Fire Retardancy of Nanocomposites Incorporated with Graphene and Nanoclay Inclusions

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Abstract

The applications of polymeric materials in many industries show the great importance of these materials. Due to the their molecular structure and chemical composition, polymeric materials are highly flammable. This study is mainly focused on the effect of nanoparticles on polymeric materials in terms of flame retardancy. In this research, the impact of various percentages of nanoparticles on the flame retardancy of the polymeric materials was investigated and the best combinatorial percentage was determined using the experimental analysis. For the purpose of the experiments, the casting of the solvents were considered and thermal tests were performed to evaluate the impact of nanoparticles on flame retardancy.

1. Introduction

Poly (vinyl chloride), PVC, is one of the most commonly used commercial plastic materials, which has the third largest production of plastics after polypropylene and polyethylene. PVC is very cost-effective material and the application of polymeric materials in daily life such as electronics, construction, and transportation proves the importance of these materials [1].

PVC is highly flammable and their flame retardancy can be improved significantly by incorporating some inclusions such as flame retardant materials. By changing the arrangement of the atoms in a desirable way, a new set of material can be produced with new characteristics. Carbon nanotubes, graphene, nanoclay and nanotalc are some of the examples of these fillers which are highly efficient and environmentally-friendly, and have the potential to improve electrical, mechanical, and thermal properties [1,2].

2. Experimental Method, Results and Discussion

Poly (vinyl chloride) [$-CH_2CH(Cl)-]_n$, the white and brittle powder purchased from Sigma-Aldrich was used as the main matrix. The solvent used was N,N-Dimethylacetmide (DMAC), purchased from Fisher Scientific company. Nanoparticles including Closite 30B (Clay), hydrous magnesium silicate (Talc) and graphene were provided by the Southern Products, Inc. The nanoparticles with different weight percentages were dispersed and sonicated in the solvent and then they were stirred for a certain time after which, PVC was added to the solvent and stirring was continued for another 24 hours. The solution consisted of 0%, 5%, 10% and 20% of nanoparticles.

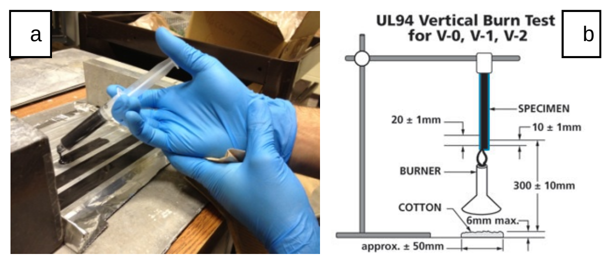

Figure 1 - a) Casting the solution, b) Schematic of UL94

First, different percentages of nanoparticles had to be added to DMAC, and depending on the weight percentage of nanoparticles it was sonicated from 1.5 to 4.5 hours and then stirred on a hot plate at a specific temperature with a magnetic stirrer of a suitable size. Then PVC was added very slowly to avoid agglomeration. The solution was continuously stirred for 24 hours and then the melt solution was cast into a specially prepared mold. Special care was taken to coat the mold before pouring the cast inorder to facilitate the removal of the samples from the mold (Figure 1.a). The melt solution was allowed to solidify at room temperature. Once the DMAC had evaporated, the cast specimen was ready for thermal testing.

UL94 Test – It is one of the most common flame tests to determine the flammability of plastic materials. It identifies the tendency of the materials to either self-extinguish or to spread the flame after ignition. In this study, the vertical UL94 Test was used to determine the flame retardancy of the specimens (Figure 1.b). Standards were followed to determine the specimen size [2].

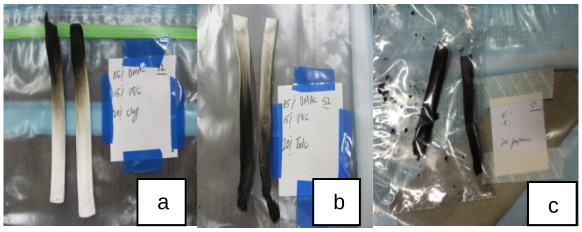

Figure 2 - 20% of a) Nanoclay, b) NanoTalc, c) Graphene

The secimen sizes were 5"x1/2" (12.7 cm x 1.7 cm) with the minimum approved thickness - 1/16",1/8" and 1/4". There are usually 3 ratings (V0, V1, V2) for a typical UL94 vertical test [2,4]. The results from all the three ratings are given in table 1.

During the application of the flame, it is essential to maintain a constant distance between the burner and specimen. All the samples were exposed to a heat source (burner) for a 10-second period successively 3 times. After each succession, the rating was determined, based on the dripping of the specimen [3,5].

Table 1 - Flame retardant studies of the specimens

UL94 / Specimen	V - 2	V - 1	V- 0
PVC → Failed			
5% Nanoclay		✓	
10% Nanoclay			✓
20% Nanoclay			✓
5% NanoTalc	✓		
10% NanoTalc	✓		
20% NanoTalc			✓
5% Graphene		✓	
10% Graphene			✓
20% Graphene			✓

The data resulting from the flame retardant studies of the samples of pure PVC and PVC with nanoparticle inclusions are shown in table 1. Based on the results, PVC with 0% of the nanoparticles failed in the first 10 second period. The whole sample burnt completely. From table 1 and figure 2 and figure 3, it can be seen that the specimens containing 20% of nanoparticles showed the best fire retardancy among different weight percentages. They are classified as V - 0 which is the best rate with no drips (Figure 2).

Further, all the samples were weighed before and after the burning test. The samples containing 20% weight percentage of nanoparticles showed the best results among all the samples.

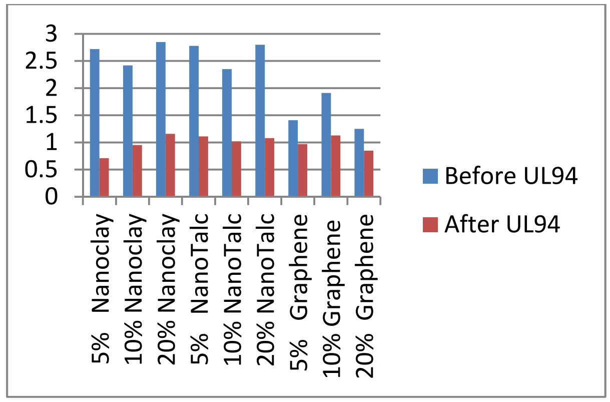

Figure 3 - Specimens weight loss before and after UL94 test within 30 seconds.

Figure 3 shows the weight of the samples before and after burning. Samples containing 20% Graphene, Nanoclay and Nanotalc lost the least amount of weight compared to the other specimens.

3. Conclusions

It was found that by adding different percentages of nanoparticles to pure PVC, the flame retardancy of this polymer significantly improved. The UL94 test confirmed this hypothesis. More research will be conducted on the same materials.

References

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