Preparation and Mechanical Property of Polyethylene/Rutile Nano-TiO_2 Composites

Ting Zheng[1], Li-Li Fan[2], Tong-Wu Li[2], Pei-Bang Dai [2*]

[1.] Guilin institute of intelligence science and technology, Guilin 541004, P.R. China

[2.] Guangxi Key Laboratory of Information Materials, School of Materials Science and Engineering, Guilin University of Electronic Technology, Guilin 541004, P.R. China

***Abstract*—The Polyethylene (PE)/rutile nanoscale titanium dioxide (nano-TiO_2) composites was prepared by compounding of PE and a modified rutile nano-TiO_2 in a twin-screw extruder. Mechanical property and morphology of the composites were characterized by electronic universal machine and scanning electron microscopy (SEM). The addition of the modified rutile nano-TiO_2 into PE caused a effective increase in tensile strength and a significant decrease in elongation at break of the PE/nano-TiO_2 composites. SEM results indicated that the nano-TiO_2 particles were out of sight on the cross section and the fracture mode was ductile fracture, meaning that superior toughness was achieved for the composites.**

Keywords-acrylic emulsion; nanometer titanium dioxide; polyethylene; composite materials; mechanical properties

I. INTRODUCTION

Polyethylene material is widely used in people's daily lives with excellent mobility, processing performance, better chemical stability, small absorbent and fine electrical insulation. But due to the smooth molecular chain and high crystallinity, the mechanical properties of polyethylene is low, which cause a large time molding shrinkage, low impact strength and poor heat resistance, aging resistance. With the continuous improvement of polyethylene composites comprehensive performance requirements, the modified polyethylene composites have become a very hot research topic. Due to the small size effect of the nanoparticles and strong interface interaction between polymer matrix and the nanometer inoganic particles, the polymer/inorganic nanocomposites showed superior properties compared to the conventional composite material, et al, more excellent physical, mechanical, electrical, magnetic, optical properties and chemical properties. Now how to solve the dispersion of nanoparticles and make it more evenly dispersed in polymer matrix becomes the research emphasis of inorganic nanoparticles modified PE.

Inorganic nanoparticles reinforced and toughened polymer material applications can be said to be very in-depth [1]. Kontou et al [2] studied the thermal properties and mechanical properties of linear low density polyethylene/SiO_2 nanocomposites prepared by different catalysts. Study found that adding SiO_2 nanoparticles increase the elastic modulus and tensile strength of the composite, and improve the elongation at break of the material. Avella et al [3] prepared PMMA / $CaCO_3$ nanocomposites by in-situ polymerization. This material exhibits good mechanical properties and the resin matrix polymer with a good wear resistance. Therefore, the polymer / inorganic nanocomposites attracted much more attention, also have great breakthrough and a good prospect.

In recent years, great progresses were achieved on the preparation of nanoscale titanium dioxide. It is thought that the addition of nanoscale titanium dioxide into polymer can cause a increase of properties of polymer material. However, due to the high melting viscosity of polymer and the high surface energy of nano-titanium dioxide, good dispersion of nanoscale of TiO_2 cannot be achieved in PE/TiO2 composites prepared by compounding of polymer and rutile TiO_2, resulting in a decrease of the performance of the composites. Therefore, the need surface-modification is needed for nanoscale rutile titanium dioxide in order to improve the mechanical properties and anti-aging properties of polymer/nano-TiO_2 composites.

To the best of our knowledge, there is no information about PE/nano-TiO_2 composites. Here, by using emulsion blending method for surface-modification of nanometer titanium dioxide, PE/nano-TiO_2 composites was prepared by a melting blend. The composites were characterized by electronic universal machine and scanning electron microscopy, in order to analysis mechanical properties and morphology change of the composite.

II. EXPERIMENTS

A. Materials

Low density polyethylene (LDPE) was purchased from Lanzhou petrochemical Co., China. Rutile nano-titanium dioxide was purchased from Shanghai jiang lugu titanium white chemical products Co., China. The chemical grade of them are Chemically pure. Dispersant, Defoaming agent and Wetting agent were purchased from Huaxia Co. Ltd., China. Acrylic emulsion was self-cortrol, They are Analytically pure. Unless otherwise noted, all starting materials and solvents used without further purification.

B. Instrument equipment and Characterization

PE/nano-TiO2 composite were prepared by a miniature conical twin-screw extruder SJSZ-10A at 170℃ and 190℃, respectively. The final shape of these materials was designed using a micro injection machine SZ-15 equipment in the temperature of 50℃ and 190℃(Wuhan Rui plastic machinery manufacturing Co.).

In the scanning electron microscopy (SEM) observation of the main information using the surface morphology of the sample secondary electrons, including topography contrast, the contrast component, the contrast and other electronics. Scanning Depth below the surface of the detection of 5- 10nm. SEM of the samples was taken by JSM-6380LV (Japanese electronics co.). The mechanical performance was tested by Shimadzu AG-20I Electronic universal machine.

C. The preparation of the modified rutile titanium dioxide

Dispersant (2‰), Wetting agent (2‰) and Defoaming agent (2‰) were mixed in deionized water under vigorous stirring. Then, the rutile titanium dioxide was added into the mixed solution with stirred for 4 h to form a homogeneous aqueous dispersion. Styrene-acrylic emulsion was put into the solution and further stirred for 1h at room temperature. Then the mixture was dried in an oven at 100℃ to collect the solid powder modified TiO_2 product.

D. The preparation of PE/nano-TiO_2 composites

The temperature of the miniature conical twin-screw extruder was controlled 170℃ at Ⅰ area and 190℃ at Ⅱ area after preheating. Mixed the modified nano-titanium dioxide and polyethylene in different proportions, and puted them into the conical twin screw extruder, the mixtures were melted in the set temperature, kept 10 minutes to make sure the mixtures were melted and mixed completely, then extruded the mixtures to obtain PE/ nano-TiO_2 composite materials.

III. RESULTS AND DISCUSSION

A. Effect of the content of the modified nano-TiO2 on the mechanical property of PE/nano-TiO2

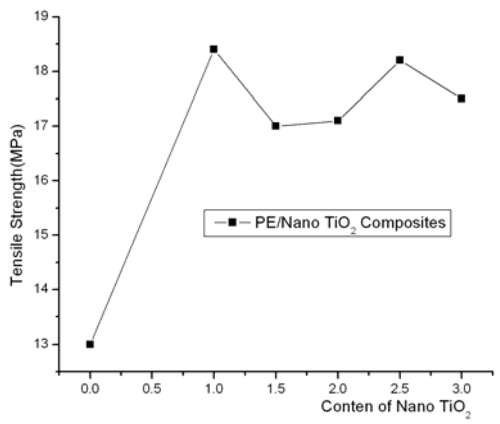

Figure 1. Effect of nano-TiO2 on the tensile strength of the composites

Figure 1. shows the effect of nano-TiO_2 on the tensile strength of PE/nano-TiO_2 composite. From Figure 1., it is seen that the tensile strength increased with the increase of the modified TiO_2 content. When the TiO_2 content of the PE/nano-TiO_2 composite was among 1.0-1.5 w%, the tensile strength decreased slightly comparing to among 0-1.0 w%. When the TiO_2 content increased between 1.5-2.0 w%, the tensile strength increased a little comparing to 1.0-1.5 w%. But when the TiO_2 content is increases from 2.0 w% to 2.5 w%, the tensile strength increased. The tensile strength decreased when the content is more than 2.5 to 3.0 w%.

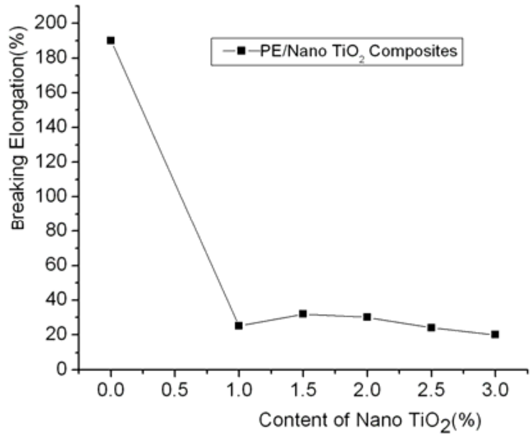

Figure 2. Effect of nano-TiO2 on the elongation at break of the composites

The effect of TiO_2 content on the elongation at break as shown in Figure 2. From Fig 2., the addition of the modified nano-TiO2 into PE caused a significantly decrease in the elongation at break of PE/nano-TiO_2 composites.

B. Mophology of the PE/nano-TiO2 composites

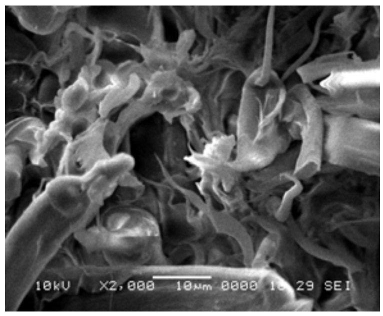

Figure 3. Mophology of PE/nano-TiO2 containing the modified nano-TiO2 of 1.0wt%

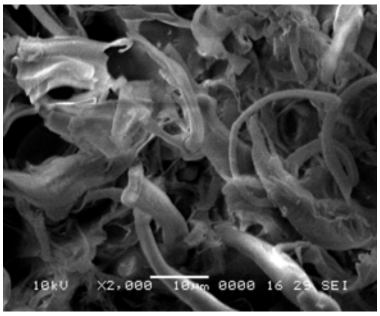

Figure 4. Mophology of PE/nano-TiO_2 containing the modified nano-TiO_2 of 3.0wt%

Figure 3 and Figure 4 show the SEM images of the fracture surface of PE/ nano-TiO_2 composite materials which the TiO_2 content is 1.0% and 3.0%, respectively. From the figures we can observe the effect of rutile titanium dioxide add to PE and the type of the quenching broken interface. The images show the nano-TiO2 particles are out of sight on the cross section, indicated that the section without PE-TiO2 two phase interface, fracture mode is ductile fracture.

IV. CONCLUSION

A modified nano-TiO_2 was prepared by compounding of nano-TiO_2 and styrene-acrylic emulsion. The effect of the modified nano-TiO_2 on the mechanical property of the PE/nano-TiO_2 composites was studied using Electronic universal machine and SEM. The TiO_2 content in PE/nano-TiO_2 composites has great influence on the mechanic performance of the composites. The addition of the modified rutile nano-TiO_2 into PE caused a effective increase in tensile strength and a significant decrease in breaking elongation of the PE/nano-TiO_2 composites. SEM results indicated that the nano-TiO_2 particles were out of sight on the cross section and the fracture mode was ductile fracture, meaning that superior toughness was achieved for the composites.

V. ACKNOWLEDGEMENTS

This research was jointly sponsored by Guangxi Key Laboratory of Information Materials (Guilin University of Electronic Technology), China (Project No.131015-Z).

REFERENCES

[1] Yilmaz C, Korkmaz T. The reinforcement effect of nano and microfillers on fracture toughness of two provisional resin materials. Mater Design., pp, 28, 2063, 2007

[2] Kontou E,Niaounakis. M. Thermo-mechanical properties of LLDPE/SiO2 nanocomposites. Polymer. , pp. 47, 1267, 2006

[3] Avella M, Errico ME, Martuscelli E. Novel PMMA/CaCO3 nanocomposites abrasion resistant prepared by an in situ Polymerization process Nano. Lett., 1, pp. 213, 2001.