Production of polyethylene/carbon nanotube nanocomposite using mechanical milling process and investigation of its microstructure

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Abstract:

In the current research polyethylene/carbon nanotube nanocomposite produced using mechanical milling method. For doing this a high energy ball mill with 70 mm in diameter and steel balls with different diameters were employed. The medium density polyethylene (MDPE) and multi wall carbon nanotube (MWCNT) at constant weight ratio of ball/powders (i.e. 10) were added to the ball mill and milled 10 hours. To clarify the role of both MWCNT content and milling time on morphology of MDPE some ball milled nanocomposites samples were investigated using scanning electron microscope (LEO 1450 VP). To evaluate the role of milling time on the microstructure of produced nanocomposites, a very thin film of MDPE/MWCNTs was prepared and studied by transmission electron microscope (LEO 912 AB). The results of the study of microscopic structure of the MDPE/CNTs nanocomposite materials produced by mechanical milling method show that milling process can be a simple method for producing MDPE/MWCNTs nanocomposite and addition carbon nanotube to MDPE causes to change its morphology at constant milling parameters.

Keywords: Carbon nano tube, Polyethylene, Nanocomposite, Mechanical milling

Introduction

Mechanical milling and mechanical alloying are techniques originally developed in the late 1960's for the solid state processing of metals. Mechanical alloying is widely used in the metals industry for producing composite metal powders with fine microstructures [1,2].

According to traditional terminology, when two or more metals are mechanically alloyed, a new phase with a different composition is formed at the interface of the two initial phases. As applications for this technique expanded to blending polymers and producing coatings, the terminology was borrowed from the metals industry, with a different meaning. In the case of polymers and ceramics, the new meaning simply implied an improved dispersion of phases or the creation of a uniform coating without the formation of a new phase. Ball mills consisting of a motor, vial, and balls are used in the mechanical alloying process. Several different ball mill configurations exist, but two key parts are common to all configurations: the vial and balls. During mechanical alloying, powders are placed in the vial with two or more metallic or ceramic balls. The mill's motor vigorously shakes the vial, resulting in high energy impacts between the balls and the material. These impacts trap material between the balls, or a ball and the vial wall with each agitation. As milling occurs, the particles are repeatedly fractured, deformed, and fused together. This process of repeated fracturing and cold-welding causes a refinement in microstructure with milling time. The result is a two-phase lamellar microstructure with an interlamellar distance dependent on total milling energy [2-8].

Total milling energy can be manipulated by changing the ratio of the total ball mass to powder mass (charge ratio), milling temperature, ball mill design, ratio of the diameter of the balls to the internal diameter of the cylindrical vial, or the milling time. The milling temperature can be critical because of its effect on both the material brittleness and thermally aided diffusion across interfaces [1-3]. Bases on literature review done by authors there is a little paper concentrated on the microstructure of polymer nanocomposites produced by mechanical milling process thus the main goal of the current research is focused on production of polyethylene nanocomposite reinforced with different multi wall carbon nanotube using ball milling and investigation of its microstructure.

Experimental

Materials

Medium density polyethylene Polyethylene (MDPE) granules were purchased from Scoopa Co., Korea. The multi wall carbon nanotubes MWNTs with purity higher than 95%, which are produced via chemical vapor deposition technique, were supplied by Iran research institute of petroleum industry with average diameter of about 10 nm and length of about 0.5-2 mm. Figure 1 shows SEM micrograph taken from the medium density polyethylene powders. It can be seen the average particle size is about 50 micron. Figure 2 shows TEM micrograph of used multi wall carbon nanotubes.

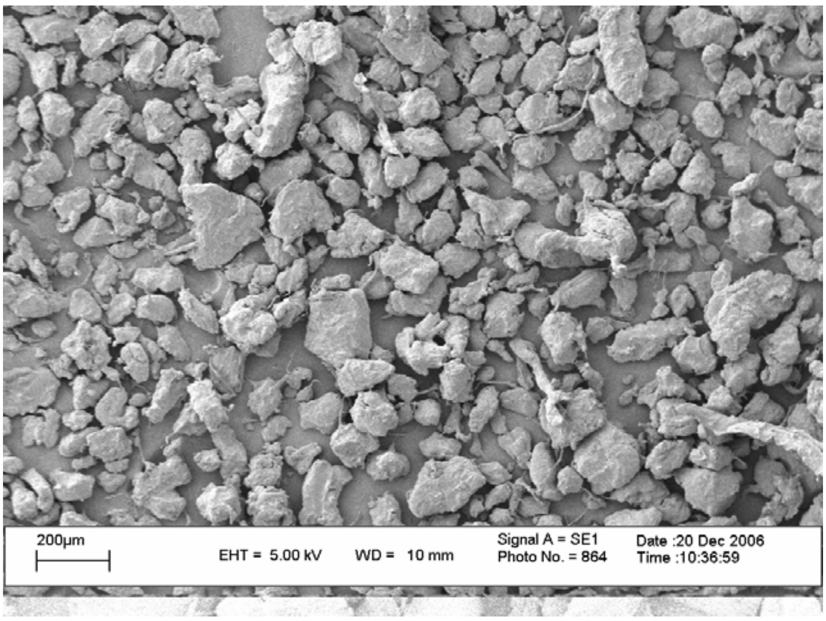


Figure 1: SEM micrograph of medium density polyethylene before milling

Figure 2: TEM micrograph of used carbon nanotube

Milling and sample preparation

A high energy ball mill with 70 mm in diameter and steel balls with different diameters were employed. The medium density polyethylene and multi wall carbon nanotubes at constant weight ratio of ball/powders (i.e. 10) were added to the ball mill and milled 10 hours.

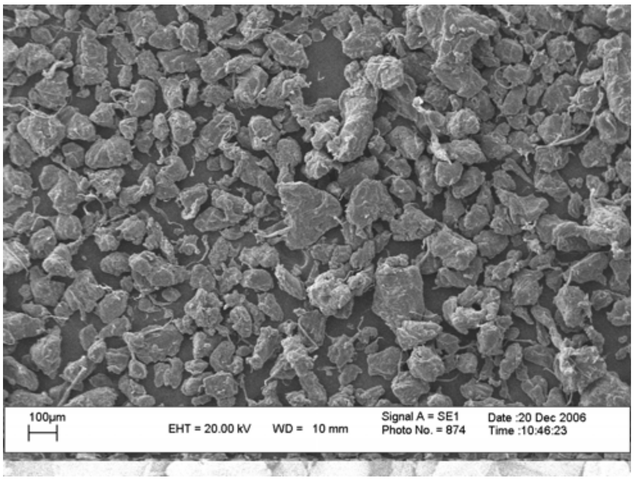
Microscopic Evaluation

In order to clarify the role of both MWCNT content and milling time on morphology of MDPE some ball milled nanocomposites samples were investigated using scanning electron microscope (LEO 1450 VP).Also to evaluate the role of milling time on the microstructure of produced nanocomposites, a very thin film of MDPE/MWCNTs was prepared and studied by transmission electron microscope (LEO 912 AB).

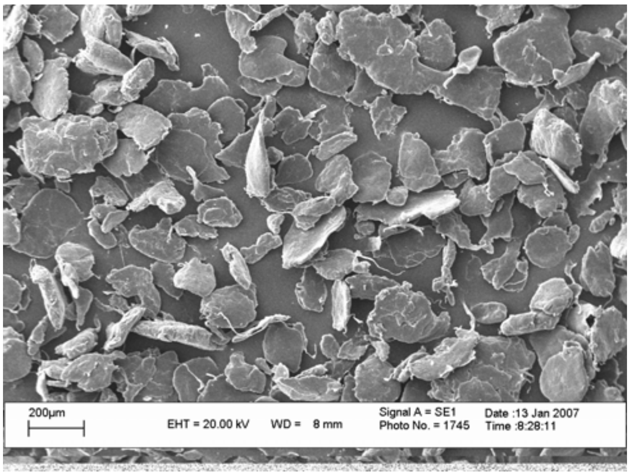
Results and Discussion

Figures (3-a) to (3-c) show the SEM micrograph taken from pure MDPE, MDPE/0.5%CNTs and MDPE/1%CNTs nanocomposites after 10 hours milling. As seen at constant milling parameters (ball/powders and milling time) addition of carbon nanotube to MDPE causes to change its morphology.
This is because thermal conductivity of CNT is so much higher than that of pure medium density polyethylene and it leads to dominate cold weld mechanism during milling.
Figure (4-a) and (4-b) show the transmission electron microscopy (TEM) micrograph taken from produced MDPE/MWCNTs nanocomposite after 10 hours milling at different magnifications. As it can be seen the multi wall carbon nanotubes are

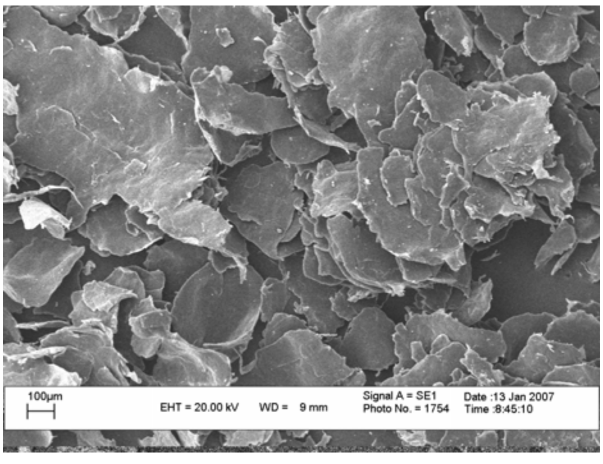
dispersed inside medium density polyethylene and it proves that the nanocomposite can be produced using milling method



(a)

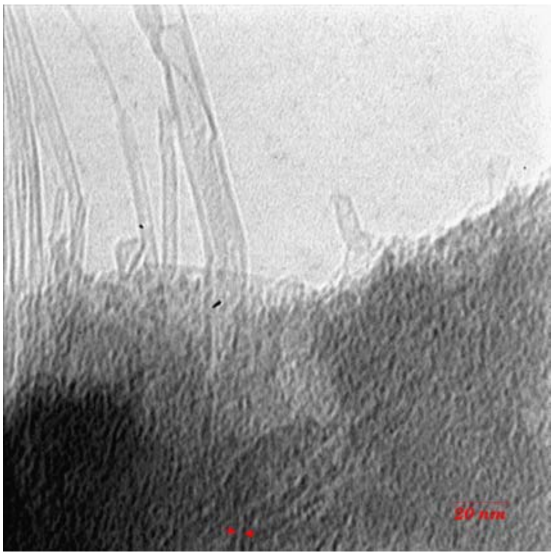


(b)

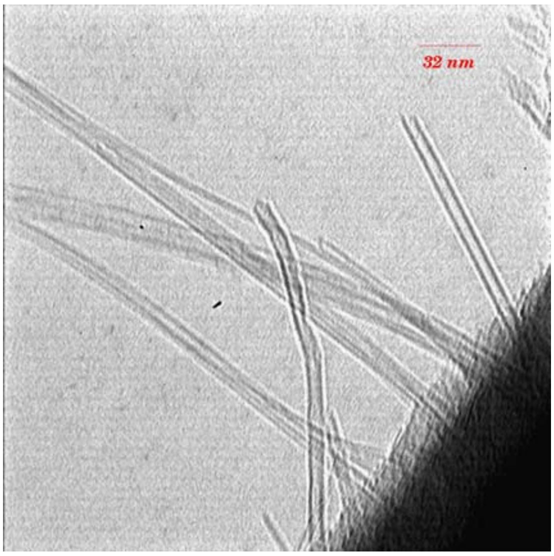


(c)

Figure 3 SEM micrographs of produced MDPE/CNT nanocomposite after 10 hrs milling (a) 0%CNT b) 0.5%CNT and c) 1%CNT



(a)



(b)

Figure 4 TEM micrographs of MDPE/1%CNT nanocomposite

Conclusion

The results of the study of microscopic structure of the MDPE/CNTs Nanocomposite materials produced by mechanical milling method are remarked as belows:
1) Milling process can be a simple method for producing MDPE/MWCNTs nanocomposite.
2) Addition carbon nanotube to medium density poly ethylene causes to change its morphology at constant milling parameters.
3) Because of high thermal conductivity of carbon nanotube, the dominate mechanism can be cold weld during ball milling process.

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