Influence of Magnesium Hydroxide/Aluminum Tri-Hydroxide Particle Size on Polymer Flame Retardancy: An Overview

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presented Abstract—Anoverview of recent is the developments concerning the use of magnesium hydroxide /aluminum tri-hydroxide (MH/ATH) as for designing polymer nanocomposites endowed with enhanced flame retardancy. Emphasis is placed on the fact that the effect of nano size of ATH/MH is beneficial mostly for retarding flame spread in developing fire as blending composites to the base component. Accordingly, the need for improving flame retardants materials in nanocomposites are discussed and compared in this particular overview paper, providing detailed examples reported in selected previous literature. The results were comparable when working with nano-sized of MH particles, suggesting that the nanoparticles claimed a noble metal serves not only as excellent filler to the polymer matrix but also provides low loading amount of filler, very good in dispersion by impressive morphological structure and better physical properties such as tensile strength and elongation at break.

Index Terms—Fire retardant, nano particles, wire and cable, nano-ATH, nano-MH

I. INTRODUCTION

The use of polymeric materials has increased rapidly over the past decades, but their flammability has turn out to be an obstacle from growing their function in varies fields. Theoretically, it is desirable for all the polymer materials to possess certain flame retardance properties, but generally polymer materials are on fireeasily because under sufficient heat, polymer material produces combustible product lead to originate and propagate the fire. Commonly by combining use of halogen-type flame retardant and antimony trioxide directly effect is acceptable in flame retardance [1]. This method, however, cause problems such as toxicity of flame retardants, emission of corrosive, toxic, and cloudy halogen compounds in fire [1], [2].Previously, more attentions had been focus to this problem and many techniques were applied into this field, one of that by introducing halogen free flame retardant to overcome the critical issue. Significantly using halogen-free flame retardants, such asaluminum hydroxide magnesium hydroxide $(Mg(OH)_2)$ replace and of conventional flame retardants, is a realistic and promising way to overcome all difficulties [1], [3], [4]. The amount of fumes and the toxicity of smoke generated during combustion decrease excellently, but a major issue are to fill more than 60% by weight $Mg(OH)_2$ or $Al(OH)_3$ [3], [4] in matrix to obtain excellent flame retardancy, because of their low flame retarding efficiency. As a result, this method extremely require high loading of fillerwhich easily causes processing difficulties and deterioration in mechanical performances of non-flammable composites [2]. Therefore, it becomes very active and important to enhance the flame retarding efficiency of Mg(OH)₂ or Al(OH)₃[3], [15], targeting at reducing their loading amount by using many methods, such as, to find some synergists of Mg(OH)₂ [3], [5] to highly exert the retarding effect by adjusting certain parameter of Mg(OH)₂,[1], [6] to improve the dispersion of filler,etc [1], [7].

In addition, it is well-known that particle size plays a big role and important parameter of flame retardant additives, which not only probably affect the mechanical properties and fluid properties of composites, Hence, In this paper will give an idea of previous work had done to give a comprehensive evaluation about the effect of particle size on the flame retardancy.

II. CONCEPTUAL OF MINERAL FILLER FOR FLAME RETARDANCY

A. Metal Hydroxide React as an Inert Filler

Knowing the important needs and requirement of polymer flame retardants to be valid in this field, metal hydroxides which serve as mineral filler need to decompose endothermically and release water at a temperature higher than the polymer processing temperature range, and also around the polymer decomposition temperature [8]. In fact, as far as the metal hydroxide concern, the two most commonly used mineral flame retardants are aluminium tri-hydroxide (ATH) and magnesium hydroxide (MH) [9]. Table I shows a number of metal hydroxide and carbonates as potential fire retardant fillers, together with published estimates of their decomposition temperature ranges and endotherms. [10]

The decomposition temperature clearly affects the relative contributions of the heat capacity of the filler, and those of the residue and gas as well. Comparing aluminium and magnesium hydroxide, it is clear in evident that the difference between their relative effects arise from the higher decomposition temperature of MH, giving that a larger contribution to the heat capacity of the un-decomposed filler, but a smaller contribution from the heat capacity of the residue that ATH, and from the heat capacity of the greatest volume of water vapour released by the ATH – even though the energy for such a release is almost identical for both fillers [11]. As a result, the higher decomposition temperature of MH means that it is better suited to polymers, which are processed at temperatures above the decomposition temperature of ATH whereby ATH becomes unsuitable due to higher processing temperatures [12]

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| Filler | Formula | $T_{decomp}(^{\circ}C)$ | $\Delta H_{ m decomp}$ (kJg ⁻¹) | % Filler | Endotherm | % Residue | % Gas |
|------------------------|-------------------------|-------------------------|--|----------|-----------|-----------|----------|
| Aluminium hydroxide | Al2O3.3H2O | 180-200 | 1300 | 9 | 55 | 13 | 23 |
| Magnesium hydroxide | Mg(OH)2 | 300-320 | 1450 | 19 | 56 | 9 | 15 |
| Calcium hydroxide | Ca(OH) ₂ | 430-450 | 1150 | 29 | 55 | 5 | 11 |
| Nesquehonite | MgCO3.3H2O | 70-100 | 1750 | 1 | 58 | 12 | 29 |
| Hydromagnesite | Mg5(CO3)4(OH)2.4H 2O | 220-240 | 1300 | 10 | 56 | 14 | 21 |
| Huntite | Mg3Ca(CO3)4 | 400 | 980 | 20 | 58 | 9 | 13 |
| Ultracarb | Huntite 60/40 | 220-400 | 1172 | 14 | 57 | 12 | 18 |
| Boehmite | AlO(OH) | 340-350 | 560 | 18 | 46 | 20 | 15 |

TABLE I: PHYSICAL PROPERTIES AND RELATIVE CONTRIBUTION OF MINERAL FILLER [10].

 $TABLE\, II: METHOD \ OF \ DISPERSING \ MINERAL \ FILLER \ MATERIAL.$

| Particle Size (Authors) | Method | Description | Result |
|------------------------------------|----------------|---|--|
| Micro Mechanic [16] al Stirring | | Using mechanical stirring equipment. The additives include into the matrix at 400 rpm to avoid disperse the additive | Well disperse into the epoxy matrix and it maintains its original grain size. |
| | | Mixing for 10 minutes at 1050 rpm and 10 minutes at 2000 rpm and then the mixture degases for 30 minutes at 90 $\%$ in a vacuum oven to eliminate entrap air and humidity. | Result shows in Fig. 1(a, b) |
| | | Liquid system pour in mould and cure at 160 $^{\circ}$ C and 180 $^{\circ}$ C respectively for 90 mins and 120 mins, according to the curing schedule sheet of the neat epoxy resin. | |
| Nano [17] | Sonicatio n | The nanocomposites prepare by using sonication process for a constant time (1 hour) at temperature of $120 ^{\circ}\text{C}$ Degases in vacuum oven at 90 $^{\circ}\text{C}$ for 30 min, and then cure considering an identical temperature cycle (1 h at 160 $^{\circ}\text{C}$ follow by 2 h at 180 $^{\circ}\text{C}$) according to the specified curing schedule. | Nano particles present and well separate each other, showing a good level of adhesion with the matrix, in fact it appears a satisfactory uniformity of single or agglomerate of nano particles. |
| | | | Result shows in Fig. 1 (c, d) |

TABLE III: EFFECT OF PHYSICAL PROPERTIES ON DIFFERENT MATERIAL SIZE.

| Particles size | Tensile (MPa) | EB (%) | LOI (%) | Materials | Filler Loading | Authors |
|-----------------|---------------|--------------|---------|---------------------|----------------|---------------------|
| of fillers (µm) | | | | | | |
| Micro | 11±1 | 180 ± 10 | - | Micro MH, EVA, clay | High > 55% | M.A. Cardenas [20] |
| (2.2 - 5.2) | | | | | | |
| Micro | 12±1 | 197 ± 10 | - | Micro MH, EVA, clay | High > 50% | M.A. Cardenas [20] |
| (1.5 - 3.5) | | | | | | |
| Micro | 12 | 116 | 35.2 | Micro MH, EVA, | - | Honghai et al [1] |
| 3.89 | | | | Irganox 1010 | | - |
| | | | | | | |
| Micro | 12.8 | 116 | 37.3 | Micro MH, ATH,LDPE, | High > 60% | Qi Zhang et al [21] |
| 2.33 | | | | EVA | | |
| | | | | | | |
| Nano | 13±1 | 177 ± 10 | - | Nano MH, EVA, MEVA, | Low < 20% | Yi Ding [22] |
| (3-6) | | | | clay | | |
| | | | | | | |
| Nano | 12.1 | 108 | 34.6 | Micro MH, EVA, | - | Honghai et al [1] |
| D=<100 | | | | Irganox 1010 | | |
| T=<50 | | | | | | |



Fig. 1. (a, b) Sample without sonication process while (c, d) Sample with sonication process [13].

B. Gap between Dispersion Method of Micro and Nano Particles Filler

As a flame retardant issueillustrate a rapidly study across the globe in previous time, many result claimed a very high loading additives need to be blend with polymer base to attain a good flame retardant. Consequently, this phenomenon leads to have poor mechanical properties. On top of that reason, current study has narrow down to the particle sized of the additives in order to reduce loading filler issue by having nano size particle filleras a new target to be set. However, thenanoparticles areeasy to aggregate within the polymers due to their high surfaceenergy and inherent characteristic of polarity and hydrophilicity especially nano MH[13], [17]. In return, difficulties in melting processing are always encountereddue to the high melt viscosity, and the mechanical properties of flame retardant polymeric composites could be significantly deteriorated [13], [14], [15]. Ultrasonic method has promising to overcome any circumstances of nano particles issue. This method clearly becomes an effective method to improve its compatibility and dispersibility within polymer matrices as ultrasonic irradiation couldrestrict the crystal growth of MH on each lattice plane and improve hydrophobicity of nanoparticles.

Morphology result showed that a sample without ultrasonic treatment express worse regularityin shape, poorer

III. CONCLUSION

This paper presents an overview of the potential of selected metal mineral filler which are magnesium hydroxide and

dispersibility (e.g. severer agglomerations), and less uniform particle size distribution. Theoretically, particle adhesion is caused by surface and field forces (van derWaals, electrostatic and magnetic forces) at direct contact, materialbridges between particle surfaces (liquid and solid bridges, flocculants)and interlocking (by macromolecular and particle shapeeffects) [13]. However a sample implies that employment of ultrasonic irradiation may well restrictcrystal growth of MH during the synthesis and effectively avoidagglomeration [14]. However prolonged ultrasonication process will result in the reagglomeration of nanoparticles [19].

C. Effect of Particle Size to the Physical Properties

The particle size generally has a big influence on tensile properties and elongation at break because the interaction of polymer matrix and filler blend reflected by the dispersion variables of the filler. The smaller the particle size will lead to the better result. The comparison clearly showed the nano particle provided better tensile and elongation at break as the nano particles dispersed well in the polymer matrix to give more homogeneous reaction [1]. Moreover, only low loading filler amount require to the polymer base and it is clearly improve the process and outcome when a nano size encounter instead of micro mineral size.

aluminium tri-hydroxide to be an additive for flame retardant with respect to previous research performed in this field. As far as the nano particle is concern special attention has been given to method which may help to improve the process regarding on nano size particles that is ultrasonic method. This method provided a good of nano dispersion to the polymer matrix, improves the reaction between the additive and polymer base. Nano MH use as flame retardant also achieve main objective of the current study whereby lowering the loading of filler compared to micro size mineral. The mechanical properties of the product produced significantly improved by having nano size even though with small loading filler amount.

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