing the nanocomposites to virgin LDPE, the greatest TS and YS were 23.2 ± 1.1 and 16.3 ± 0.8 MPa, respectively, up by roughly 47% and 58%. There are two factors that contribute to this improvement in mechanical characteristics. First, by acting as the cross-linking point, the modified nanosilica strengthened the adhesive force between the LDPE, limiting molecular deformation and enhancing tensile resistance. Additionally, the nanosilica assisted the LDPE matrix under partial stress during the pulling process, causing the stress crack to deflect, altering the crack's developmental trajectory, lengthening the crack's route, and increasing the energy cost. These effects all contribute to the composites' increased strength. At 21.3 ± 1.0 MPa for TS and 14.8 ± 1.1 MPa for YS, on the other hand, a lesser effect was observed. In nanocomposite samples made with the S2 compatibilizer, clay layers showed improved dispersion, as indicated by the composites' melt rheological behavior. Figure 5 illustrates how compatible nanocomposites' TM improved linearly when compared to the uncompatibilized one, reaching 2% for P2 and 1% for S2 compatibilizer loading before declining as

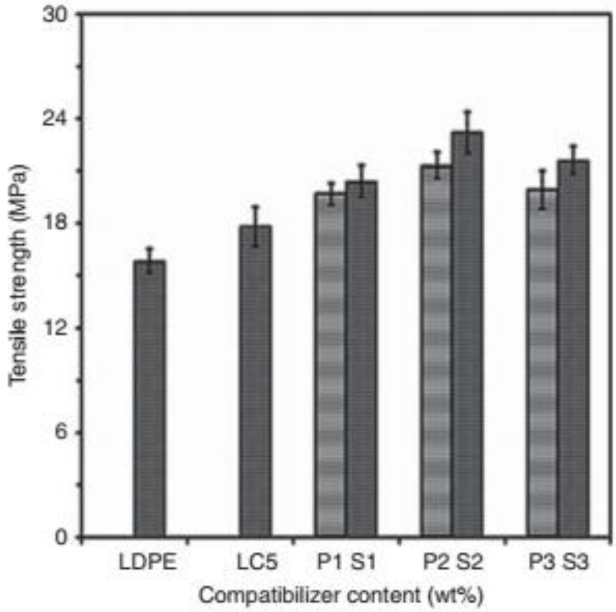

Figure 3. Impact of compatibilizer's content on the nanocomposites' TS.

compatibilizer loading increased. At approximately 393.4 ± 8.2 MPa, S2's TM was greater than P2's (355.1 ± 5.3 MPa). The composites' modulus is enhanced more when the fillers are evenly distributed and interact with the matrix [14]. According to the TEM examination, S2 most likely has a mixed morphology of exfoliation and intercalation. The compatibilized blends' TM is probably improved by the stronger addition between fillers and matrix that results from the inclusion of S2.

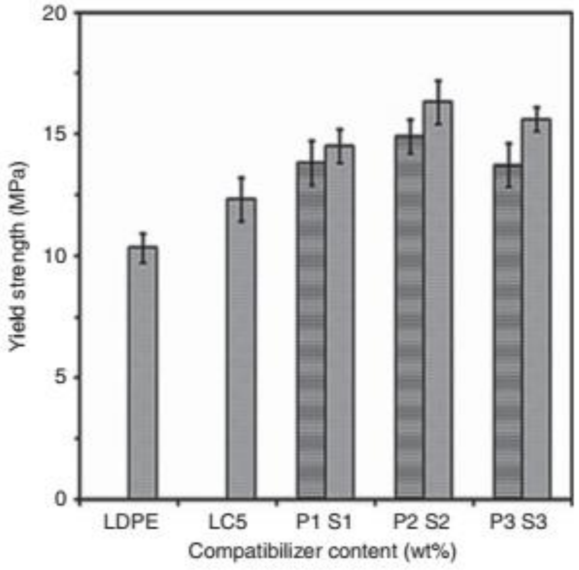

Figure 4. Impact of compatibilizer's content on the nanocompatibilizer's YS.

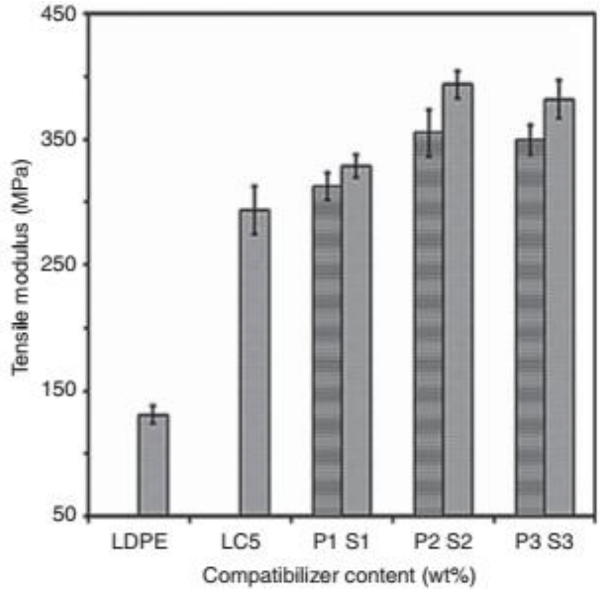

Figure 5. Impact of compatibilizer's content on the nanocomposites' TM.

Properties of Melt Rheology in Nanocomposites

Properties of Dynamic Oscillatory Shear Flow

From the perspective of polymer processing, the study of melt rheology is crucial. Additionally, it gives a sense of the melting microstructure. Rheological characteristics assessed at high shear rates and angular frequency regions are known to reflect the processability of polymers and polymer composites, while those measured at low angular frequency range are known to reflect the fluid's internal structure, such as filler dispersion and molecular interaction [23]. The frequency dependency of the storage modulus (G′) and dynamic viscosity (η*) of the LDPE, LC5, P2 (OxPE), and S2 (Organosilane) samples derived from the frequency sweep test are displayed in Figure 6. It is evident that, out of all the frequencies examined, the S2's G′ is the highest (Figure 6A). As is typical of solid-like materials, it was found that G′ for S2 and P2 becomes frequency independent, particularly at the low-frequency range. Strong interactions between the clay layers and polymer matrix are indicated by a low-frequency improvement in G′. To quantify clay dispersion, the following section will address this behavior and the size of the G′ enhancement at the low-frequency zone. At ω = 0.01 rad/s, the G′ values for LDPE, LC5, S2, and P2 are 1.7, 2.9, 2350, and 110 Pa, respectively. These findings suggest that the LDPE chains and the organoclay layers do not interact and that 5% (wt) of the organoclay cannot exhibit a noticeable filler effect in the absence of a compatibilizer. The LC5 sample might therefore be referred to as a "macro-composite." However, compared to the samples made with the S2 at a specific organoclay quantity, the G′ increase at the terminal region clearly shows that the P2 causes a considerable interaction at the interface between the polymer and clay layers, albeit at a lower level. For a given sample composition, it is reasonable to assume that clay layers will exhibit superior dispersion in the S2 series as opposed to the P2 series.

The frequency sweep test results for the LDPE, LC5, S2, and P2 samples are displayed in Figure 6B as η* vs. ω curves. As the frequency increased, the nanocomposites' η* declined, indicating "on non-Newtonian behavior." The orientation of stiff molecular chains in the polymer nanocomposites during the applied shear force may be the cause of the shear-thinning behavior seen in the nanocomposites. The strong shear-thinning behavior of the polymer nanocomposites with compatibilizers caused the compatibilizers' effect on η* of the nanocomposites to be more noticeable at low frequencies than at high ones, and this effect diminished with increasing frequency. It is evident that, at a specific organoclay quantity, the S2 produces a stronger contact at the interface between the clay and polymer layers than the samples made with the P2. The significant rise in the G′ was strongly associated with this enhancing effect.

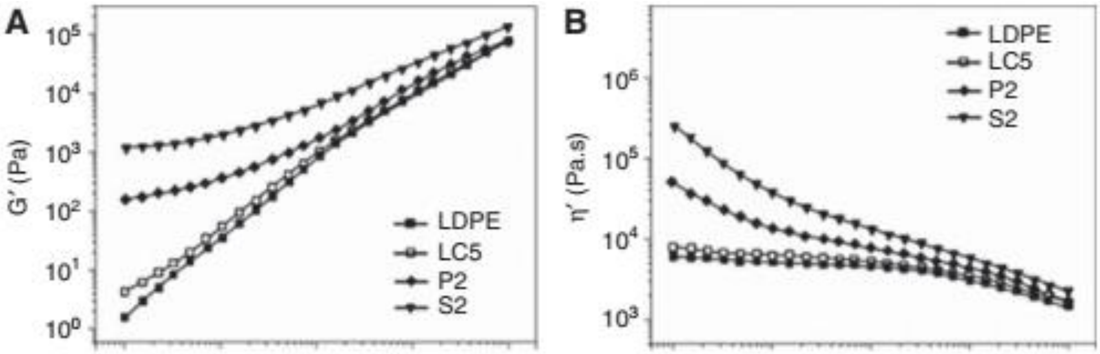

Figure 6. A comparison of the rheological characteristics of LDPE, LC5, P2 [oxidized polyethylene (OxPE)], and S2 (Organosilane). (A) The frequency dependence of storage modulus (G′); (B) the frequency dependency of dynamic viscosity (η*).

Clay Dispersion State

TEM has generally been used to clarify the structure of nanocomposites in the nanoscale range because it provides direct proof of the intercalation or exfoliation of the polymer chains into the silicate galleries. It is challenging to achieve homogeneous dispersion of the nanoparticles in the thermoplastic matrix. Silicate stacks with three to ten layers may be present in "very good" composites with a high degree of dispersion [24], but only under the right component and manufacturing circumstances can this be accomplished. When organosilane is added as a compatibilizer, a good dispersion can be obtained. The TEM micrographs for the LDPE/5 weight percent clay (designated as LC5) (Figure 1(A)), LDPE/7 weight percent clay (designated as LC7) (Figure 1(B)), LDPE/2 weight percent OxPE/5 weight percent clay (designated as P2) (Figure 1(C)), and LDPE/1 weight percent organosilane/5 weight percent clay (designated as S2) (Figure 1(D)) nanocomposites are displayed in Figure 7. The organic matrix is represented by the remaining region in these TEM photomicrographs, while stacked silicate platelets stand in for clay tactoids. Larger, non-intercalated clay particles are seen in Figure 7(B), where a typical "microcomposite" structure is created. However, some tactoids might be a sign of insufficiently distributed clay particles. As a result of the clay particles being divided into smaller units during the mixing process, Figure 7(A) displays relatively smaller clay particles than Figure 7(B). Figures 7(C) and 7(D) make it evident that the clay is evenly distributed throughout the LDPE matrix. Nevertheless, the use of the S2 compatibilizer resulted in a decent dispersion (Figure 7(D)). Because there were fewer black tactoids in S2's TEM micrograph than in P2, S2 showed a better and more consistent dispersion of clay in the LDPE matrix. Although there aren't many clay aggregates and intercalated platelets present at the same time, the S2 composite (Figure 7(D)) displayed well-dispersed structures with exfoliated platelets. The melted rheological characterizations of the nanocomposite samples agreed with these TEM morphological observations.

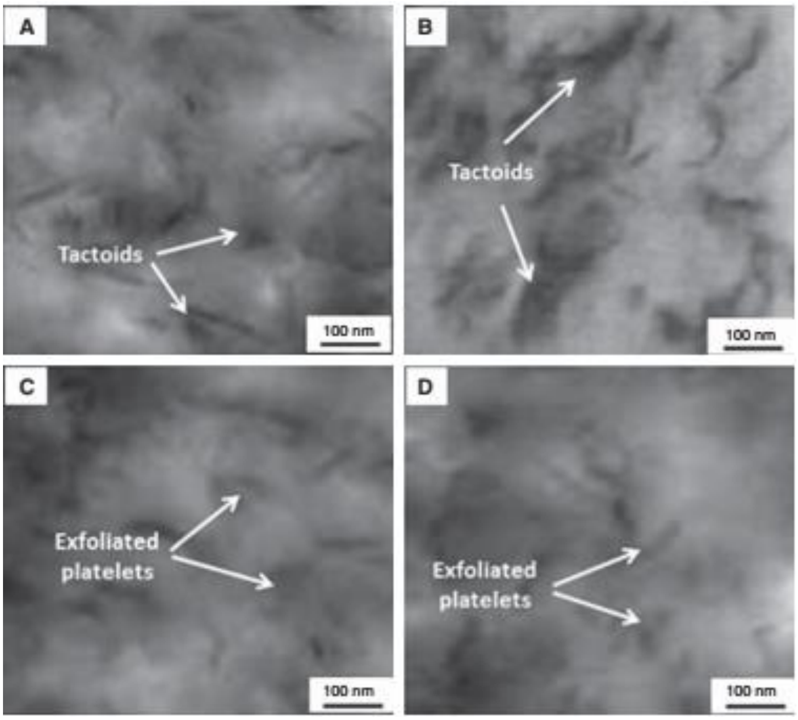

Figure 7. Images of nanocomposite samples taken with a TEM:
(A) LC5; (B) LC7; (C) P2, and (D) S2.

DSC Evaluation

In general, DSC analysis is among the most practical techniques for examining first-order transitions, such as melting and crystallization. The DSC cooling and melting thermographs of virgin LDPE, LC5, P2, and S2 nanocomposites are displayed in Figures 8(A) and (B). Table 2 displays the degree of crystallinity, melting parameters, and crystallization. It is evident that the crystallization behavior of LDPE is considerably altered by the addition of compatibilizers and clay. As the compatibilizer concentration increases, the specimens' Tc changes to higher temperatures when compared to virgin LDPE, as seen in Figure 8(A). Due to the heterogeneous nucleation of compatibilizer content, Figure 8(A) shows that the addition of compatibilizer raised the T_c of LDPE by approximately 2.9°C–7.9°C. It is hypothesized that clay and compatibilizer heterogeneous nucleation work in concert to promote LDPE crystallization. It is evident from Table 2 and Figure

8(B) that the peak melting temperatures rise marginally as the compatibilizer concentration rises, while the T_m barely changes. This is explained by clay's surface heterogeneous crystallization, which can enhance LDPE crystallization and marginally raise the T_m of nanocomposites. As can be observed, the T_m of virgin LDPE and LC5, P2, and S2 composites fall between 110.9°C and 112.6°C. The T_m of the nanocomposites shifts to higher temperatures as compared to virgin LDPE, with S2 obtaining the greatest T_m. Figure 9 displays the samples' variation in X_c (%). In the composite filled with P2 and S2 composites, the compatibilizer contents had an impact on the X_c, which was higher than that of the virgin LDPE. Because of this, the composites' YS was greater than that of virgin LDPE. Because the composite filled with S2 had a greater X_c than the composite filled with P2, the YS of the P2-filled composite was lower than that of the S2-filled composite. Higher crystallinity and T_c are the outcomes of semicrystalline polymers' tendency to increase the rate of crystallization through the addition of clay and compatibilizer components [24]. When clay and compatibilizer are added to LDPE matrix, the percentage of crystallinity increases, suggesting that the clay serves as an effective nucleating agent for the LDPE matrix's crystallization, according to Chiu et al. [25].

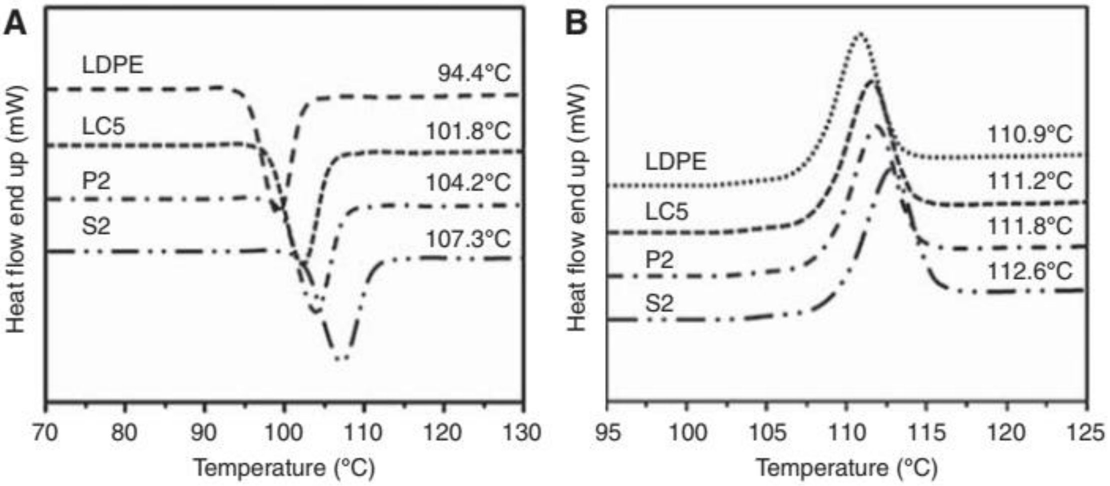

Figure 8. Crystallization and melting curves of virgin LDPE and its nanocomposites using DSC.

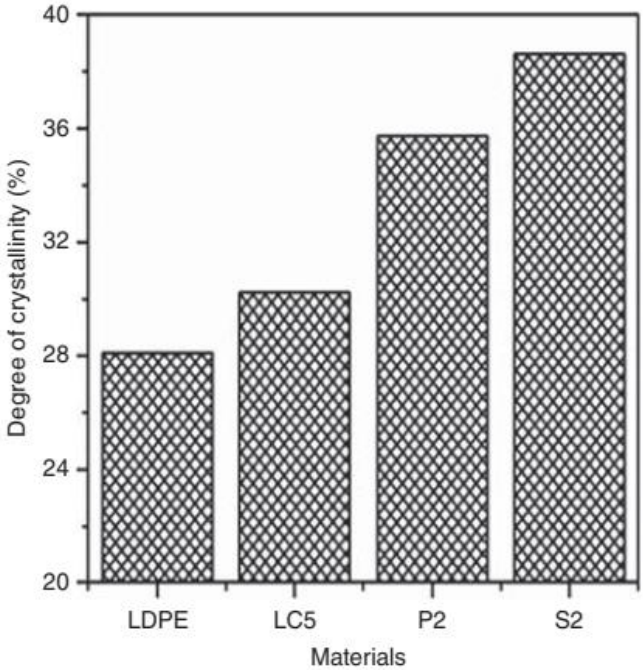

Figure 9. Virgin LDPE and its nanocomposites' crystallinity.

Table 2. Thermal characteristics of virgin LDPE and LDPE/clay nanocomposites.

Samples	**Crystallization Temperature (T_c) (ºC)**	**Melting Temperature (T_m) (ºC)**	**Degree of Crystallization (X_c) (%)**
Virgin LDPE	99.4	110.9	28.1
LC5	101.8	111.2	30.2
P1	102.3	111.3	31.6
P2	104.2	111.8	35.2
S1	105.1	112.1	35.7
S2	107.3	112.6	38.6

CONCLUSIONS

In this work, two compatibilizer types (OxPE or organosilane) were used to successfully manufacture LDPE/organoclay nanocomposites via melt-processing, and their mechanical properties were examined. The morphological, mechanical, and thermal properties of LDPE/organoclay nanocomposites were investigated by varying the compatibilizer addition. TEM images demonstrated that both compatibilizers were successful in promoting the delamination of silicate platelets. Compared to OxPE, organosilane made it easier to partially exfoliate the LDPE/organoclay nanocomposites. The samples' rheological characteristics also supported this conclusion. Higher mechanical qualities were supplied by the organosilane compatibilized instance compared to the OxPE compatibilized condition. DSC thermograms demonstrated that as the compatibilizer content rose, the LDPE system's crystallinity increased. It was also noted that the nanoparticles scattered throughout the nanocomposites might serve as a heterogeneous nucleation agent for the LDPE matrix's crystallization. Nonetheless, blends and nanocomposites showed notable variations in melting and crystallization temperatures.

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