

Characterization of Polymer Blend (Polystyrene/High Density Polyethylene) Using Scanning Electron Microscope (SEM) and Fourier transform Infrared Spectrophotometer (FTIR)

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Abstract: World's population increases by the day, calling for more modern technological needs, polymer blending is the alternative in the realm of material science and engineering because today's technology necessitates materials with amalgamated properties that are deficient in conventional class of polymers. In this research work, high-density polyethylene (HDPE) and polystyrene (PS) were blended in various percentage proportions, which are 100% HDPE 0% PS, and 50% HDPE/50% PS. Various characterization research was conducted to determine the properties of both the PB1 and PB2 using a scanning electron microscope (SEM) and Fourier transform Infrared Spectrophotometer (FTIR). A water absorption test was also conducted on the prepared blends. The results revealed that the PB2 exhibits better properties than the PB1 due to more strength and water absorption.

Keywords: characterization, polymer blends, absorption

I. INTRODUCTION

In today's world, technology requires polymeric materials with hybrid properties that conventional polymers such as polyvinyl chloride (PVC), polyterephthalate (PET), polyethylene (PE), polystyrene (PS), and others cannot provide. As a result, technologists, engineers, and scientists are bound to investigate novel polymeric materials to suit the diverse needs of today's applications. Low density, high abrasion resistance, impact resistance, and corrosion resistance are all desirable material properties. The advancement of blended materials has met and continues to widen these material property combinations and ranges (Brydson, 2015).

Polymer blending can improve toughness, durability, processability, chemical resistance, weatherability, heat stability/high distortion temperature resistance, and rheological behaviour in polymer melt (Hegberg et al., 1992).

Blending, in particular, provides a convenient and less expensive alternative to generating novel polymers. Blending can be customized to fit the needs of certain applications. Blending can produce a greater combination of attributes than either component alone (Ebewele, 2000).

Plastic composites are being studied for potential replacements for conventional materials such as aluminum, concrete, glass, and steel due to their low cost, lightweight, and high durability (Culbert et al., 2018).

Shao et al. (2018) described an innovative and effective technique for achieving better continuity at a lower interphase volume fraction by utilizing compatibilizers in a ternary blend of PVDF, PS, and HDPE. PVDF-g-PS was synthesized using an electron beam radiation-induced free radical graft copolymerization reaction and studied via FTIR, DSC, and ¹H NMR.

According to Dobrovsky and Ronkay (2016), producing polymer blends is an excellent technique to tune the good features of plastics, yet the most often used polymers are incompatible. As a result, an appropriate copolymer or compatibilizer must be added to blends in order to develop new contacts between the phases in order to minimize interfacial tension and achieve a finer and more stable morphology.

Polymers are large molecules or macromolecules that are made up of many repeated subunits. Polymer blends, on the other hand, are physical mixtures of two or more polymers that are made commercially using screw compounders and extruders to mix the polymers mechanically (Momohet et al., 2006).

Since the beginning of the 20th century, conventional polymers made from fossil fuels have been made. Because these polymers are useful, the plastics industry has grown steadily, leading to a huge amount of plastic being used in many ways (Mulder et al., 1998).

Blending polymers is a better way to make new materials with specific properties than making a new polymer from scratch. It is also often faster and cheaper than making a new polymer from scratch (Chirawithayaboon and Kiatkamjornwong, 2004).

In the field of polymer blends, it is well known that even small changes in the molecular structure of the different parts of the blend can have a big effect on how well they mix (Feed and Dudowicz, 2005).

Even though both PS and PE are widely used individually, there is little literature on PS and PE blends, including compatibilization of PE/PS and PE/PP, effects of blends on processing conditions, and formulation (Tasnim et al., 2002). In this study, it was found that the properties of both compatibilized and non-compatibilized blends were the same.

Furthermore, the morphology and properties of SEBS (poly [styrene]-b-(ethylene)-b-styrene) block copolymer-compatibilized PS/HDPE blends (Versna et al., 2007) Here, twin-screw extruders were used, and morphology was obtained using SEM.

Individual component characteristics and mix morphology interact to produce the material properties of polymer blends. Immiscible, moderately miscible, and completely miscible polymer blends are all examples of the third category of polymer blends based on thermodynamic miscibility. It is recognized that many polymer systems can be somewhat miscible, even though most polymer blends are impermeable. (Paul and Bucknal, 2002).

LDPE is frequently employed in the production of different containers, dispensing bottles, wash bottles, tubing, plastic bags for computer components, and various moulded laboratory equipment. Plastic bags are where it is most frequently used. Trays and multipurpose containers with corrosion-resistant work surfaces, flexible machinable parts, and parts that need to be weldable are some other products made from it (Brydson, 2016).

Mechanical recycling is a well-known technology for recovering conventional plastics such as polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), and polystyrene (PS). Its main advantage is that a portion of the resources used in the production of plastic materials is not wasted, but rather saved for use in the same, similar, or different applications. One disadvantage is that materials lose some of their physical and mechanical properties as their degradation increases as the number of processing cycles increases. Degradation can be minimized by using additives or virgin polymers, among other methods (Lazarevic et al., 2010).

Currently, there is a dearth of information on the qualities of polystyrene/waste high-density polyethylene blends, therefore this research aims to fill that gap. This will help with the development of novel materials for specific scientific and engineering uses that have balanced properties distinct from those of high-density polyethylene and polystyrene individually.

II. MATERIALS AND METHODS

Materials

KBr anhydrous, vacuum hydraulic (Graseby Specac), sticky carbon tape Distilled water, lint-free cloth, energy dispersive X-ray spectroscopy (SEM-EDS) Phenom Prox mode, vacuum hydraulic (Graseby Specac), Shimadzu Fourier transform Infrared Spectrophotometer FTIR 8400 SW weighing balance (Ohaus Corp Max capacity 150g), triple beam balance (Ohaus TBB Model 710-00 TBB), roll mill machine (NO. XH-401CE), compression machine (ASTM D1621 Plastic compression testing-ADMET), hacksaw.

Methods

Procedure for Blending, Weighing, and Compounding

Firstly, 100g of PB1 was measured with a triple beam balance and kept separately as a control sample, and about 50g of PB2 was also measured using a triple beam balance. As a result, there are two samples in total. Afterward, the two-roll mill machine was allowed to heat up to a temperature of 180 oC for both the rear and front rollers and was used for the compounding of each sample

Heat Pressing

The temperature of the heavy-duty compression machine was set at 160 oC with a pressure of 4.0 mPa. Processing oil was applied to the mould, and each sample to be pressed was placed in the mould, covered, and put into the machine. The samples were preheated for about 5 minutes, compressed for about 10 minutes, and cooled for about 5 minutes using the heavy-duty compression machine. A hacksaw was used to cut each sample into the desired shape (dumbbell) and sizes required to carry out the tensile strength test. A mold of the size of 10 cm x 0.3 cm was used to give each sample the required shape for carrying out other tests.

Procedure for Scanning Electron Microscope (SEM)

The morphology analysis was carried out using a Scanning Electron Microscope energy-dispersive X-ray spectroscopy (SEM-EDS) Phenom Prox model manufactured by Phenom-World Eindhoven, Netherlands. Using adhesive carbon tape, the sample was fastened to the aluminum holder stub. The sample was insulated with gold and then electrically grounded. The samples are then tagged on the stubs and dried in a 60 °C oven. To properly purge the chamber, the nitrogen line was opened to 50 psi and the vent button was pressed to fill the region with nitrogen. The sample holder stub was then inserted into the sample chamber holes, the door was closed, the rotary pump was activated, and a vacuum of 5×10^{-5} Pa was created. The filament light was turned on, and the monitor was turned on as well. The accelerator voltage was 15 kV at this point, and the filament had burned out. The electron beam excites the atoms on the surface, causing them to emit specific wavelengths of X-rays that are characteristic of the element's atomic structure. These X-ray emissions can be analyzed using an energy-dispersive detector (a solid-state

device that discriminates between X-ray energies). The composition of the atoms on the specimen surface is determined by assigning appropriate elements. The lowest scan mode of 10x is selected, and the TV scan button is pressed. The magnification is then increased at a slow scan to 1000x, 2000, 3,000, and 5,000. The intensity of each element present in the energy dispersion spectrum can be used to calculate the molar concentration in percent, and the image is saved

Procedure for Using a Fourier Transform Infrared Spectrophotometer (FTIR).

For functional unit determination, the Shimadzu Fourier transform Infrared Spectrophotometer FTIR 8400S was used. Samples were weighed in at 0.01g and homogenized with 0.01g of KBr anhydrous by mortar agate. The mixtures were pressed by vacuum hydraulic (Graseby Specac) at 1.2 psi to obtain transparent pellets. The scanned sample passed through infrared, where its continuing wave by the detector is connected to a computer and gives a description of the tested sample spectrum. Samples were usually scanned in the absorption area of 600 to 4000 cm⁻¹. As basic spectrum types, the results of the analysis were the chemical structure, the way molecules stuck together, and certain functional groups of the samples that were tested.

Water Absorption Procedure.

ASTM D570: Standard Test Method for Water Absorption of Plastics.

This test method for rate of water absorption has two chief functions:

first, as a guide to the proportion of water absorbed by a material and, consequently, in those cases where the relationships between moisture and electrical or mechanical properties, dimensions, or appearance have been determined, as a guide to the effects of exposure to water or humid conditions on such properties; and second, as a control test on the uniformity of a product. It is particularly applicable to sheet, rod, and tube arms when the test is done on the finished product.

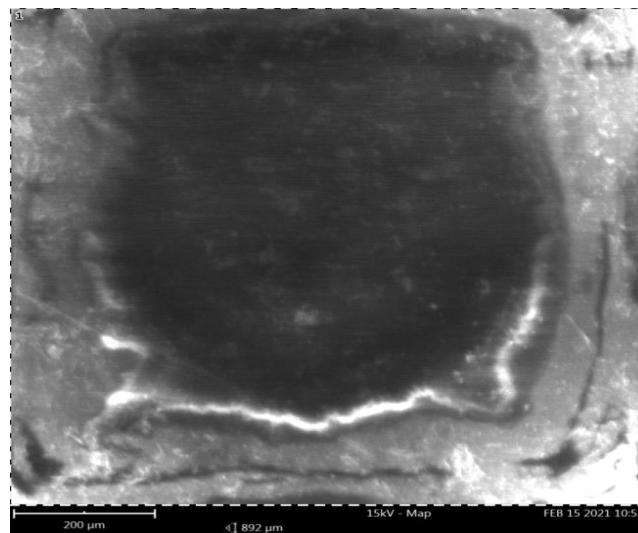
For the water absorption test, the specimens are dried in an oven for a specified time and temperature and then placed in a desiccator to cool. Immediately upon cooling, the specimens are weighed. The material is then immersed in water at agreed upon conditions, often 23°C for 24 hours or until equilibrium. Specimens are removed, patted dry with a lint-free cloth, and weighed.

III. RESULT AND DISCUSSION.

SEM Results and Discussion for a 100-0 HDPE/Polystyrene (PS) Blend

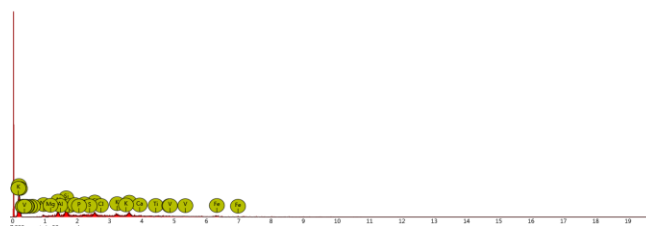
Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	55.62	32.28
14	Si	Silicon	8.40	11.40
20	Ca	Calcium	5.45	10.56
17	Cl	Chlorine	5.47	9.38
26	Fe	Iron	2.83	7.65
13	Al	Aluminum	5.79	7.55
19	K	Potassium	3.02	5.71
11	Na	Sodium	4.95	5.49
16	S	Sulfur	2.57	3.98
15	P	Phosphorus	1.66	2.49
12	Mg	Magnesium	1.07	1.26
7	N	Nitrogen	1.84	1.24
8	O	Oxygen	1.31	1.01
22	Ti	Titanium	0.00	0.00
23	V	Vanadium	0.00	0.00

Fig 1: SEM Analysis on 100-0 HDPE and Polystyrene (PS) Blend

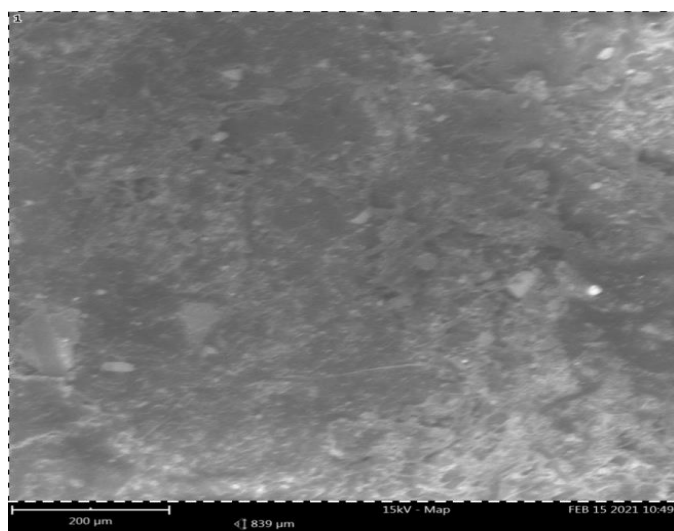


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Fig 2. Result And Discussion For Sem On 50-50 Polystyrene And Hdpe Blend

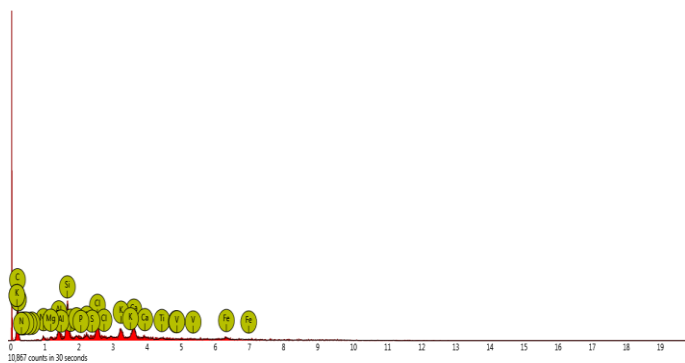


Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	39.83	19.39
14	Si	Silicon	15.23	17.34
17	Cl	Chlorine	9.67	13.89
20	Ca	Calcium	7.47	12.14
19	K	Potassium	5.53	8.77
26	Fe	Iron	2.96	6.70
13	Al	Aluminium	5.29	5.78
11	Na	Sodium	4.27	3.98
22	Ti	Titanium	1.59	3.09
16	S	Sulfur	2.29	2.98
15	P	Phosphorus	1.45	1.82
12	Mg	Magnesium	1.67	1.65
23	V	Vanadium	0.51	1.06
8	O	Oxygen	1.61	1.05
7	N	Nitrogen	0.62	0.35



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Fig 3: SEM Analysis on 50-50 Polystyrene and HDPE Blend

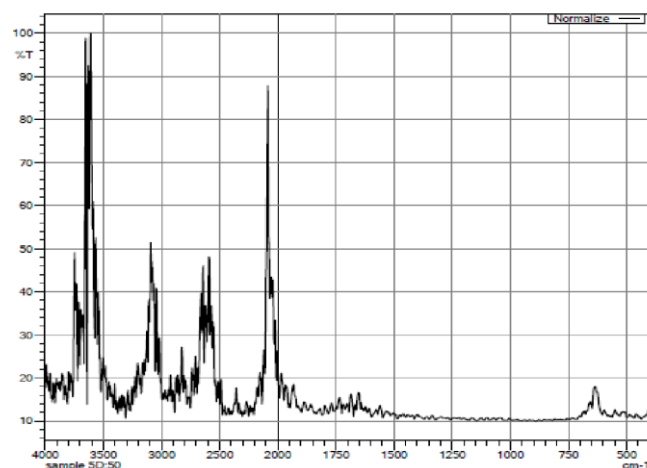


Result and Discussion for FTIR

An FTIR analysis of polystyrene and High Density Polyethylene (HDPE) blends 50-50 and 100-0 is described. A spectra of the blend at 50-50 is shown in Figure 4. The frequencies and assignments of FTIR absorption bands are summarized below. The band at 3448 cm^{-1} is related to the stretching vibrations of OH groups. As can be seen from the spectra of carbon/polyester and glass/polyester, the stretching vibrations of the OH group were shifted to 3444 and 3445 cm^{-1} . From this point of view, it is probable that hydrogen bonds may occur between blend samples. The bands in the range of $2900\text{--}3100\text{ cm}^{-1}$ correspond to stretching vibrations of CH groups such as CH_2 and CH_3 . After the blends are cured, it is seen that the stretching vibrations of CH groups have about the same absorption bands.

In the spectrum of the blend, a very intensive band was observed at 1728 cm^{-1} due to stretching vibrations of the CO group. Small changes occur, leading to the shifts of wavenumber toward higher frequencies in the spectra of the blends. Weak bands at 1599 , 1580 , and 1493 cm^{-1} were observed in the spectrum, which can be assigned to the aromatic ring. It can be said that these bands attributed to aromatic rings do not change their positions. No interaction occurs between the aromatic ring and either fibre. The bands located at 1453 and 1380 cm^{-1} may correspond to asymmetric and symmetric deformation bands of methyl groups, respectively. It is seen from the spectrum of blends that these bands appear simultaneously.

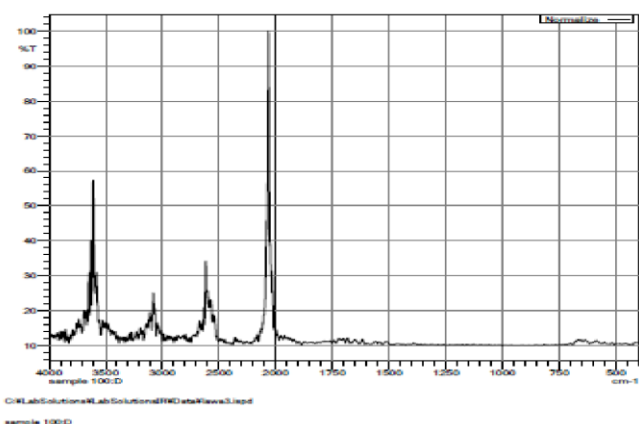
Fig 4: FTIR Analysis of 50-50 HDPE and Polystyrene blend.



The strong band at 1284 cm^{-1} , which appears in the spectrum of polyester, is due to the twisting vibration of CH_2 groups. After the polystyrene resin is transferred, blended, and cured, the band shifts to lower frequencies. The band locations are different in the spectra of 1280 and 1282 cm^{-1} , respectively. It can be claimed that CO weak interactions may occur between CH_2 groups and aromatics. Two strong bands at 1121 and 1065 cm^{-1} , which are thought to be CO stretching vibrations, don't move in the spectra of the blends.

The spectra of the 100% cured Polystyrene neat resin, as shown in fig. 5, demonstrates the assignment of the main infrared absorption of the neat Polystyrene used in this work. OH, stretching vibrations of polystyrene give a typical broadband of 3364 cm^{-1} . As can be seen from the spectra of the neat polystyrene, the stretching vibrations of OH groups of the polystyrene resin were shifted to 3397 and 3419 cm^{-1} . Aliphatic CH stretching vibrations can be seen in the range of $3000\text{--}2800\text{ cm}^{-1}$. There are not so many variations on these bands. The band at 2360 cm^{-1} in the spectrum cannot be seen properly in the spectra of the neat polystyrene resin. A new absorbing peak at 2360 cm^{-1} was observed in the spectrum, showing a weak Bond

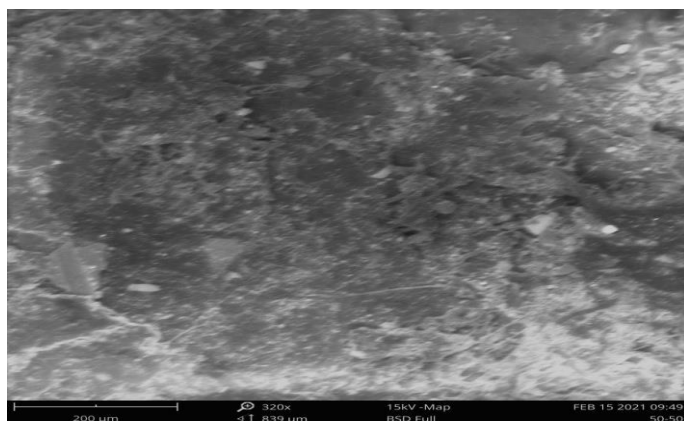
Fig 5: FTIR Analysis of 100% HDPE and 0% Polystyrene



Morphological analysis of polyester-based composites

The clean 100-0 surfaces indicate extensive interfacial failure. In addition, there is no matrix material to blend the materials on the post-fracture surface with the matrix material. Because of the weak matrix adhesion, damage evolution occurs at early stages, and the stress transfer from critically stressed fibers to lower-stressed regions cannot be done properly. 50-50 surfaces are almost completely devoid of challenges, designating them with no failure. Furthermore, the matrices are holding each other together more tightly. These results may suggest that bonding between the blends at the interface between blends is good with quality interfacial adhesion, which could be the dominant mechanism of non-failure for this loading mode. It is possible to observe clear local differences in the representative images of the strong bond region for blended specimens. In the lower photomicrograph, a higher magnification image clearly shows a clean blend surface, although a small amount of polymer can be seen between the blends. From these, chemical bonds take place in the matrix material. These observations may suggest an adhesive at the interface between blended matrices.

Fig 6: Morphological analysis of polyester-based composites of 100-0 HDPE AND PS



Morphological analysis of epoxy-based composites

The fracture surface of a composite glass fiber with an intermediate bond strength is shown in Figure 7. The noncoupled composite showed uncoated fiber ends pulled from the polymer. Note the considerable amount of fiber pull-out and the irregular fracture surfaces. The clean fiber surfaces on the debonding cracks indicate extensive interfacial failure. Despite this fact, the fiber still shows traces of matrix in and around the fiber. The fibers are loosely held by the matrix material after failure.

Failure occurred in plies of carbon fabric laminate due to both matrix cohesive fractures and fiber breakage. However, the composite showed considerable matrix failure, with the fibers being tightly held by the matrix material. A considerable amount of matrix tearing propagated along the resin-rich region could be observed, together with cavities left by the pull-out fibers. In this case, the broken matrix pieces still adhered to the fibers.

Fig 7: Morphological analysis of polyester-based composites for 50-50 HDPE and PS

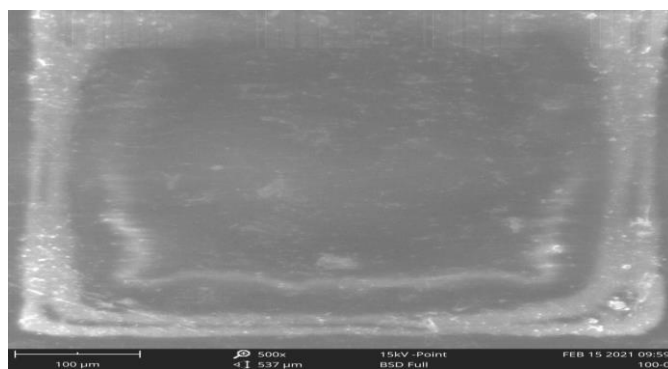


Table 1. Water Absorption Results And Discussion For 50% Hdpe/50 Ps Blend And 100% Hdpe/0% Ps Blend

SAMPLE	INITIAL WEIGH(g)	FINAL WEIGHT (g)
50% HDPE/ 50% PS	50g	52.47g
100% HDPE/ 0%PS	50g	50.76g

The initial weight of the 50 % HDPE/50 PS blend was 50g, whereas the final weight was 52.47g, indicating an increase in the weight of the 50 percent HDPE/50 PS. The initial weight of 100% HDPE/0% PS is 50g, while the end weight is 50.76g, indicating a very minor weight increase due to the low level of water absorbed. By comparing the water absorption values of both samples, it was discovered that the water absorption of 50% HDPE and 50% PS is greater than the water absorption of 100% HDPE and 0% PS.

IV. CONCLUSION

Based on the results obtained from the scanning electron microscopy (SEM) analysis of the 50% HDPE/50 PS blend and 100% HDPE/0% PS blend, it is evident that there is an absence of titanium (Ti) and vanadium (V) atomic concentration and weight concentration in the 100% HDPE/0% PS blend, whereas there is 1.59 atomic concentration and 3.09 weight concentration of titanium (Ti) in the 50% HDPE/50 PS blend and 0.51 atomic concentration and 1.06 weight concentration of vanadium (V) in the blend to make it stronger.

In the FTIR analysis, the clean 100% HDPE and 0% PS surfaces indicate extensive interfacial failure. In addition, there is no matrix material to blend the materials on the post-fracture surface with the matrix material. Because of the weak matrix adhesion, damage evolution occurs at early stages, and the stress transfer from critically stressed fibers to lower-stressed regions cannot be done properly. whereas surfaces made of 50% HDPE and 50% PS are almost completely devoid of challenges, designing with no failure. Furthermore, the matrix is holding each other together more tightly. These results may suggest that bonding between the blends at the interface between blends is good with quality interfacial adhesion, which could be the dominant mechanism of non-failure for this loading mode.

For the water absorption, comparing the value of water absorbed by both samples, it was observed that the water absorption of 50% HDPE and 50% PS is higher than the water absorption of 100% HDPE and 0% PS.

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