



Modification of Polyethylene and Incorporation of $\text{Al}(\text{OH})_3$ for Improvement of Mechanical Properties, Burning Behaviour and Thermal Stability

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ABSTRACT

In order to improve thermo-mechanical and flame-retardant properties of polyethylene, the polymer was cross-linked with vinyltriethoxysilane by using benzoyl peroxide as an initiator; and then various concentrations (0-35%) of aluminium hydroxide (ATH) were incorporated. The effect of curing was observed with respect to improvement in mechanical, thermal and burning properties. The three types of blends (unmodified PE, uncured silane-grafted PE and silane-cross-linked PE loaded with ATH) in the form of heat pressed sheets, were characterized for their mechanical properties like tensile strength and elongation-at-break. Solvent uptake, thermogravimetric analysis and burning behaviour of the blends were studied to determine the effect of increased filler concentration, thermal stability and time required for burning, respectively. It was observed that modification of polyethylene (PE) not only mitigates the reduction in these properties in simple polyethylene but actually enhances them by modification. In the case of simple PE, the incorporation of filler causes a marked deterioration in mechanical properties (elongation-at-break and tensile strength). However, approximately 20% increase in tensile strength and 50% control over the drastic decrease in elongation-at-break were observed for modified and filled polyethylene. The previously reported results show degradation of both these properties. In the proposed method, modification of polyethylene by silane cross-linking improves the burning time approximately 2.5 fold that of the same amount of filler. A clear difference in these properties for the incorporation of ATH to PE, uncured silane-grafted PE and silane cross-linked PE has been found. These properties follow the order of superiority as: silane cross-linked PE > silane-grafted uncured PE > physically filled PE. The influence of cross-linking and filler concentration on thermo-mechanical and burning properties due to efficient interaction of filler with PE, and that of silane cross-linked PE is discussed and analyzed.

Key Words:

polyethylene;
vinyltriethoxysilane;
cross-linking;
mechanical properties;
thermal stability;
burning behaviour.

INTRODUCTION

Flammability and smoke emission problems in polymeric materials have acquired importance during the past few years, mainly for applications in automotive and cable and wire industry. In cable insulations, good flame resistance is desirable which can usually be achieved by the addition of metal-

lic oxides and hydroxides. Aluminium hydroxide or ATH is the most widely used flame-retardant filler, being available at modest cost and with wide range of particle sizes and shapes. It is a white non-toxic material soluble in acid and alkalis.

ATH was known to be a flame-

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retardant even almost a hundred years ago. Its use as a flame-retardant for elastomers appeared in 1921 and its further application to improve arc resistance was reported in 1956 [1]. Commercial use of ATH as flame-retardant seems to have started in polyester in 1960, whereas its low smoke benefits were recognized in 1970s [2-4].

High loading of metallic hydroxide fillers, for example magnesium hydroxide causes marked deterioration in physical properties [5]. To improve the physical properties and filler-polymer interactions, either filler is coated with some selected material or base polymer is modified or functionalized with polar molecules. Silane cross-linking is a useful technique to modify non-polar polymer matrix to rather polar one, which results in better polymer-filler interactions [6-9]. There have been many previous studies of cross-linking of PE by silanes, such as methyltriethoxysilane or vinyltriethoxysilane. Modification of LLDPE by silane cross-linking showed more enhancement in mechanical properties [10] than in the case of LDPE; and the incorporation of functionalized polyethylene combined with dicumyl peroxide and the silane coupling agent led to a pronounced improvement in the tensile strength compared to the composites with ATH untreated or treated by silane coupling agent alone [11]. Morshedian et al. [12] studied the effect of polymer structure and additives on the silane grafting of polyethylene by FTIR. The grafting efficiency of low molecular weight PE with silane was found to be superior. In another report [13], the silane cross-linking and its superiority over other cross-linking techniques have been reviewed in detail. The increase in tensile properties was either negligible or less pronounced. However, other physical and thermal properties have shown marked improvement by silane cross-linking.

As a well-known non-halogenated flame retardant for polymers, aluminium hydroxide (ATH) can be easily incorporated into thermoplastics due to its relatively non-toxic nature [14,15]. A recent report [16] also shows that modification of PE and PE/EVA blend with vinyltrimethoxysilane, and incorporation of ATH resulted in a somewhat enhanced tensile strength and flame-retardancy but decrease in elongation-at-break could not be controlled. The

synergistic behaviour of the ATH with Sb_2O_3 in the presence of tetrabromobisphenol-A, as a flame-retardant agent in high impact polystyrene has been studied by Mahdavian et al. [17]. The effect of ATH on flame-retardancy was not much pronounced as compared to Sb_2O_3 , while ATH exhibited better thermal stability as compared to the former.

In the present work, the improvement in mechanical and thermal properties, solvent uptake and burning behaviour of PE/ATH and modified PE/ATH blends has been studied in detail for the first time and compared with the recent published work. Modification of polymer base (LDPE) was followed by incorporation of filler with respect to enhancement in tensile properties and burning time; to control polymer dripping during burning and resistance to thermal degradation in the initial stage has also been discussed. The development of effective interactions in modified PE/ATH composite due to silane cross-linking and bringing about improvement in mechanical properties make the formulation suitable for high service temperature and ablative applications. This work provides guidelines for tailoring the above-mentioned properties of the material for specific purpose.

EXPERIMENTAL

Materials

Low density polyethylene (LDPE) (commercially known as Lotrene, MFI 3.5 g/10 min) granules were supplied by Qatar Petrochemical Limited Company, Qapco, Doha, Qatar; vinyltriethoxysilanes (F.Wt. 190.32, assay > 98%) was supplied by Fluka Chemika, dibutyl tin dilaurate (F.Wt. 631.56) of analytical grade was purchased from Merck-Schuchardt, benzoyl peroxide was purchased from Fluka Chemika and Xylene (99%) from Merck. Aluminium hydroxide used was white powder (Aldrich M = 78) with particle size \approx 7-15 micron. The powder was dried at 70°C keeping overnight in an oven before use. These chemicals were used without further purification.

Modification and Filling of PE and its Characterization

Grafting of silane onto PE was carried out by follow-

ing the procedure reported in a previous article [18]. In the first step, vinyltriethoxysilane was grafted onto PE chain through a free radical reaction initiated by benzoyl peroxide. A weighed amount (40 g) of powdered LDPE, 0.36 g (0.83%) of benzoyl peroxide, 3 mL of silane (6.3% w/w) and 0.2 g (0.46%) of catalyst dibutyl tin dilaurate were homogeneously mixed for 5 min in a closed Brabender mixer type (Rheodrive 5000-Haake, Germany) set at a temperature of 140°C. After 5 min of mixing, a weighed amount (5, 15, 25 and 35% by weight) of the filler, aluminium hydroxide was slowly added to each blend. Mixing was continued for further 5 min. Each blend was pressed into sheets (4 × 6") of 1 mm thickness in a heat press at 180°C.

In the second stage, the heat pressed sheets were cured in the presence of organotin catalyst dibutyl tin dilaurate in an autoclave at 105°C for 4 h.

Characterization of Gel Contents

Determination of Gel Content and Solvent Uptake

The gel content or insoluble fraction of silane-cross-linked filled material after solvent extraction was determined according to ASTM D2765-01 [19]. A sample of about 0.3 g was wrapped in a 120-mesh stainless steel cage. The wrapped sample was put in the Soxhlet apparatus and extracted with xylene by refluxing for 24 h. After extraction, the samples were weighed before and after drying in a vacuum oven at 70°C until constant weights were reached. The gel content and solvent uptake were then calculated using the following equations:

$$\text{Gel content (\%)} = \frac{\text{Final weight of the sample}}{\text{Initial weight of the sample}} \times 100 \quad (1)$$

$$\text{Solvent uptake factor} = \frac{\text{Weight of swollen gel}}{\text{Weight of gel}} \times 100 \quad (2)$$

Tensile Measurements

Tensile strength was measured according to the standard specifications and methods as reported earlier [5]. Specimens for the tensile tests were cut with a dumb-bell cutter according to BS 903 Part A2

1956 D. A rubber testing machine of an Instron Model 4301 S.No. H2711 High Wycombe (England) was used for measurement of tensile properties. The tests were carried out at a strain rate of 50 mm/min. The load cell of 500 kg was used. The corresponding isothermal stress-strain curve was used for determination of the ultimate tensile strength and percent elongation-at-break.

Burning Characteristics of the Samples

The burning properties of the samples were measured by a candle type flammability tester model D, made by Toyo Seiki Seisaku-SHO, Ltd. Japan. It works according to JIS K 7201 (Flammability test for high polymer materials by oxygen index method). A minimum LOI (19.5) for burning of the sample measured on the basis of hit and trial method was set for all the sample tests. The pressure of nitrogen and oxygen was adjusted by regulating values to 1.5 kg/cm² by following the manual instruction. The mixture of these gases was fed to the combustion section where it is uniformly mixed by means of glass beads at the bottom of the combustion section and then fed into the combustion column. After allowing the flow of gas mixture for 30 s, the upper portion of the specimen (dimension: 1 × 6.5 × 140 mm³) was ignited. After making sure that the entire upper end of the test specimen is burning like a candle, the igniter was removed and immediately started measuring the combustion time and burning behaviour. The combustion time and the visual observations about the burning properties for the whole samples are recorded in Table 2.

RESULTS AND DISCUSSION

Gel Contents and Solvent Uptake

The results of gel content of the ATH filled silane cross-linked PE blends are shown in Figure 1. In these results, the individual reported values were averaged from three test results with the standard deviation of 0.0-4.0%. Gel content increases with increase in ATH concentration in silane cross-linked PE. This behaviour is contrary to the case reported earlier [16] and it shows effective entanglement of ATH within the cross-linked network. The high value (81.5%) of

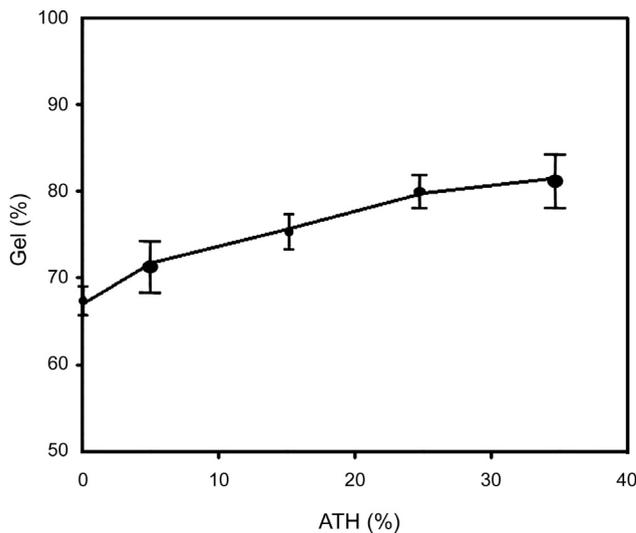


Figure 1. Effect of ATH concentration on gel contents of cross-linked PE.

gel found for 35% ATH loading could possibly be due to two reasons. First, with the increase of ATH, the LDPE concentration decreases simultaneously; which means that for the same concentration of silane and catalyst, the efficiency of cross-linking and gel formation increases. Secondly, either a significant amount of filler is chemically bound to the silane end of silane cross-linked PE or it is effectively trapped within the cross-linkages. Hence the free amount of filler, which could be in the form of aggregates or agglomerates, is comparatively smaller. Comparably, the unfilled silane cross-linked PE shows only 67% gel after 24 h of refluxing time. The increasing trend in gel contents (Figure 1) shows that an increase in filler concentration increases the efficiency of cross-linking as well as the effective interactions among the filler and polymer.

Figure 2 shows that the values of solvent uptake of various silane cross-linked PE/ATH blends decrease appreciably with filler concentration. These results can be explained on the basis of the difficulty in the diffusion of xylene into cross-linked samples with the increased amount of filler. The decrease in the diffusion of xylene into the network in this case is associated with the effective linkages (due to cross-linking and/or entanglements) and also filling of voids within the network with filler. In other words, increase in the filler concentration enhances the

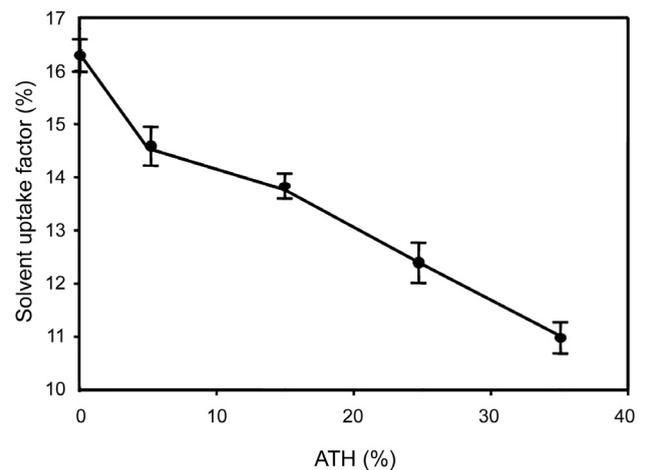


Figure 2. Effect of ATH concentration on solvent uptake factors of cross-linked PE.

network strength and decreases the free volume distributed within the cross-linkages, thus resulting in the reduction of solvent diffusion into the polymer network.

Effect of ATH on Mechanical Properties

The effect of incorporation of aluminium hydroxide (ATH) as non-halogenated filler over a concentration range of 0-35% w/w shows that its addition to modified (silane cross-linked) PE, imparts improvement in tensile properties. Table 1 shows the results of tensile strength and elongation-at-break for the composites prepared with ATH. Generally, it was observed that both of these properties (tensile strength and elongation-at-break) show a tendency to decrease with ATH concentration in PE samples. However, addition of ATH in silane cross-linked PE shows an improvement of about 20% (1.6 to 1.9 kg/mm²) in tensile strength. Nevertheless, elongation-at-break of the materials show marked deterioration in simple PE than in the case of modified PE. The tensile properties of the samples containing 5 to 35 wt% ATH, showed the worst effect on PE as compared to modified PE, which can be attributed to the non-homogeneity due to non-compatibility between the polar filler (ATH) and non-polar polyethylene matrix. On the other hand, the composites containing 5 wt% ATH with silane cross-linked and silane grafted samples showed improvement in tensile strength. It is an established

Table 1. Effect of Al(OH)₃ concentration on the mechanical properties of PE.

Sample	Al(OH) ₃ concentration	PE (Unmodified)		Silane grafted PE (uncured)		Silane grafted PE (cured)	
		Elongation-at-break (%)	Tensile strength (kg/mm ²)	Elongation-at-break (%)	Tensile strength (kg/mm ²)	Elongation-at-break (%)	Tensile strength (kg/mm ²)
Control	0%	720 ± 7.2	1.52 ± 0.21	234 ± 5.2	1.61 ± 0.23	150.1 ± 5.7	1.61 ± 0.32
A-1	5%	120 ± 2.1	0.94 ± 0.18	96.4 ± 2.2	1.41 ± 0.18	110.8 ± 5.3	1.89 ± 0.52
A-2	15%	34 ± 1.3	0.88 ± 0.11	57.1 ± 5.1	1.64 ± 0.19	43.52 ± 1.8	1.72 ± 0.14
A-3	25%	20 ± 2.2	0.87 ± 0.09	52.8 ± 4.2	1.47 ± 0.29	42.96 ± 2.1	1.74 ± 0.11
A-4	35%	15 ± 1.2	0.71 ± 0.12	35.6 ± 3.2	1.42 ± 0.22	26.88 ± 3.2	1.91 ± 0.13

fact that mechanical properties of the filled polymer are dictated by size, shape, concentration and nature of the dispersed phase and by its degree of interaction with the matrix [20]. In the case of PP, it has been reported [21] that when PP matrix is highly filled with aluminium hydroxide, although it achieves an adequate level of flame retardancy, but at the cost of a decrease in the physical properties due to an inadequate adhesion between the aluminium hydroxide particles and the PP matrix.

In modified PE, the incorporated filler acts as a reinforcing agent and shows a 20% increase in tensile strength of silane cross-linked PE. On the other hand, elongation-at-break shows a decrease from approximately 150% to 27% in modified samples, in contrast to unmodified samples where only 2-3% of elongation-at-break was retained. In a previous report, Wang et al. [15] suggested that it is the cross-linking, which is induced by the presence of the silane groups and is responsible for the improvements in tensile strength for PE/ATH composites prepared with silane cross-linked PE. However, our study shows that cross-links are formed due to the interaction between the Si-O of the silane on the PE with the filler promoted reinforcement and hence they give superior tensile strength as well.

In the mechanical properties study, the loss in tensile strength and elongation-at-break for unmodified filled and unfilled PE was found to be similar as reported in the previous article [16]. However, in this study, modification of PE by vinyltriethoxysilane resulted in improvement of tensile strength by

approximately 15% for the modified and ATH filled PE. The comparatively low value for elongation-at-break (150%) is due to an excessive amount of vinyltriethoxysilane used in this case, which created more cross-linking nodes. Nevertheless, for ATH-filled PE, the drastic decrease in elongation-at-break was somehow controlled (~43% as compared to 23% reported earlier). This is possibly due to cross-linking and effective interactions between the polymer and the filler, which result in reinforcement of tensile properties.

Effect of ATH on Burning Properties

The burning characteristics of the PE having ATH loaded through different modes of incorporation are shown in Table 2. In this case three types of samples; simple PE, silane grafted but uncured PE and that of cured PE were selected. For PE samples, not only burning time was shorter, but dripping and roll over phenomenon were observed as well. The silane cross-linked PE samples show improvement with respect to burning time and resistance to dripping behaviour. The silane grafted filled PE for each concentration of ATH presents better fire resistivity while the cross-linked samples show its further improvement. Physically loaded PE showed dripping behaviour especially at lower filler concentration. For physical incorporation, high ATH concentrations (~50% or more) are necessary for adequate flammability level [2,15]; however, high loading causes deterioration in physical properties. For the reinforcement in other physical and burning properties better interaction

Table 2. Effect of the Al(OH)₃ concentration on the burning properties of PE.

Filler concentration	Oxygen setting (LOI)	Samples		
		Physically bound	Chemically bound	
			(Uncured)	(Cured)
Al(OH) ₃ = 0% Control	19.5	Sample melts and drips and rolls over, small flame, falls within 41 s.	Sample withstands its standing position, no dripping and rolling off, burning time 92 s.	Sample withstands its standing position, no dripping and rolling off, burning time 100 s.
Al(OH) ₃ = 5%	19.5	Sample melts and drips, rolls over itself, small flame, falls within 90 s.	Sample withstands its standing position, no dripping and rolling off, burning time 148 s.	Sample withstands its standing position, no dripping and rolling off, burning time 158 s.
Al(OH) ₃ = 15%	20.0	Sample melts and drips, rolls over itself, falls within 105 s, small flame, no smoke.	Sample withstands its standing position no dripping and rolling off, burning time 155 s.	Sample withstands its standing position, no dripping and rolling off, burning time 180 s.
Al(OH) ₃ = 25%	24.0	Sample melts and drips, rolls over itself, falls within 30 s, medium flame, no smoke.	Sample withstands its standing position, no dripping and rolling off, burning time 115 s.	Sample withstands its standing position, no dripping and rolling off, burning time 135 s.
Al(OH) ₃ = 35%	28.0	Sample melts and drips, rolls over itself, falls within 58 s, medium flame, no smoke.	Sample withstands its standing position, no dripping and rolling off, no dripping observed, burning time 125 s.	Sample withstands its standing position, no dripping and rolling off, burning time 135 s.

between filler and matrix is important. For this purpose, a number of procedures are used. For example, functionalization of base polymer, coating of filler with selected materials and use of silane coupling agents are important in achieving higher interaction between the filler and polymer and hence improving the properties of the composite.

The mechanism of ATH acting as a non-halogenated flame retardant is well known. During burning, ATH produces Al₂O₃ and water as a result of thermal decomposition. Thus Al₂O₃ acts as refractory oxide that forms a protective layer inhibiting oxygen from feeding the fire [15] while water dilutes the combustible present in the gas phase and thus retarding the thermal degradation of the polymer. The order of superiority for three kinds of ATH filled PE with respect to fire retardancy shows: silane cross-linked PE > silane-grafted PE > PE at the same load-

ing level. The observation illustrates that silane cross-linking can increase the flame retardation of ATH filled PE in terms of burning characteristics. The reinforcement of the polymeric network due to the chemical nature and size of the filler particle has been reported previously [3,22-27]. In one of the reports [22], incorporated pyrogenic silica resulted into 100% increase in modulus and ten times increase in tensile strength of the silicon network. The enhancement in these properties was attributed to the small particle size of the filler (5-30 nm) and high concentration of silanol groups (2-3.5/nm²). Our results dictate that the hydrophilic metal hydroxyl groups on the surface of filler are usually incompatible with organic polymers. Alkoxysilanes provide a natural fit to modify the base polymer or surface of the filler to make it more compatible and dispersible in the polymer matrix.

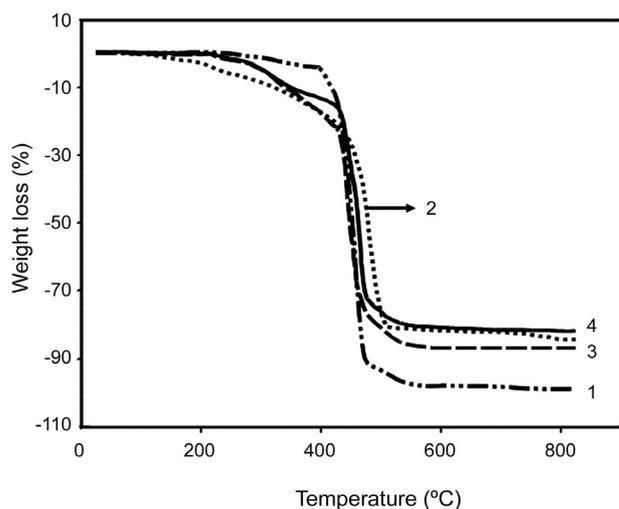


Figure 3. TG curves of modified and unmodified PE with 25% filled ATH: (1) silane-cross-linked (unfilled) PE, (2) unmodified and filled PE, (3) silane-grafted but uncured filled PE, (4) silane-cross-linked filled PE.

Thermal Stability

Thermogravimetric analysis was carried out to investigate the effect of ATH on modified (silane grafted and silane-cross-linked) and non-modified PE during heating under oxidative atmospheres. Out of the filled samples, 25% filled compositions were selected for thermal analysis (Figures 3-5). Because, at this ATH concentration not only drastic decrease in elongation-at-break was stopped but a marked improvement in tensile strength as well as burning time was achieved by silane cross-linking of base polymer. For polyethylene degradation, it is already reported [28] that the overall decomposition temperature of LDPE grafted with silane is higher than that of the virgin polymer.

To compare the thermal stabilities of the samples, the TGA curves have been divided into three regions (Figure 3). First the initial degradation region with temperature range from ambient to 450°C, the middle region from 451-480°C and the last region > 480°C. The first region which represents the initial degradation up to 450°C is rather slow and shows about 25% mass loss. In the second region, 30-80% mass loss occurred and this is the sharp degradation region. In the third region, the rest of the degradation occurred in the temperature regime of about 480-570°C, but at a slower rate. The thermal curves

show that in the silane cross-linked and ATH filled sample, degradation started at about 210°C as compared to unmodified counterpart which started degrading at about 120°C (Figure 3). Similarly, in the modified sample the initial 10% mass loss occurred at 280°C, whereas the same mass loss was observed at about 200°C for unmodified sample. The temperature difference decreased as the degradation proceeded further to 25% mass loss where degradation temperatures were observed at about 435°C and 405°C for filled silane cross-linked PE and filled unmodified PE, respectively. The second part of the curve is sharp and shows a drastic degradation region with mass loss of 55-60% at about 450-480°C. The TG curve for unmodified PE somehow exceeded the silane-cross-linked PE curve in the middle region. The DTG peak for modified PE was observed at slightly lower temperature (~10°C) as compared to unmodified PE (Figure 5). This behaviour could be due to some unknown secondary reactions. However, the initial degradation is important and more representative of the formulation's behaviour as compared to that in the second and third degradation regions. In the case of filled silane cross-linked PE, the additional thermal stability during the initial phase of degradation is attributed to the development of effective interactions between the filler and the matrix as a result of PE modification and the formation of linkages between Si-O- and ATH during cross-linking. It is believed that neither any interaction is developed between the filler and polymer, nor any cross-linking occurs between the filler and polymer. Then both decomposition temperatures should have been the same. DTA curves (Figure 4) show major peak for physical changes at 452-458°C for unfilled and filled (grafted but uncured) samples followed by additional minor peaks at 218-221°C. The loss of water from ATH in terms of Al_2O_3 and H_2O might have occurred in the latter low temperature regime.

However, two major peaks around 460°C and 483.1°C were observed for filled and cross-linked sample. There was no additional degradation peak observed that could be caused by elimination of pendant ethoxy groups from PE-vinyltriethoxysilane. Traditionally, ATH dissociates into Al_2O_3 and H_2O at about 200°C, but this apparently simple reaction is

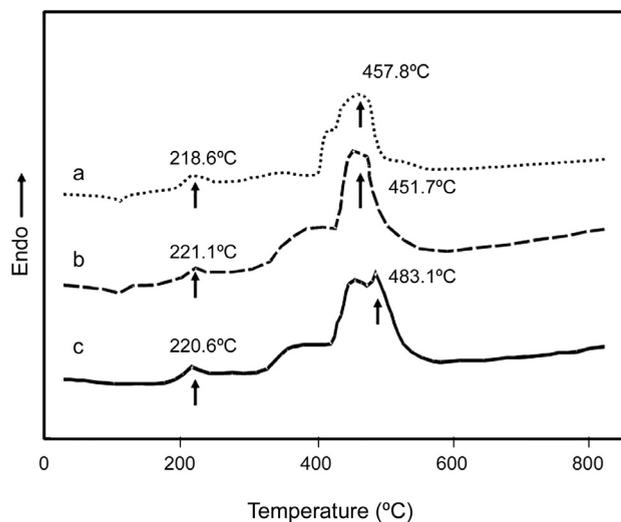


Figure 4. DTA peaks for modified unfilled and filled PEs: (a) silane-cross-linked PE (unfilled), (b) silane-grafted PE (25% ATH filled) and (c) silane-cross-linked PE (25% ATH filled).

quite complex. The rate and extent of decomposition are followed by two pathways. In addition to direct decomposition to oxide, a hydroxyl-oxide intermediate $\text{AlO}(\text{OH})$ can also be formed which decomposes at about 500°C . It is well known that formation of hydroxyl-oxide increases with the increase in particle size of ATH [29]. Non-uniform dispersion and then aggregate formation may lead to hydroxyl-oxide formation, but at this stage it is not easy to explain whether there is a hydroxyl-oxide formation from ATH or some fractions of filler is chemically bonded to PE resulting into the formation of Si-O-Al linkages. However, it was observed that all three samples always decompose within the same temperature range in all composites independently of PE-vinyltriethoxysilane and ATH concentration for analysis performed in air (Figure 3). These results show that none of the components affected the degradation mechanism of PE under the employed conditions. However, a small decomposition peak was observed near 218°C for unfilled and filled uncured samples corresponding to approximately 5-10% weight loss. This peak can be either attributed to further condensation of ethoxy groups or water elimination from ATH [30]. The residue left for filled silane cross-linked PE sample can be observed (Figure 3) as ~16% compared to that (~12%) of filled non-modified PE

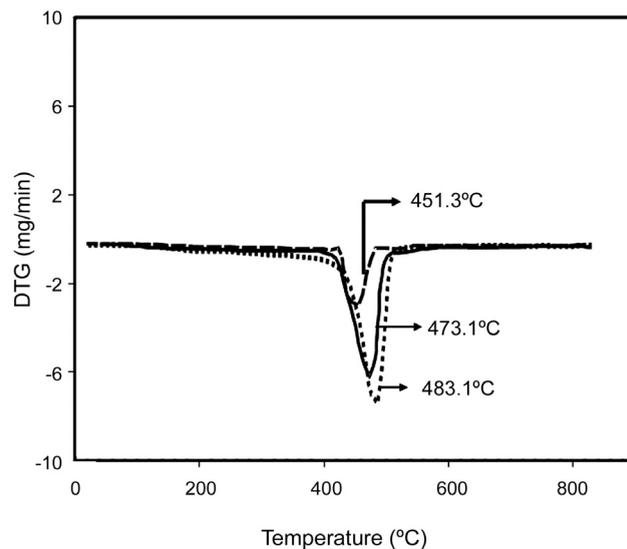


Figure 5. DTG peaks for 25% ATH filled PEs: (a) unmodified PE, (b) silane-grafted PE and (c) silane-cross-linked PE.

sample. This difference shows that silane cross-linked PE has relatively greater thermal stability as compared to non-modified filled PE.

CONCLUSION

Modification of polyethylene using silane cross-linking technique provides a considerable improvement in tensile strength as compared to its simple counterpart. However, due to the incorporation of ATH, a decrease in elongation-at-break (~97%) which was observed in simple PE, seems to be relatively controlled (~82%) silane cross-linked PE. Better mechanical properties (elongation-to-break and tensile strength) were observed at low filler concentration (5% filled) but for higher concentrations (15-35%), brittleness occurred in the samples.

Gel content increases with the increase in ATH concentration in silane cross-linked PE. This behaviour is contrary to the reported earlier and it shows an increase in cross-linking efficiency as well as effective entanglement of ATH within the cross-linked network.

Flame retardant properties for silane-grafted filled PE significantly increased for all filler concentrations. Increase in burning time and loss of dripping

behaviour in silane-modified PE shows that ATH is more compatible to be incorporated in silane cross-linked PE.

An improvement in thermal stability was observed for modified PE in terms of degradation as well as the residue left. The results of thermal gravimetric analysis showed that a filled-silane cross-linked PE is more thermally stable than silane-grafted (uncured) and unmodified filled LDPE. The shifting of the major degradation peak temperature (from 451 to 483°C) was observed for silane-cross-linked filled PE, which shows the effectiveness of interactions among the polar groups of the filler and the matrix.

The solvent uptake study revealed that increasing the ATH concentration in silane cross-linked PE, a decrease in solvent uptake was observed due to filling of voids by ATH in the cross-linked network.

Modification of polyethylene in such a way exerts somehow an "organizing" effect on distribution of filler. At lower concentration, this effect is observed to be pronounced due to its homogeneous distribution as compared to that of higher concentration of filler where agglomeration occurs.

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