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Improving the Flame Retardancy of Polypropylene and High Density Polyethylene Using Aluminum Hydroxide

[1]R.U. Arinze, [1]A.N. Eboatu, [2]P.I. Udeozo, [1]P.U. Ofora,
[1]N.H. Okoye, [1]E.G. Amadi and [1]M.O. Muogbo

[1]Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria
[2]Department of Chemistry, Tansian University, Umunya, Anambra State, Nigeria

Abstract: This work studied the effect of aluminum hydroxide as flame retardant chemical on the flame characteristics of high density polyethylene (HDPE) and polypropylene (PP). This was by incorporating varying percentage concentrations of the flame retardant into the samples. The results showed that the flammability properties improved. The incorporation of flame retardant reduced flame propagation rate and after-glow time whereas ignitability time was enhanced.

Key words: Polypropylene · High density polyethylene · After-glow time and ignitability time

INTRODUCTION

Polymers are known for their relatively high flammability, most often accompanied by the production of toxic gas and smoke during combustion. Polypropylene and polyethylene are most commonly used thermoplastics owing to their easy processing and good mechanical strength [1]. Consequently, improving the fire retardant behaviour of polymers is a major challenge for extending their use in most applications. There is an old saying that goes “never scream fire in a crowded theater”. The reason for this is that the word fire has been known for centuries to cause fear and panic among people who witnessed its destructive power. Flames retardant when added to combustible materials render them more resistant to ignition. They are designed to minimize the risk of fire starting in case of contact with a small heat sources such as cigarette, candle or electrical fault. If the flame retarded material or an adjacent material has ignited, the flame retardant will slow down combustion and often prevent the fire from spreading to other items. Aluminum hydroxide is effective flame retardant filler for polymers, which is free from halogens apart from being easily handled and relatively nontoxic [2]. It exhibits an endothermic decomposition, cooling the substrate and diluting the ignitable gas mixture due to formation of inert gases associated with the formation of an oxide protective barrier [3, 4]. The chemistry of the combustion process has been well studied [5]. Making polymers resistant to burning is of great Importance to their safe use in today’s society. One way of making polymer retardant is by blending in additives. The development of flame retardant additives has been a subject of serious investigation for many years. Flame retardancy can be achieved by causing “char” formation in the polymer zone, adding material that decomposes to produce nonflammable gas or endothermic ally cools the pyrolysis zone and prohibiting the combustion process vapour phase [6].

The objective of this work is to enhance the flame retardant properties of polypropylene and polyethylene by incorporating fire retarding substance in it since these materials are widely used in our everyday life.

MATERIALS AND METHODS

Materials: High density polyethylene used was procured from Innoson Plastic Industry, Enugu, polypropylene was sourced from Alpha Gate Industries Limited and aluminum hydroxide with product code “ Farma” was produced by BDH Chemical Company Singapore.

Methods: 2000.0g of HDPE each was weighed into six separate containers and different quantities of flame retardant required were calculated with respect to the percentages (0.0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5%) as shown.

Corresponding Author: R.U. Arinze, Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria.

W =%FR /100 x Mp

W = weight of flame retardant required, FR = flame retardant and Mp = mass of HDPE = 2000.0g

The sample and FR for each concentration was mixed before transferring to the injection moulding machine. The PP samples were given the same treatment.

Flame Test: Each of the treated samples as well as the untreated samples was clamped vertically to a retort stand and ignited at the base using a lighter and the stop watch was activated immediately to note the ignition time (IG). The time taken for the flame to traverse 7cm marked on the sample before flame out was also recorded. The flame propagation rate was calculated as shown.

$$\text{Flame propagation rate, FPR (cm/s)} = \frac{\text{Distance moved by char front (cm)}}{\text{Time (s)}}$$

After-glow time (AGT) for each sample was obtained by recording the time between flame out and the last flicker of light. The same method was repeated for other samples and each concentration was performed three times and average calculated. The adopted method was according to [7, 8].

RESULTS AND DISCUSSION

In Fig. 1 it is evident that incorporation of flame retardant, Al $(OH)_3$ to HDPE and PP samples dramatically increased the ignition time of the treated samples. However as the concentration of the FR increase, the ignition time also increased. As the samples received heat, the temperature increased and the heat redistributes by conduction. Hence, ignition occurs with sufficient heat. This agrees with the observation made in [9]. The PP samples gave better favourable ignition time than HDPE.

Fig. 2 depicts that the FPR reduces with increase in the amount of FR. The reason may be attributed that as the polymers combust, the Al $(OH)_3$ on decomposition liberates water vapour which absorb heat thereby providing cooling effect.

$2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O$

Furthermore, formation of Al_2O_3 an excellent heat conductor which serves as a protective coating between the gaseous phase of the flame and the solid phase deflects heat away from the combustion zone. As the concentrations of the FR in HDPE and PP increase, the heat content of the system decreases. This conforms to the result reported [10]. Consideration of FPR indicates that HDPE burn at a faster rate than PP.

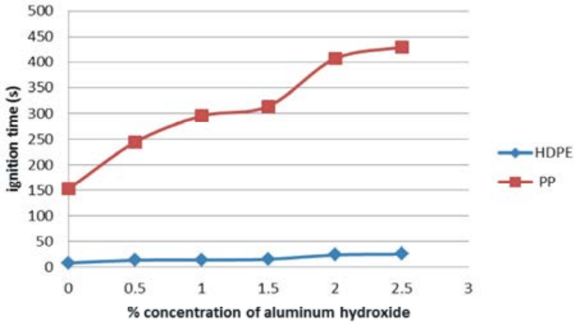

Fig. 1: Effect of aluminum hydroxide on ignition time of HDPE and PP.

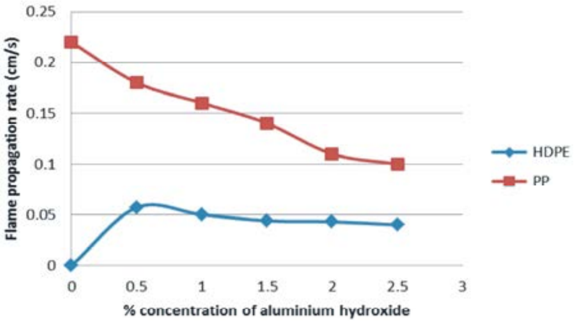

Fig. 2: Effect of aluminum hydroxide on flame propagation rate of HDPE and PP.

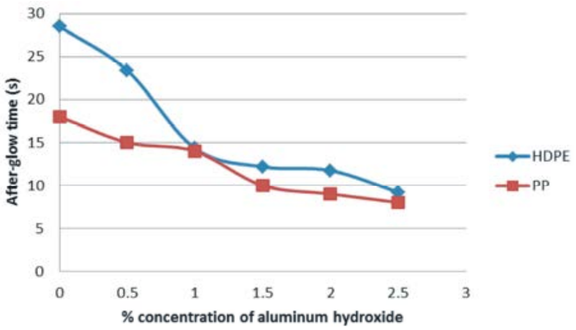

Fig. 3: Effect of aluminum hydroxide on after-glow time (s) of HDPE and PP.

The effectiveness of FR on after-glow time in Fig.3 shows reduction with increase in concentration of the FR. Glow is a surface oxidative process that depends on the quality of char left at the end of the heating as well as the available oxygen. Thus, the appreciable decrease in after-glow time is likely due to diminished char formation as a result of the Al $(OH)_3$ treatment. PP also gave more favourable after-glow time than PE.

CONCLUSION

The PE and PP after-glow time and flame propagation rate were effectively reduced with Al (OH)3 whereas, ignitable time was reduced. In this work PP gave better result than PE.

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