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Improvement Mechanism of Fracture Toughness of HDPE with Mixing Mechanism (Nano particle) for Pipe Application

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Abstract

This work studies the effect of TiO_2 on mechanical properties of high density polyethylene (HDPE)/titanium dioxide (TiO_2) nanocomposites for pipe application. The HDPE/TiO_2 nanocomposites were prepared by melt mixing technique in a twin-screw extruder. Nanocomposites with weight fraction (0.5, 2.5, 4wt. %) were fabricated. Mechanical behavior tests include (tensile strength, impact, and hardness tests) and structure test (FTIR) were used. Values of mechanical tests for titanium dioxide (TiO_2) nanoparticle reinforced High density polyethylene (HDPE) nanocomposites were much better than the neat high density polyethylene. Result of FTIR test showed physical reaction without the formation of new peaks.

Keywords: High density polyethylene, titanium dioxide, nanocomposite

INTRODUCTION

Polymers are used in many areas, such as automotive, electronics, and different construction equipment. Generally, they are used after being reinforced with various inorganic nano fillers are often added into polymer matrix to improve its mechanical, thermal, optical, magnetic, electrical, surface wear properties . These kinds of composites that are reinforced with nano-scale fillers are called nanocomposites [1,2]. mixtures good interfacial adhesion and to reduce the interfacial tension between the components, is necessary[3].High density polyethylene is well resistant to many different solvents ,it has a wide variety of applications including container , storage shed , water pipes, etc.[4].

High-density engineering plastic pipe is one of the most important applied to transport the water, gas, and corrosive liquid because of its low price, easily installed and good corrosive resistance. It is found that one of the failure modes of high density polyethylene pipe is the crack slowly grows cross the thick direction leads to failure at last .Recently, as the application of high-density polyethylene pipe becomes much more popular, it becomes more urgent and necessary to study the toughness properties in order to the safety assessment procedure based on the fitness for purpose[5]. High density polyethylene is an important polymer with high-tonnage production due to its superior mechanical and physical properties. However its toughness, weather resistance, processability and enviromental stress cracking resistance are not good enough, which have limited its application in many high tech fields [3]. High density polyethylene is a vastly used engineering material owing to its low cost, high formability, recyclability, relative availability and good flow properties and is widely used in commodity markets, as traditional extrusion processes [6]. Fillers have an important role in modifying the properties of various polymers. In polymeric materials, inorganic particles are used as fillers to improve their strength, toughness and wear properties. The effect of fillers on the properties of the composites depends on their concentration and particle size and shape, as well as their interaction with the matrix [7].

Titanium dioxide is a white solid inorganic substance that is highly rigid, thermally stable, non-flammable, poorly soluble in many solvents, biocompatible and not classified as hazardous. Its major applications can be seen in a variety of products, which include paints, coatings, plastics, paper, inks, food, medicine and cosmetics. Furthermore, it has been successfully used to fill many polymers. It was particularly selected in this study due to its ability to bond with many substrates and apparent chemical inertness [8] .In nature, nano titanium dioxide exists in rutile, anatase, and brookite in which rutile phase exhibits high stiffness, UV light absorbability, high refractive index 2.7, and super hydrophilic. With such advantage aspects, nanocomposites based on thermoplastic and titanium dioxide nanoparticles were expected to generate the new material class with superior properties such as excellent mechanical properties, light density, and thermal degradation [9].

This work studies the effect of titanium dioxide nano particles to improve fracture toughness of high density polyethylene for pipe application. High density reinforced nano composites with varying concentration of titanium dioxide were prepared by melt mixing technique in a twin screw extruder.

MATERIALS USED

Pure high density polyethylene (HD-52518). high density polyethylene , melt flow index (MFI) was (190℃/2.16 Kg, 18 g/10min); Density was 0.952 g/cm3. TiO2 with an average particle size 40 nm purchased from HWNANO/china. TiO_2 is in form of a white powder. TiO2 is in form of a white powder.

Sample Preparation

Pure HDPE granular and TiO_2 powders were dried in an oven at 110 °C for 2 h before melt extrusion. The HDPE granules and TiO_2 nanoparticles were melt compounding in desired compositions in a twin-screw extruder at temperatures in a range of 190-200 °C and a screw rotation rate of 20 rpm. The extradites were palletized at the die exit. After compounding, the blends were compression molded into standard dumb-bell tensile bars and rectangular bars, the mold temperature was kept at 190 °C.

Sample Characterization

Tensile tests were conducted according to ASTM D 638 with Instron 5556 Universal Testing Machine type (WDW/5E). The test starts by applying specified load (5KN) and the cross head speed was 5 mm/min. Impact strength tests were performed according to ASTM D 256 by using CEAST Resil impact German, gant (HAMBURG) company; model WP 400 charpy type instrument. The tests were performed at room temperature. Solid Density test is performed using (matsu haku high Precision Density Tester GP-120S D=0.0001 g/cm³) which contain water at room temperature based on ASTM D-792.Fourier transform infrared FT-IR spectra for the specimens was determined by using FTIR-8300 spectrometer (Bruker, Germany) by reflection mode technique.

RESULTS AND DISCUSSION

Impact strength for the nanocomposites of HDPE/TiO_2 after adding 0.5, 2.5, and 4 wt% of nanoTiO_2 is shown in Figure 1 the observed the impact strength values were significantly increased when 0.5 wt.% nanoTiO_2 was incorporated in the polymer matrix. It can be seen in Figure 2,that Tensile strength of HDPE/TiO_2 nanocomposites increased with 0.5 wt. % TiO_2 content as result good intermolecular forces between two phase that distributed uniformly in the HDPE matrix lead to decrease the crack propagation through tension. Hardness increased at 0.5 wt% nanoTiO_2 as shown in Figure 3, the reason of increase is the ability of TiO_2 nanoparticles to inter the spaces between the HDPE chains, and occupy sites between the chains that leads to reduce the free volume space and restrains the movement of the HDPE chains lead to create link between the HDPE and TiO_2 nanoparticles that indicate of increase the intensity of HDPE. Fig 4 and Figure 5, Showed result of FTIR test of pure HDPE and HDPE Nano composite respectively. FTIR test for high density polyethylene shows many bands such as the bands at 2912.61 and 2946.55 cm^{-1} for (C-H stretching), the band at 1466cm^{-1} for (CH_2 bending), The band at 718.55 cm^{-1} for (CH_2 rocking) the addition of TiO_2 nano particle caused lightly shafting in peaks and did not cause appearance of new peaks and this indicated that there is no chemical reaction between the nano particle and HDPE matrix, only physical reaction.

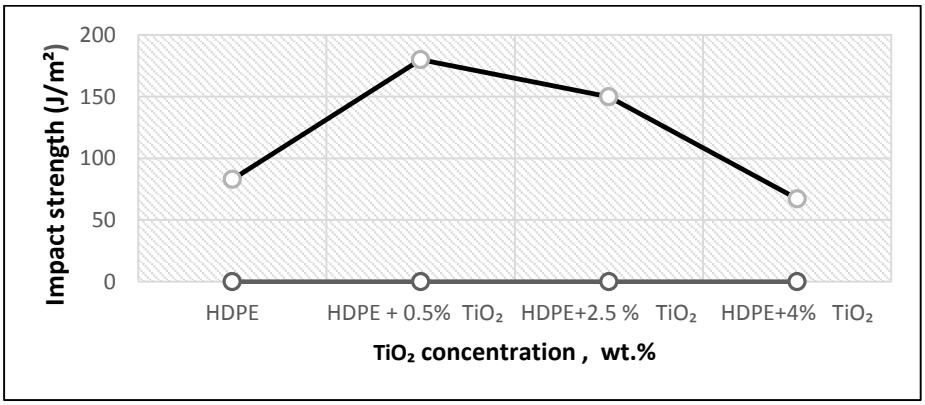

Figure 1: Impact strength of HDPE Reinforced with TiO2 nanopartices

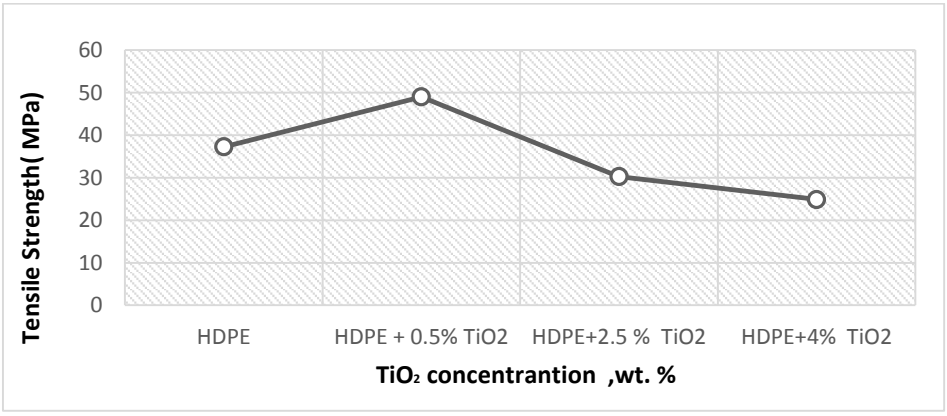

Figure 2: Tensile strength of HDPE Reinforced with TiO2 nanopartices

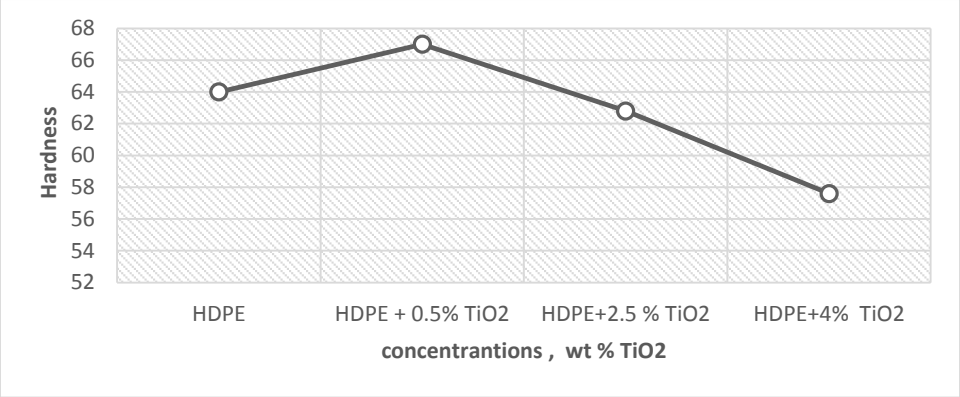

Figure 3: Hardness of HDPE Reinforced with TiO2 nanopartices

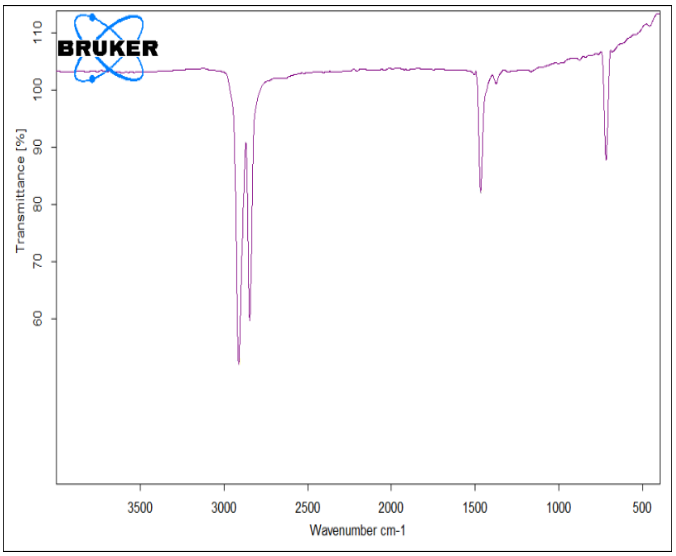

Figure 4: FTIR of pure HDPE

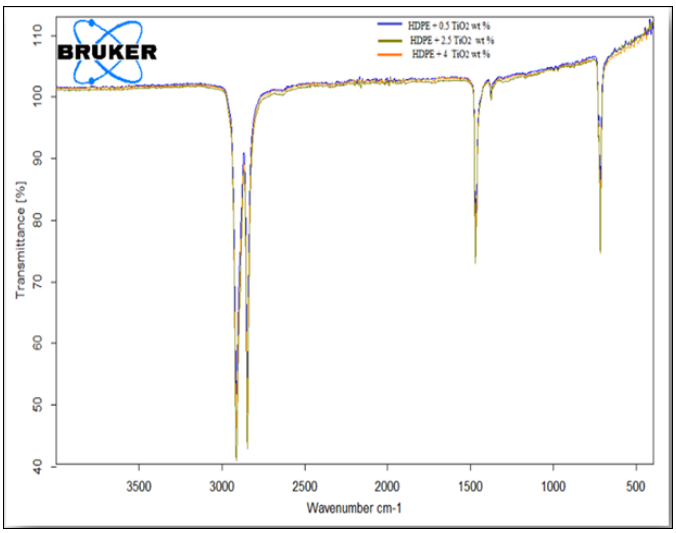

Figure 5: FTIR of (HDPE + TiO_2) nano composites.

CONCLUSIONS

The effect of TiO_2 on fracture toughness of HDPE/TiO_2 nanocomposites were studied. The HDPE/TiO_2 nanocomposites were prepared by melt compounding in a twin-screw extruder. Values of mechanical tests for TiO_2 nanoparticle reinforced High density polyethylene nanocomposites were much better than the neat high density polyethylene. The presence of nanoparticles titanium dioxide .Improved mechanical properties nanocomposite (tensile strength, impact, and hardness), especially in the TiO_2-filled HDPE compound at adding 0.5 wt.% nano TiO_2 .FTIR test result no chemical reaction between the nano particle and HDPE matrix, only physical reaction.

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