

## Flame Retardancy Enhancement of Polystyrene Using Ammonium Bromide

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**Abstract:** The effectiveness of ammonium bromide as flame retardant was determined by characterizing treated and untreated polystyrene for ignition time, flame propagation rate and afterglow time at different percentage concentrations of salt. Results showed that flame propagation rate and afterglow time decreased with increases in the concentration of ammonium bromide while ignition time was observed to have increased with increases in ammonium bromide. The results were interpreted on the basis that on heating, ammonium bromide evolved gases, viz  $\text{NH}_3$  and  $\text{HBr}$  which not only dilute  $\text{O}_2$  concentration but also generate radicals that interfere with the chemistry of combustion of these polystyrene plastic samples.

**Key words:** Flame retardant • Polystyrene • Ammonium bromide

### INTRODUCTION

Polystyrene as well as other polymeric materials are increasingly used in our everyday life. The combustion of these polymers is a complex physico-chemical process that liberates gas phase fuels which combine with air and sustain the fire [1, 2]. Attempts have been made to substitute these native polymers with those that have improved fire performance and achieve the required fire safety standard, by modifying them with flame retardant additives [3]. Generally, polystyrene (PS) has varied and important application in automotive parts, furniture, insulation packaging, electrical appliances, toys, etc.

Flame retardants are chemicals which are added to combustible materials to render them more resistant to ignition and reduce the rate of flame spread [4, 5]. These chemicals can be chemically inserted into the polymer molecule (reactive flame retardants) or physically blended after polymerization (additive flame retardants) [5].

Halogen-containing compounds (organic or inorganic) are the common and most efficient group of flame retardant for producing flame retarded polystyrene because they retard flame efficiently by acting quickly as a radical trap, thus reducing the burning rate and increases the thermal stability of the polymer [6, 7]. This study is aimed at investigating the effect of ammonium bromide ( $\text{NH}_4\text{Br}$ ) as flame retardant on polystyrene plastic.

### MATERIALS AND METHODS

**Materials:** The SOLARENE General Purpose Polystyrene (PS) used was purchased from Hyundai Engineering Plastics, Nam-gu Ulsan, Korea and the ammonium bromide procured from BDH Laboratory Supplies Pool, England.

#### Method

**Sample Preparation:** The different quantities of flame retardant used for the production of the samples were calculated with respect to the required percentages: 0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5%, using the formula below:

$$m = \frac{FR\%}{100} \times Mp$$

where  $Mp$  = mass of polystyrene = 1000g

$FR\%$  = percentage of flame retardant

$m$  = weight of flame retardant needed to be incorporated in the polymer.

The control samples (0% concentration of flame retardant) were produced by injection moulding of 1000g polystyrene at  $180^\circ\text{C}$  under 160 bar pressure. Other sample sheets were produced under the same conditions by injection moulding the same quantity of polystyrene but in this case, mixed with different weights (5g, 10g, 15g, 20 and 25g) of ammonium bromide. The sample sheets were labeled properly.

**Characterization of the Polystyrene Samples:** The burning test, were carried out to determine the flammability parameters of the treated and untreated polystyrene samples. The sample sheets produced were cut to test samples of uniform sizes with dimensions 13cm × 1.5cm × 0.26cm.

**Determination of Ignition Time (I.T):** The test sample was clamped vertically and the flame from a cigarette lighter was applied to the bottom of the test sample. The top of the flame from the cigarette lighter was located at 2cm from the bottom edge of the test sample. Ignition time was recorded using a stopwatch as the time interval between striking the lighter and a tiny visually perceptible flame on the sample. The test was repeated three times for each sample and the average calculated.

**Determination of Flame Propagation Rate (F.P.R):** The method adopted was according refs. [8, 9]. The test sample was supported vertically at one end and was ignited at the base in a draught-free room. The time required for the flame to propagate to the 6cm mark from the point of ignition was recorded. The flame propagation rate (F.P.R) was calculated as the distance moved per time taken to travel to the mark. The same method was repeated for other samples and for each concentration, was performed three times.

**Determination of After Glow Time (A.G.T):** This was taken as the time required for the fire glow to disappear after extinction. The test was also repeated three times for each sample and the average calculated.

## RESULTS AND DISCUSSION

Figure 1 depicts the effect of ammonium bromide (NH<sub>4</sub>Br) on ignition time. The results indicate that as the concentration of flame retardant increases, the ignition

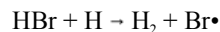
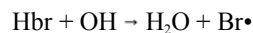
time increases. As the polystyrene sample receives heat from the flame the temperature increases and the heat redistributes to the other parts of the sample by conduction causing the sample to decompose [3, 10]. These observations could be attributed to the fact that NH<sub>4</sub>Br at high temperature generates gaseous effluents which dilute oxygen concentration in the flame zone, thus inhibits exothermic reactions that result in combustion. Expectedly, the more the concentration of the flame retardant, the more retarded the ignition be.

Figure 2 shows the results of flame propagation rate. It is observed that the flame propagation rate decreases as the quantity of flame retardant increases showing that ammonium bromide has some retarding effect on the burning of the plastic.

Ammonium bromide decomposes to sublime upon heating, thus:



The flame retardant action of ammonium bromide follows the gas-phase mechanism, which is a chemical mechanism in the gas phase where the flame retardant material reduce the heat released in the gas phase from combustion of the plastic by scavenging free radicals (particularly OH• and H•) [10]. At combustion heat HBr removes OH• and H• radicals needed for combustion sustenance and replace with lower energy Br• radical, thus:



This radical reacts with the plastic hydrocarbon to produce the hydrogen bromide, thus regenerating the flame retardant [6, 7] and the cycle continues.

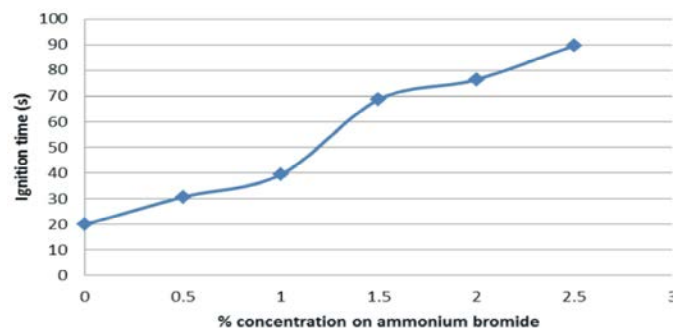


Fig. 1: Effect of ammonium bromide on Ignition time

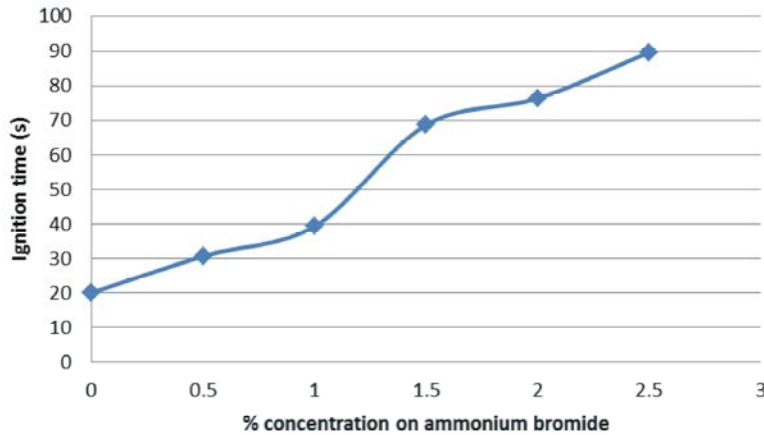


Fig. 2: Effect of ammonium bromide on Flame Propagation rate

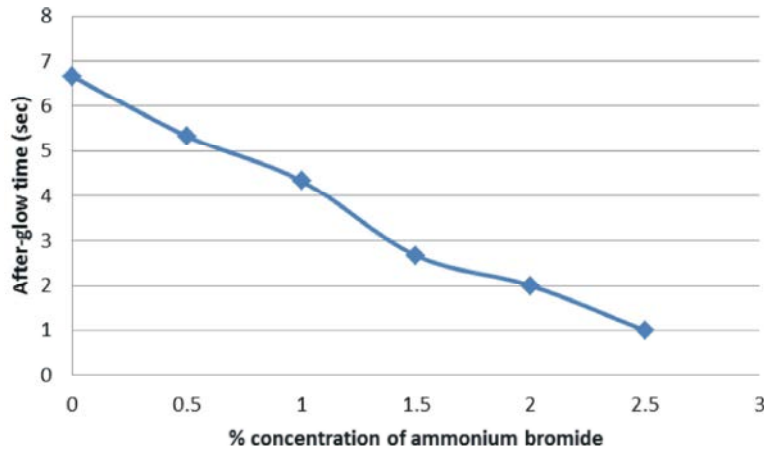


Fig. 3: Effect of ammonium bromide on After Glow time

Figure 3 depicts the effect of ammonium bromide on afterglow time. It indicates that the afterglow time decreases as the quantity of flame retardant increases. At 0% concentration, the plastic sample gave the highest value of afterglow time. Glow is a surface oxidation process that depends on the quality of char left at the end of heating as well as available oxygen. Thus, the higher the char, the longer the afterglow time (AGT) values and the longer the afterglow time, the higher the chances of re-enlightenment of a fire [11]. It is clear that the presence of  $\text{NH}_4\text{Br}$  reduces char formation, thereby decreasing after-glow time.

### CONCLUSION

From the foregoing results, it is concluded that  $\text{NH}_4\text{Br}$  acts as FR for PS by reducing the FPR while increasing IT. On the other hand AGT was observed to have decreased which is also an advantage.

### REFERENCES

1. Gallo, E., 2009. Progress in Polyesters Flame Retardancy: New Halogen-free Formulations, Universta' Degli Studi Di Napoli Federico II, Naples, pp: 8-37.
2. Takashi, K., 1994. Polymer Combustion and Flammability- Role of the Condensed Phase, Twenty-fifth Symposium (International) on Combustion/The Combustion Institute, Maryland, pp: 1423-1429.
3. Onuegbu, T.U., E.T. Umoh and I.E. Iwuchukwu, 2012. Flame Retardant Effects on Flexible Polyurethane Foam Treated with Potassium Aluminium Sulphate, APRN Journal of Science and Technology, 2(11): 1098-1100.
4. Beard, A., 2007. Flame Retardants: Frequently Asked Questions, European Flame Retardants Association, Brussels, pp: 1-31.

5. Al-Maamori, M., A. Al-Mosawi and A. Hashim, 2011. Flame Retardancy Enhancement of Hybrid Composite Material by Using Inorganic Retardants, *Materials Sciences and Application*, 2: 1134-1135.
6. Troitzsch, J.H., 1998. Overview of Flame Retardants, *Chimica Oggi/Chemistry Today*, 16: 2-18.
7. Walter, M.D. and M.T. Wajer, 2000. Overview of Flame Retardants Including Magnesium Hydroxide, *Martin Marieta Magnesia Specialties LLC*, Maryland, pp: 1-5.
8. Abdullah, N.M. and I. Ahmad, 2013. Fire-retardant Polyester Composite from Recycled Polyethylene Terephthalate (PET) Wastes Reinforced with Coconut Fibre, *Sains Malaysiana*, 42(6): 811-818.
9. Odinma, S.C., A.N. Eboatu, R.U. Arinze and N.H. Okoye, 2013. Answer to the Call-For-Help on the Flammability Nature of Rural Housing, *IOSR Journal of Engineering*, 3(8)4: 06-09.
10. Qingsheng, W., 2013. Polymer Nanocomposite: A Promising Flame Retardant, *Journal of Materials Science and Nanotechnology*, 1(2): 202.
12. Arinze, R.U., A.N. Eboatu, N.H. Okoye, P.U. Ofora, P.I. Udeozo and J.C. Ayika, 2014. Studies on the Effectiveness of Flame Retardant Paint Treatment of Timbers, *Middle-East Journal of Scientific Research*, 21(9): 1652-1654.