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Effect of Milling Time and Clay Content on the Thermal Stability of Polyethylene-Clay Nanocomposite

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1. Introduction

Polymer/clay nanocomposites have a long history of development. The progress of development has been reported since the nineteen sixties and early seventies [1]. Polymer nanocomposites, in particular, nanoclay-reinforced polymers have attracted significant interest both in the industry and in academia during the past decade [2], owing to their potential for exceptional improvements in properties at lower filler concentrations compared to conventional micro- and macro-composites [3].

Nanocomposites are usually prepared by vacuum deposition or chemical methods. However, synthesis by mechanical methods offers unique advantages. Recently, it has been proved that High Energy Ball Milling (HEBM) can help to obtain novel nanocomposites with new characteristics which are difficult to obtain by other conventional techniques [4]. In our previous papers [5, 6], we proposed the HEBM as an alternative fabrication method for polyethylene-clay nanocomposite and indicate that although the milling time and the addition of clay have not affected on the crystal structure of MDPE matrix, the crystallinity of MDPE decreases with increasing milling time and clay content. In the present work, we try to investigate the thermal properties of polyethylene-clay nanocomposite fabricated using ball milling as a new method.

2. Methods

A medium-density polyethylene (MDPE, density: 0.937 g cm⁻³, MFI: 4.2, Vicat softening point: 117) was used as composite matrix resin and the used clay was china clay. These two commercial chemicals were used as received without further purification. High-energy ball milling was performed in a stainless steel container at the speed of 300 rpm. Total mass of the powder was 10 g. The weight ratio of ball to powder was kept 20:1. Medium density polyethylene and clay particles were mixed mechanically before ball milling, to achieve medium density polyethylene-clay nanocomposite with different clay contents i.e. (5, 10, 15 wt%). The process was done at different milling times (0-60 hours). The powder of neat polyethylene was also milled at the same times for comparison.

The microstructure of the nanocomposites was examined by transmission electron microscopy (TEM) and Fourier transform infrared spectroscopy (FTIR). Thermal stability of all milled samples including pure polyethylene and polyethylene-clay nanocomposites was measured by thermal gravimetric analysis (TGA).

3. Results and discussion

The results of TEM and FTIR show that the clay particles have been homogeneously dispersed in the polymer matrix without any aggregation of clay and there is not any detectable interaction between PE and clay.

The results of the TGA and derivative thermogravimetric (DTG) curves of pure PE, PECN10, and PECN15 after 40 and 60 hours of milling show that the clay layers play like a good barrier which can improve the thermal stability of polymer clay nanocomposites. On the other hand, clay itself can catalyze the degradation of polymer. At the initial stage of degradation, PECN10 and PECN15 show an earlier onset temperature in contrast to pure PE. This suggests that the addition of clay catalyzes the initial decomposition of PE. It has been reported [7] that the complex crystallographic structure and the habit of clay minerals can result in some catalytically active sites. Perhaps the initial decomposition of PE matrix is provoked by these catalytically active sites. Moreover, the addition of clay shifts the degradation of polyethylene to higher temperature after initial stage of the degradation. This is probably related to the lowering of the diffusion of oxygen molecules into the nanocomposites due to barrier property of clay and physicochemical adsorption of the volatile degradation products on the silicates [7]. All these effects increase the stability of PE-clay nanocomposites. The temperature corresponding to maximum decomposition rate obtained from the DTG curves are 415.62, 430.41, and 436.49 °C for pure PE, PECN10, and PECN15 after 40 hours of milling



and 421.36, 436.41, and 433.59 °C for pure PE, PECN10, and PECN15 after 60 hours of milling, respectively. These data also prove that the thermal stability of PE increases as clay content increases.

4. Conclusions

In a summary, thermal stability of PE increases with increasing milling time. Clay plays two opposed functions on the thermal stability of PE-clay nanocomposite, one as a barrier effect to improve the thermal stability and the other as a catalyst leading to decrease of the thermal stability.

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