MECHANICAL AND THERMAL PROPERTIES OF DOLOMITE FILLED POLYCARBONATE/ACRYLONITRILE BUTADIENE STYRENE COMPOSITES

Obinna Emmanuel Ezenkwa[1], Ahmad Safwan Ismail[1], Muhammad Akmal Ahmad Saidi[1], Rashitah Abd Rashid[2], Azman Hassan[1]* and Reza Arjmandi[3]

[1]School of Chemical & Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor.
[2]Mineral Research Centre, Department of Minerals and Geoscience Malaysia, Ipoh, Perak.
[3]Aston University, Polymer Processing & Performance Research Unit, Aston Institute of Materials Research, School of Engineering & Applied Science, Aston Triangle, Birmingham B4 7ET, England UK.

* Corresponding Author: azmanh@cheme.utm.my

ABSTRACT

Polycarbonate (PC)/acrylonitrile butadiene styrene (ABS) composites usefulness is majorly due to its good mechanical properties and low cost to performance ratio. The purpose of adding fillers into polymers is to further lower the cost and improve the mechanical properties of the composites. The objective of this study is to investigate the effects of dolomite content on the mechanical properties of PC/ABS blend and to determine the optimum formulation for the PC/ABS/dolomite composites. Dolomite content in the PC/ABS/dolomite composites was varied ranging from 0 to 15 wt.%. The composite samples were then tested for mechanical, thermal and flame retardancy properties. The study concluded that 5 wt.% dolomite content was the the optimum filler content for PC/ABS/dolomite composites.

Keywords: Dolomite, PC/ABS, Flammability, Mechanical, Thermal stability.

1.0 INTRODUCTION

Polycarbonate (PC) is a type of ductile thermoplastic polymer comparable to other polymers such as polyamide and polyesters [1]. PC is an ideal thermoplastic with good electrical insulating properties making PC a suitable material to be used in production of electrical appliance. It is characterized by its excellent dimensional stability, high elastic modulus, but with difficult processability [2]. PC has also been used widely in automotive industries. However, its notch sensitivity in thicker samples and processing properties limit its usability. This limitation can be improved by blending PC with other polymers such as acrylonitrile butadiene-styrene (ABS).

ABS is the largest-volume thermoplastic resin and known as bridge between commodity plastics and higher performance engineering thermoplastics [1]. ABS is characterized by its notch insensitivity, low cost but has poor chemical resistance, flammability and thermal stability properties [2]. The major composition in ABS is styrene which is over 50%. Styrene provides rigidity and processability whilst acrylonitrile offers chemical resistance and limited heat stability [3] to the composition. Butadiene offers toughness and impact strength. While PC is known for its good mechanical properties, ABS is of good chemical resistance [4]. Blending PC

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and ABS together produces a material with improved properties and processability, hence wider usability.

Although a blend of PC/ABS has shown improved mechanical properties with applications in automotive and electrical/electronic industries, fillers can be utilized to improve its properties of sound proof, thermal stability and stiffness-toughness balance. Filler incorporation also offers economy of scale by lowering cost of production. Several researchers [1, 5] have studied the effect of particulate fillers such as mica and silica on PC/ABS blend and found that filler incorporation enhances the stiffness of the composite blend but depreciates its tensile strength, flexural strength, elongation at break and impact strength. However, surface treating these fillers considerably improved these properties. Pour et al. [6], further reported that incorporation of graphene nanoplatelets filler into PC/ABS blend resulted in a nanocomposite with highly improved stiffness, flexural strength, tensile strength and thermal stability properties. The observed enhanced nanocomposite properties was due to uniform dispersion and alignment of the nano-filler within the matrix.

Dolomite is another inorganic material that can be utilized as filler in polymer composites. It is composed of calcium magnesium carbonate ($CaMg(CO_3)_2$) with varied amounts of impurities. Dolomite is known to have good thermal stability as reported in Bessa et al. [7]. A study by Savas et al. [8] reported that huntite/hydromagnesite filler, a variety of dolomite inorganic filler, improved the flame retardancy and thermal stability of its host thermoplastic polyurethane (TPU) matrix. Enhanced thermal stability and flammability properties of dolomite filled polymer composites has been attributed to its inherent endothermic decomposition and dilution effect via water and gas release as well as its formation of protective char layer in the condensed phase [9]. Adik et al. [10] and Din et al. [11] reported that incorporation of dolomite in polypropylene matrix improved the stiffness of the resulting polymer composites but decreased the tensile, flexural and impact strength.

Currently, there seems not to exist any study in the published literature on mechanical, and thermal properties of dolomite filled PC/ABS composite. This study therefore, investigates the effect of dolomite filler on the mechanical and thermal properties of PC/ABS blend.

2.0 METHODOLOGY

2.1 Materials

The main materials used which were PC (Panlite-L-1225Y) and the ABS (Toyolac 700-324), were supplied by Tenjin Chemical and Toray Plastic respectively. Both materials were supplied in pellet form. Dolomite was supplied by Department of Minerals and Geoscience Malaysia, Ipoh, Perak, Malaysia and received in powder form.

2.2 Preparation of PC/ABS/dolomite Composites

Based on literatures [6,12], the optimum formulation for PC/ABS was found to be 70:30 wt.% that is used throughout this research. Prior to compounding, PC was dried in a circulation oven at 120 °C for 8 hours and ABS was dried for 6 hours at 85 °C to remove moisture. The materials were physically mixed according to Table 1 in a tumbler mixer for 15 minutes to ensure homogeneity. Each formulation was then compounded via a co-rotating twin screw extruder with L/D =36 (Sino-Alloy PSM32) at a speed of 200 rpm. The extruded strands were then air-cooled

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and pelletized. After that, they are injection molded (Battenfeld 1600/200CDC) into several standard test samples i.e. tensile, flexural and Izod impact. The temperature profiles for both extrusion and injection molding were 220/230/240/250 °C.

Table 1 Formulations for PC/ABS/dolomite composites

Blends	70/30 PC/ABS (wt.%)	Dolomite (wt.%)
PC/ABS	100	-
PC/ABS/D-5	95	5
PC/ABS/D-10	90	10
PC/ABS/D-15	85	15

2.3 Tests and Characterizations

2.3.1 Tensile Properties

The tensile strength, Young's modulus and elongation at break of the composites were determined at room temperature ($25 \pm 2°C$) and $50 \pm 5\%$ relative humidity according to ISO 527-2. Tensile properties were done using a Lloyd EZ20KN universal testing machine with the crosshead speed of 5 mm/min. The tensile properties were expressed as an average value of measurement made from at least five samples per formulation.

2.3.2 Flexural Properties

Flexural test was carried out using a Lloyd EZ20KN universal tensile machine according to ASTM D790. The span was set to 4.96 cm and the strain rate was 3 mm/min. The flexural properties were measured at room temperature ($25 \pm 2°C$) and $50 \pm 5\%$ relative humidity. The average value of at least five samples for each formulation were taken and reported.

2.3.3 Izod Impact Test

The impact test was performed according to ASTM D 256A by using a Ray-Ran Izod impact tester, pendulum type model (Model Toyoseiki). The test specimens were notched using a notching machine in which the notch depth fixed at 2.50 ± 0.05 mm. The test was repeated ten times for each formulation and the average reported in J/m. Each test was performed at room temperature ($25 \pm 2°C$) and $50 \pm 5\%$ relative humidity.

2.3.4 Thermogravimetric Analysis

Thermogravimetric analysis (TGA) of PC/ABS blend and PC/ABS/dolomite was performed using a Perkin Elmer thermogravimetric analyzer (TGA 7). The temperature ranged from 30 to 700 °C with heating rate of 10 °C/min under nitrogen atmosphere to examine the thermal degradation behavior.

2.3.5 Differential Scanning Calorimetry

Differential scanning calorimetry (DSC) were carried out using a Mettler Toledo 882e DSC equipment to obtain the glass transition (T_g), melting (T_m), and crystallization (T_c) temperatures.

The heating/cooling rate was set to 10 °C/min within temperature range of 30 to 260 °C under nitrogen atmosphere. To eliminate thermal history of the samples, the second heating of the samples was taken.

2.3.6 Limiting Oxygen Index (LOI)

In this research, LOI was performed according to ASTM D2863. The specimens with dimension of 6.5 mm x 3 mm x 50 mm were positioned vertically in a transparent test column. A gas mixture of oxygen and nitrogen with the desired concentration was pumped through the column. After 30 seconds, the specimens were ignited at the top. The oxygen concentration was adjusted until oxygen level was sufficient to support flaming combustion of the samples. The amount of oxygen needed to support the combustion was then recorded. Each test was repeated five times.

### 3.0 RESULTS & DISCUSSION

3.1 Tensile Properties

The tensile strength of PC/ABS 70/30 blends with varying percentage of dolomite shown in Figure 1. Addition of dolomite into PC/ABS 70/30 reduced its tensile strength. There was only a minimal reduction in the tensile strength in the presence of 5 wt.% dolomite. However, as the percentage of dolomite present in the blends increased, the tensile strength decreased sharply. This pattern of changes indicates that the strength of PC/ABS blends was compromised in the presence of dolomite as filler. The PC/ABS blends contain 15 wt.% of dolomite showed the lowest value of tensile strength. This is consistent with a previous study on mica filled PC/ABS which showed that tensile strength of the blends decreased as mica content increased [1]. The tensile strength decreased due to inevitably increased agglomeration of dispersed filler particle. Decrease in the mechanical strength of polymer blends in the presence of filler could be due to poor dispersion of filler, presence of agglomerates or existence of defect such as void [13].
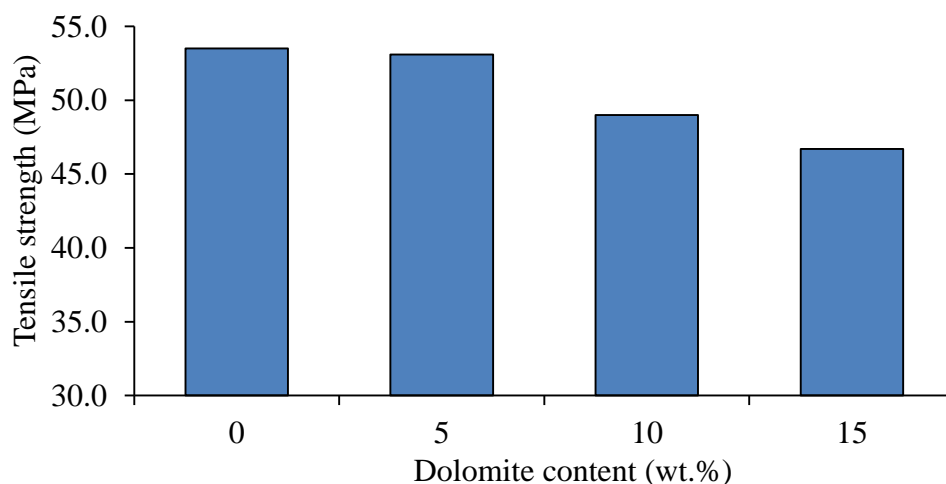
Figure 1 Effect of dolomite content on tensile strength of PC/ABS 70/30 blends
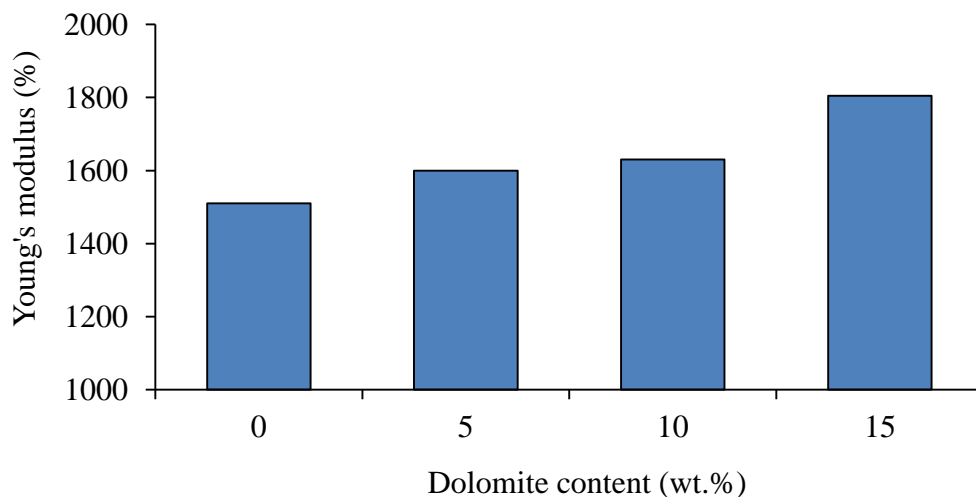
The effect of dolomite content on elongation at break of PC/ABS blends is shown in Figure 2. The elongation at break of the blends decreases dramatically to about 78 % in the presence of 5 wt.% dolomite. However further addition of dolomite only affects the property minimally as demonstrated by the slower rate of reduction in the percentage of elongation at break with increasing dolomite content. This shows that the blends become more brittle with

increase in dolomite loading owing the stress concentration effect of dolomite. Similar observation was reported in previous studies [1, 14]. Decrease in elongation at break is due to development of crack around the filler particles and possible formation of agglomerates and voids resulting local detachment of the matrix from the particles [2].
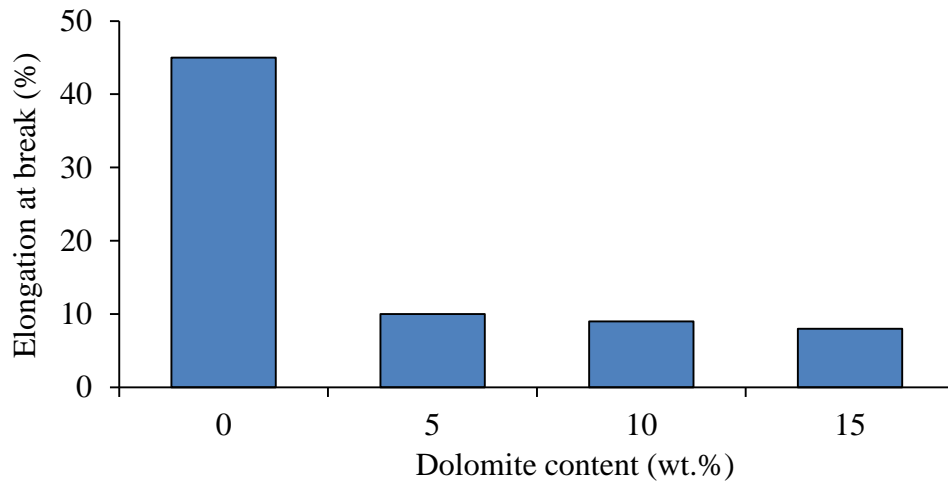
Figure 2 Effect of dolomite content on elongation at break of PC/ABS 70/30 blends

Figure 3 shows Young's modulus of PC/ABS 70/30 increases steadily as the dolomite content increases. Young's modulus for the blend containing 5 wt.% dolomite increases about 6 % and the blend containing 15 wt.% dolomite has the highest Young's modulus which is 1804 MPa. Stiffness enhancement by the increasing filler content is due to the inherent stiffness property of the inorganic filler which in most cases are higher than the stiffness of the polymer matrix. Din et al. [11] and Zhu et al. [15] reported that increasing content of inorganic fillers increased the stiffness of the resulting polymer composites.
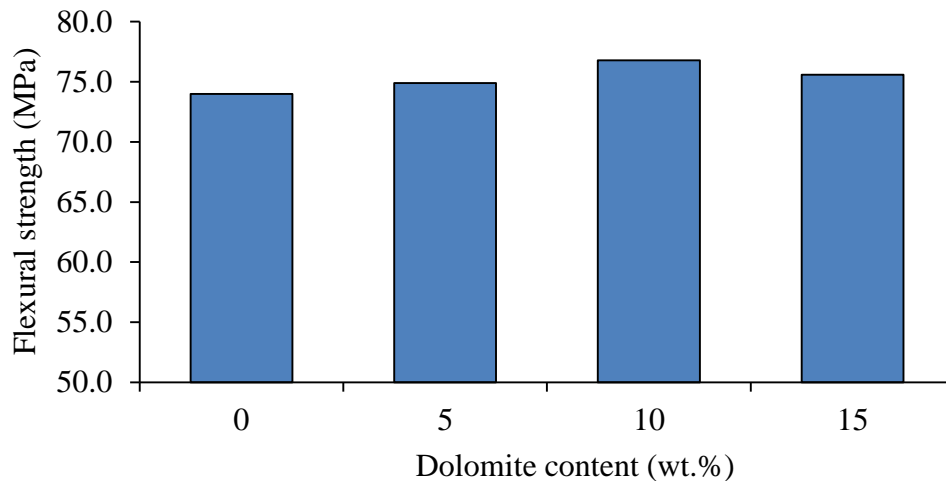
Figure 3 Effect of dolomite content on Young's modulus of PC/ABS 70/30 blends

3.2 Flexural Properties

Flexural strength for PC/ABS incorporated with dolomite is shown in Figure 4. Interestingly, the addition of dolomite initially increased the flexural strength until 10 wt.% after which further

addition of filler decreased the flexural strength. The reduction in flexural strength at higher filler incorporation (15 wt.%) could be due to filler agglomeration which reduces stress transfer from the matrix to the filler. Consequently, the flexural strength of this blend is highest (76.3 MPa) at 10 wt.% of dolomite which is 4% increase compared to unfilled PC/ABS blend. The same trend is reported in a study on the effect of huntite filler on polyester matrix [14]. However, a closer look at the effect of dolomite filler on flexural strength and tensile strength properties suggests that flexural strength had a better enhancement than the tensile strength. Possible explanation to the differing result in tensile strength and flexural strength could be due to differing failure mechanism of the test procedures. Flexural failure usually takes a gradual process, with bundles of fibers breaking first at the surface and then progressively through the thickness of the composite [16]. Whereas, in tensile failure, composites fail with extensive splitting occurring between bundles of fibers leading to decreased strength [17].

Figure 4 Effect of dolomite content on flexural strength of PC/ABS 70/30 blends

Figure 5 clearly demonstrates that the flexural modulus of the blends gradually increases at a rate of about 30 % with every addition of 5 wt.% dolomite. The presence of dolomite improves the stiffness for PC/ABS blends. The highest flexural modulus was 3215 MPa for PC/ABS contain 15 wt.% dolomite. This result is consistent with the previous studies where they found that as the filler content increases, the flexural modulus increased [1,14] due to inherent stiffness nature of the inorganic filler
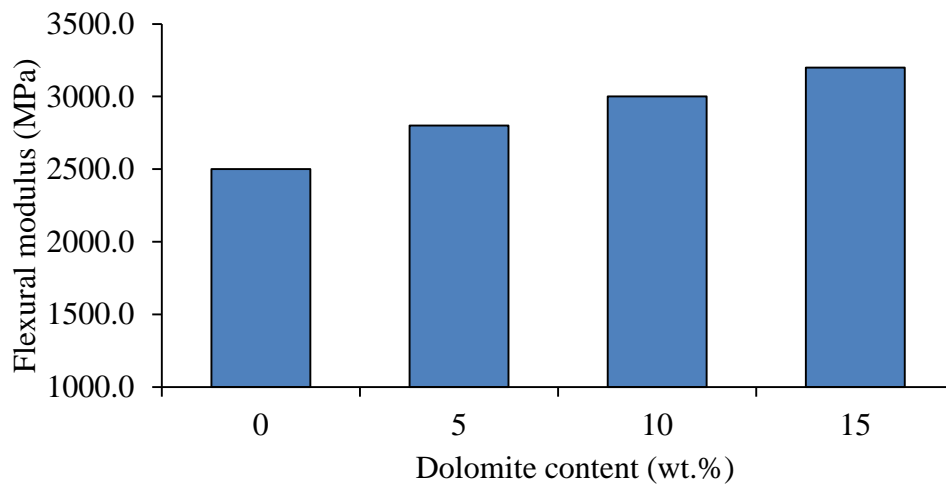
Figure 5 Effect of dolomite content on flexural modulus of PC/ABS 70/30 blends

3.3 Impact Strength

Based on Figure 6, the toughness of the blends decreases as the percentage of dolomite content increases. The toughness of the blends containing 5, 10 and 15 wt.% of dolomite decreases about 79, 85 and 89 %, respectively. This shows decrement in the impact value with increasing amount of fillers. This finding is consistent with the finding of previous study where they found that increasing the mica content in PC/ABS blends, reduces the toughness of the blends [1]. The reduction in izod impact strength due to the agglomeration of the dolomite.
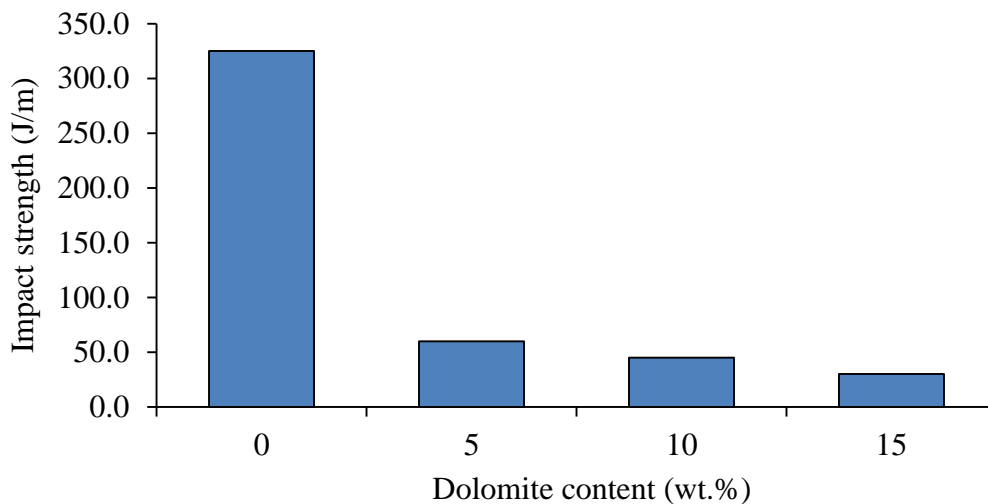
Figure 6 Effect of dolomite content on izod impact strength of PC/ABS blend

## 3.4 Differential Scanning Calorimeter

The study on DSC was restricted to the changes on T_g since the blends do not show melting peak due to the amorphous nature of PC polymer [18]. The T_g for the blends was determined and reported in Table 2. From Table 2, it can be concluded that PC/ABS containing 5 wt.% dolomite showed the highest T_g whereas increasing addition of filler reduced the T_g value. The reduction in T_g value on increasing inclusion of dolomite filler could be due to matrix mobility restriction. Pastorini and Nunes [19] observed that increasing filler content lowers the matrix mobility there

by lowering its glass transition temperature (T_g). Figure 7 shows the thermograph for DSC test. From the thermograph, it is clear that there is no melting peaks for dolomite filled PC/ABS.

Table 2 T_g of PC/ABS with different dolomite content

Dolomite content (wt.%)	T_g (°C)
0	125
5	144
10	127
15	139
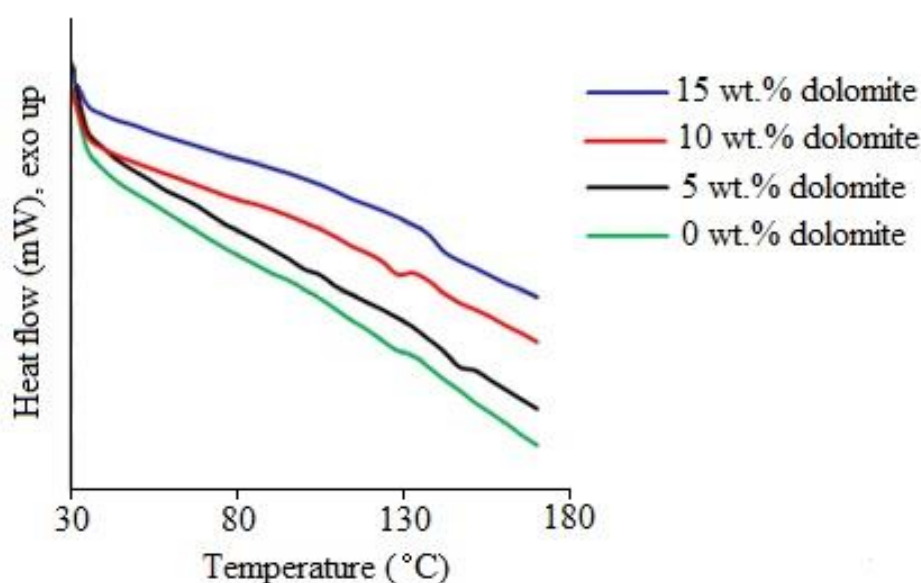
Figure 7 DSC analysis heating scans of PC/ABS and PC/ABS Dolomite at various Dolomite content

3.5 Thermogravimetric Analysis

The initial thermal stability is characterized by the temperature at 5 and 10 wt.% weight loss, referred as $T_{5\%}$ and $T_{10\%}$ respectively. Onset temperature refers to the temperature at which the weight loss begins. The data for TGA and DTG is summarized in Table 3. The degradation temperature for the blends slightly increased thereby improved the thermal stability of the dolomite composites at peak temperature of 410 °C for 10 wt.% dolomite content. Further increase in filler content rather showed a decrease in the onset degradation temperature.

Figure 8 shows the graph for TGA where the thermal stability of the blends in the presence of dolomite filler slightly increased with increased filler content at 10 wt.% for the onset temperature at 410 ^{0}C. Also, Figure 9 shows DTG curves of PC/ABS and PC/ABS/dolomite composites. There is no significant change in the decomposition temperature of dolomite filled PC/ABS containing 5 wt.% of dolomite in comparison to the initial PC/ABS. Further addition of dolomite filler however, lowered the decomposition temperature. Although, the influence of dolomite filler on the thermal stability of the PC/ABS composite was insignificant, its poor thermal enhancement could be due to filler agglomeration and poor

dispersion. Pour et al. [20] reported that filler-matrix interaction can strongly influence the thermal stability of a composite blend. Dolomite filler relatively of high decomposition temperature ranging between 650 ^{0}C and 830 ^{0}C [21]. Evidently, addition of mineral fillers such as dolomite is known to increase the induction period or thermal stability time of its polymer composite due to its rigidity [22].

Table 3 TGA and DTG result of PC/ABS and PC/ABS/dolomite

Dolomite content (wt.%)	$T_{5\%}$ (°C)	Onset (°C)	DTG (°C)	Residue (%)
0	397	408	428	13.7
5	397	406	428	17.8.
10	401	410	426	20.9
15	397	405	423	27.2
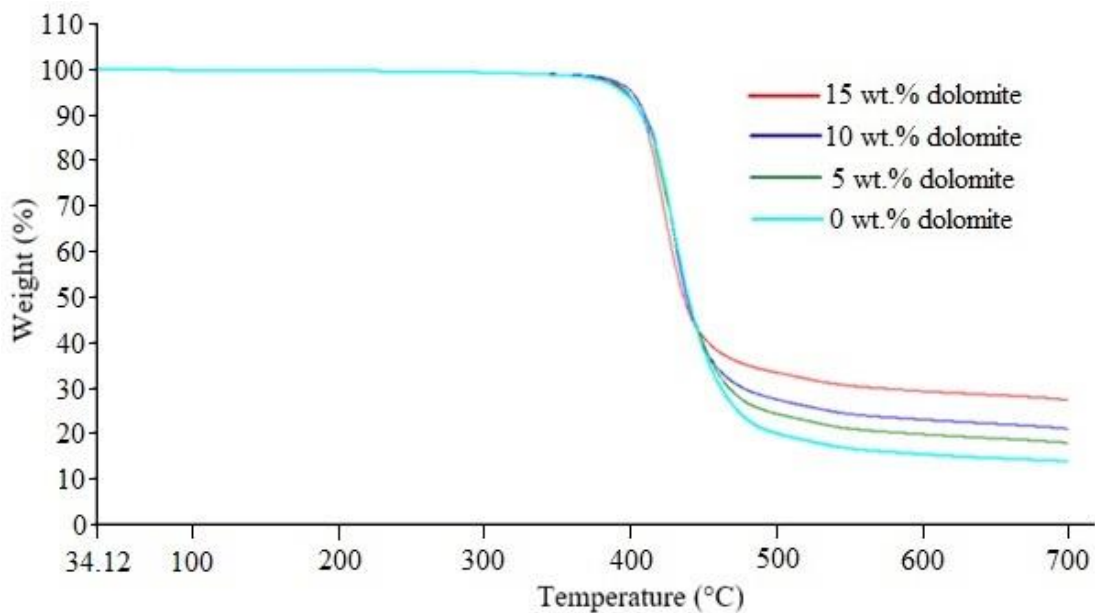
Figure 8 Curves of Thermogravimetric Analysis (TGA)
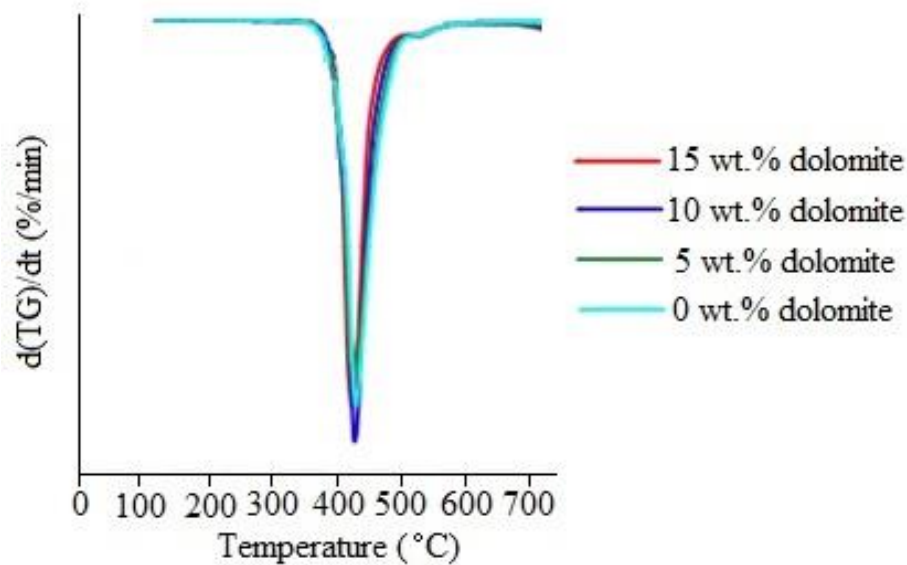
Figure 9 DTG Curves of PC/ABS and PC/ABS/dolomite

3.6 Limiting Oxygen Index

LOI refers to minimum concentration of oxygen needed to support combustion of polymer. Table 4 shows the LOI for dolomite filled PC/ABS with different dolomite content. Based on the result it is clearly shown that PC/ABS with 5 wt.% of dolomite has the highest LOI which is 24 and further addition of dolomite seemed to decrease the LOI for the blends. The decreasing pattern in the LOI may be due to the agglomeration. Proper filler dispersion has been reported to improve flame retardancy [20]

Some compounds break down endothermically when subjected to high temperatures. Magnesium and aluminium hydroxides are an example, together with various carbonates and hydrates such as mixtures of huntite and hydromagnesite [9]. The reaction removes heat from the substrate, thereby cooling the material.

The other way to stop spreading of the flame over the material is to create a thermal insulation barrier between the burning and unburned parts. Pour et al. [20] observed that increased char yield due to the formation of a network of char layers during combustion, retards the out-diffusion of gaseous decomposition products which could support flammability. Flame retardant compounds in their role in polymer composites, turn the polymer surface into a char, separating the flame from the material and so slows the heat transfer to the unburned part. Another way of decreasing flammability by these compounds is to provide a thorough path for the gases to travel.

Table 4. LOI of PC/ABS with different dolomite content

Dolomite content (wt.%)	LOI
0	20
5	24
10	23
15	22

4.0 CONCLUSION

The composition of the material in composite blends will affect its overall performance. Based on the result of this study it can be concluded that the tensile strength, elongation at break and izod impact test of dolomite filled PC/ABS decreased as dolomite content increased. Flexural properties of the PC/ABS incorporated with dolomite increased as dolomite content increased but beyond 10 wt.% addition of dolomite, the flexural strength of the composite decreased. There was an insignificant change in the thermal stability of the blends as increasing the dolomite content to 10 wt.% increased the decomposition temperature by only 4 ^{0}C at $T_{5\%}$. Based on the DSC results, the blends did not show melting peak and the highest temperature transition, T_g was 144 °C in the presence of 5 wt.% dolomite. The highest LOI recorded was 24 for PC/ABS with 5 wt.% dolomite. Based on these results, the optimum formulation for PC/ABS/dolomite is PC/ABS with 5 wt.% dolomite.

Acknowledgements

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