



Mechanical Properties of Nylon Fiber Reinforced by Nanosilica

Supanut Wichitamornloet^{1,2}, Sirisart Ouajai³ and Thirawudh Phongprayoon^{1,2*}

¹ Department of Chemical Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand

² Center of Eco-Materials and Cleaner Technology, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand

³ Department of Industrial Chemistry, Faculty of Applied Science, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand

*Corresponding author's e-mail address: Thirawudh.p@eng.kmutnb.ac.th

Abstract

The nylon compounds containing 1%, 3% and 5% wt/wt of nanosilica were melt-mixed by twin screw extruder at temperature ranges of 230-240 °C. The composites of nylon/nanosilica fibers were processed by melt spinning process. The morphology of the composites was observed by scanning electron microscope (SEM), the results reveals that nanosilica was well dispersed in the composite fibers. The mechanical properties of the nylon/nanosilica fiber were examined. The results showed that the stress at break was increased with increasing nanosilica content, whereas Young modulus and elongation at break were minimum at 3% nanosilica content in the fiber.

Keywords: Nylon fiber, Nanosilica, Mechanical properties

Introduction

The engineering materials nylon (polyamide) is one of the synthetic fibers made from the chemical process. Nylon has been widely used for their advantages. It has many potential applications in rope, appliances, carpet and other commercial products in which stiffness, and some toughness [1]. But that use of nylon in some industries, such as the polyamide industry, still requires strength fibers. It is suitable for applications requiring high tensile strength. As being used in many ways, modifying nylon to improve the properties is necessary. Recently, polymer nanocomposites have received great interest due to their superior properties when compared with conventional composite materials. The incorporation of inorganic particulate fillers has proved to be an effective way of improving the mechanical properties, particularly the toughness, of nylon [2].

Nanoparticle-filled polymers are attracting considerable attention since they can produce property enhancement that is sometimes even higher than the conventional filled polymers. With regard to particulate filled composites, it is well known that the smaller the filler dimensions, the greater the specific area of the filler. Nanoparticles possess the characteristics of large specific area, large amount of surface atoms, high surface energy, as well as deficiency in surface coordination, and thus have high surface activity. The interfacial adhesion between inorganic particles and polymer matrix plays an important role in the properties of nanocomposites. It is attributed that the interface existed in the composites could transfer the force the matrix suffered to the particles so that the composites suffered homogeneous force to decrease the damage. The produced strong interface between nanoparticles and polymer matrix could improve the mechanical properties of the composites [3].

Silicon dioxide nanoparticles have shown a great potential as the nano-filler for plastics as well as for fibers [4-5]. Another interesting choice is nano-sized silica which has been explored as the filler for polymeric materials and held a great potential for developing high performance polymer.

In this work, nylon/nanosilica composites were prepared by melt spinning process. The properties of nylon/nanosilica composites were evaluated and were compared in terms of tensile strength.

Materials and methods

Materials

Nylon (PA Compound grade) was purchased from Zig Sheng Industrial co., Ltd (Taiwan). Nanosilica with a particle size of 12 nm and specific surface area of 200 ± 25 m²/g was purchased from Jebsen & Jessen Ingredients (T) Ltd (Thailand). Ethanol (absolute for analysis) was purchased from Merck (Germany).

Methods

Nanosilica was dried at 100 °C for 3 h. Nylon was also dried at 60 °C for 3 h. The nanocomposite compounds were prepared by a twin-screw extruder with a 20 mm diameter and L/D ratio of 40. The screw speed and barrel temperature of the extruder were set up at 70 rpm and 230–240 °C, respectively. The nanosilica content was varied at 1%, 3% and 5% wt/wt. in the nylon fibers.

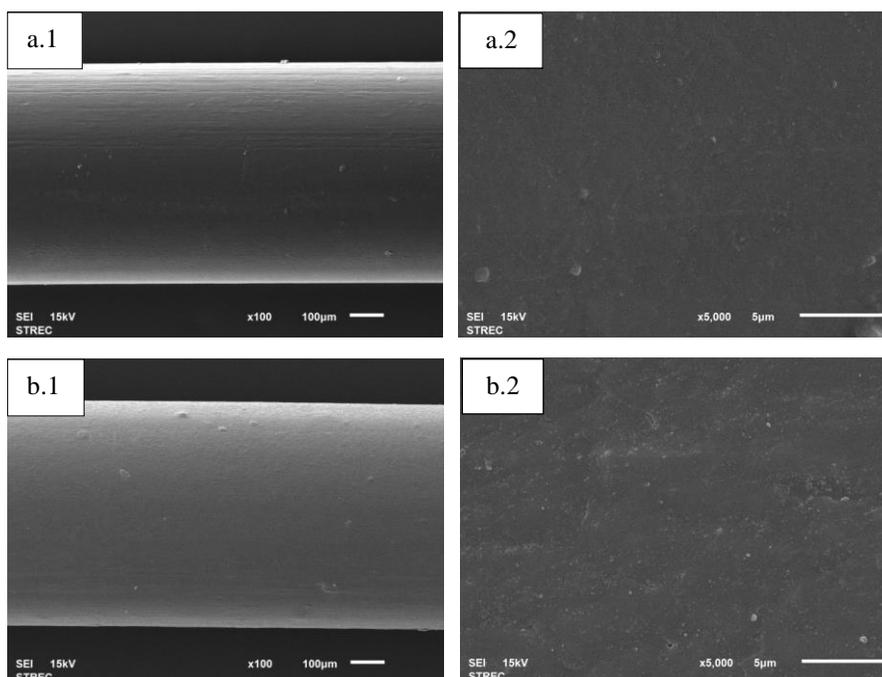
Property tests

The morphology of the composite fibers were observed by scanning electron microscopy (SEM) JSM-6610LV. The universal testing machine (UTM H10 KM) was used for mechanical property test. The test of the fiber was conducted with a crosshead speed of 50 mm/min and load cell of 75 N. All these tests were conducted at room temperature and an average value of at least five repeated tests was taken for each composite.

Results and discussion

SEM morphology

The dispersion of silica nanoparticles in nylon matrix was observed by SEM. Figure 1 and 2 shows the surface and cross-section images of nanofiber composites with 0-5% wt/wt silica nanoparticles loading prepared by melt spinning process. The dispersion of silica nanoparticle at 1% loading in both images, surface and cross-section was better than the dispersion of other loadings. When the amount of nanosilica particles increased, the nanoparticles were agglomerate according to silanol groups on silica surface strongly interacted by hydrogen bonding together shown in the cross-section images. For this reason, silica nanoparticles are difficultly dispersed and distributed in nylon. When the large quantity of silica nanoparticles was added to nylon, the agglomeration of silica nanoparticles was formed on the fiber surface and inside the nanofibers that show the bigger agglomerates of nanoparticles. From the cross-section images in Fig 2, the agglomeration tendency was obviously greater when increasing the amount of nanoparticles of silica. In 5% loading of silica nanoparticles, the agglomeration size was greater than 3 μm.



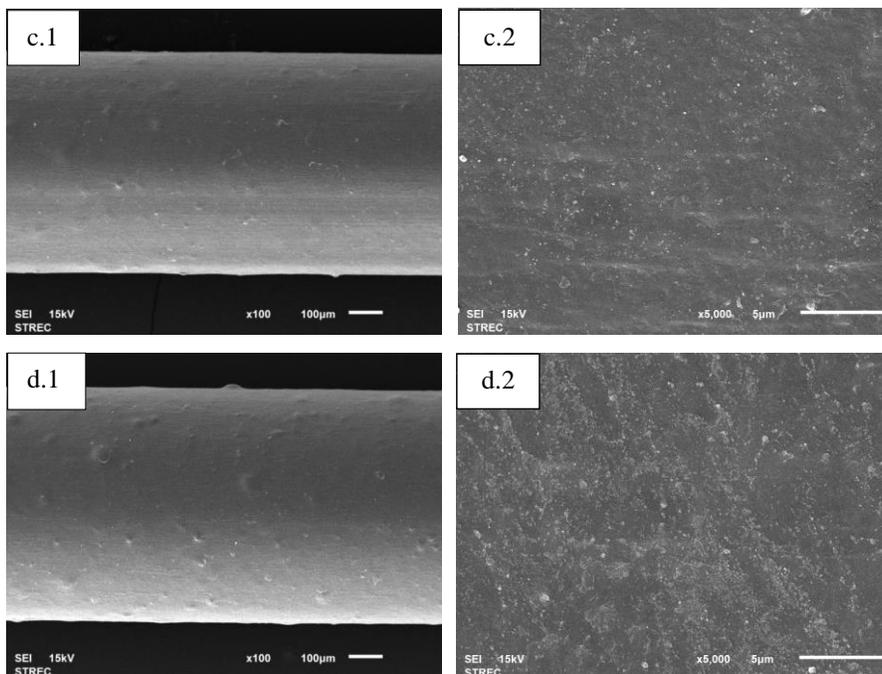


Figure 1 SEM nanofiber surface images of (a) neat nylon and composites of (b) 1% nanosilica, (c) 3% nanosilica and (d) 5% nanosilica in nylon fibers.

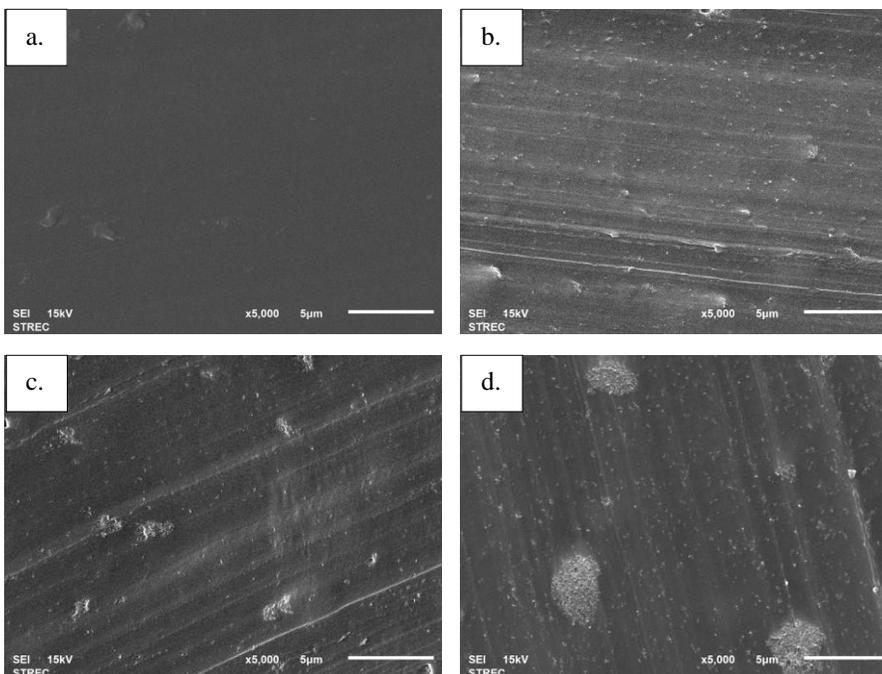


Figure 2 SEM cross section images of (a) neat nylon and composites of (b) 1% nanosilica, (c) 3% nanosilica and (d) 5% nanosilica in nylon fibers.

The mechanical properties of nylon/nanosilica fibers

Figure 3 shows the effect of nanosilica content on the mechanical properties of nylon/nanosilica composites. It is well known that the mechanical properties of composites are highly related to the filler-matrix interfacial interaction and the size of nanoparticles. As nanosilica particles are easy to aggregate during the process of melt blending and form the agglomeration of random size, the effect of nanoparticle size on composite properties has been weakened. Therefore, we consider that interface structure plays an important role in the mechanical properties of composites. Moreover the content of filler also has the effect for agglomeration. From the results the Young's modulus and elongation were decreased until 3% nanosilica and increased again, but the stress at break was increased with increasing nanosilica content that was higher than that of neat nylon.

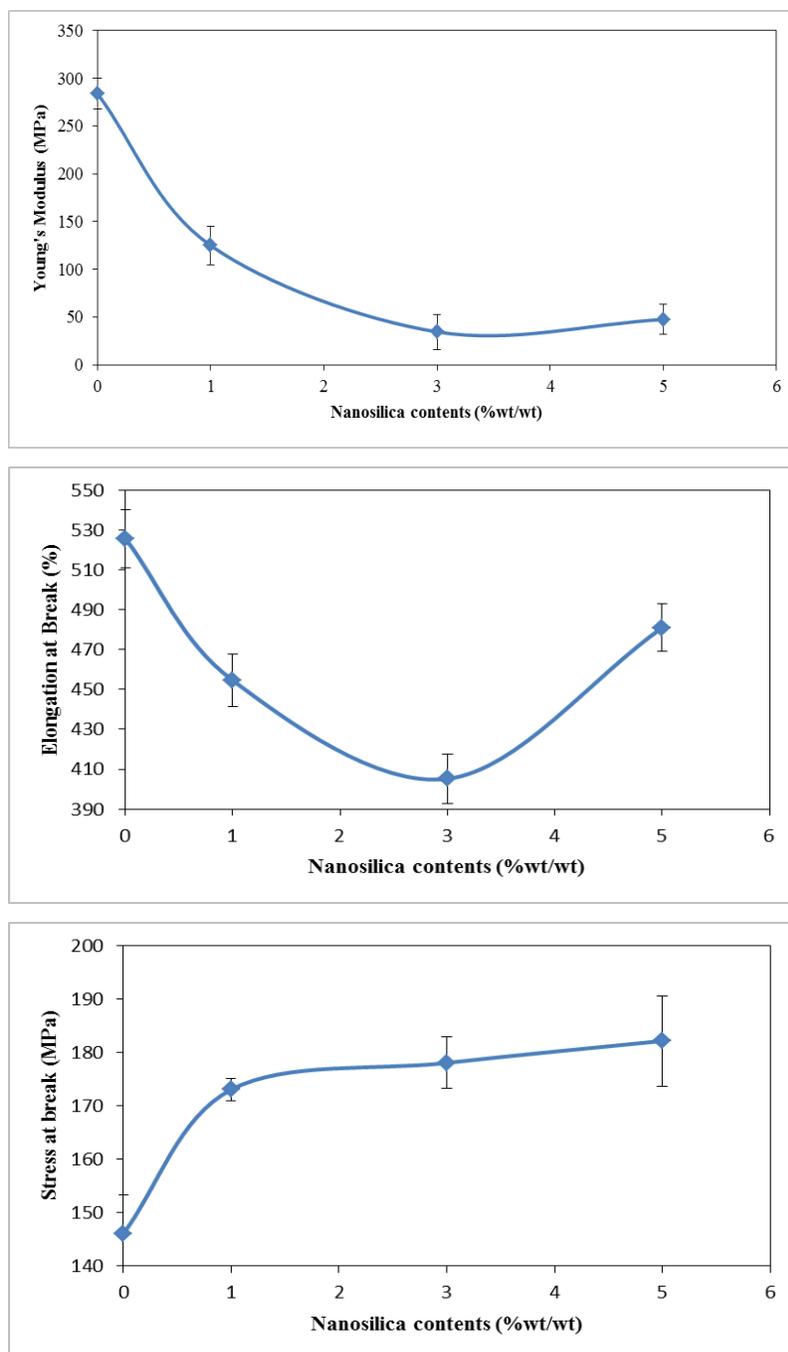


Figure 3 Mechanical properties of nylon /nanosilica fibers versus nanosilica content of: (a) Young's modulus (b) elongation at break and (c) stress at break.

Conclusion

Nylon/nanosilica composites were prepared as the fibers by melt spinning process. Nanosilica particles were well dispersed in composite fiber, when examined by SEM. The composite fiber exhibits an increased stress at break with an increase in nanosilica content that higher than the stress at break of the neat nylon.

Acknowledgements

The authors gratefully acknowledge the financial supported from The Thailand Research Fund (TRF), under the project of Research and Researchers for Industries (RRI), Master's degree (No.MSD60I0107) and Khon Kean fishing net Co., Ltd. for partial support of this fund. We also thank the financial supported by the Graduate Thesis Research Grant (GTRG) from the Graduate College, King Mongkut's University of Technology North Bangkok under award number 53/fiscal year 2561.

References

- [1] Someshwar Bhattacharya, & Chaudhari, D. S. B. (2013). Change in physico-mechanical and thermal properties of polyamide/silica nanocomposite film. *Engineering Research and Development*, 7(6), 1-5.
- [2] Feng Yang, Yuchun Ou, & Yu, Z. (1997). Polyamide 6/silica nanocomposites prepared by in situ polymerization. *Applied Polymer Science*, 69, 355-361.
- [3] Juan Liu, Hongling Yi, Heng Lin, Ting Wei & B. Zheng. (2014). Effects of functional group on the mechanical properties of PA 6/SiO₂ Composites. *Polymer Composite*, 435-440.
- [4] Patel, B.H. & Patel, P.N. (2012). Synthesis and application of nano-sized SiO₂ to textiles: a review. *International Dyer*, 35-39.
- [5] Jankong, S. & Srikulkit, K. (2008). Preparation of polypropylene/hydrophobic silica nanocomposites. *Journal of Metals, Materials and Minerals*, 18, 143-146.
- [6] Ying Li, Jian Yu, & Guo, Z.-X. (2001). The influence of silane treatment on nylon 6/nano-SiO₂ in situ polymerization. *Applied Polymer science*, 84, 827-834.
- [7] Haiwen Gu, Yangbo Guo, Siew Yee Wong, Chaobin He, Xu Li, & Shim, V. P. W. (2013). Effect of interphase and strain-rate on the tensile properties of polyamide 6 reinforced with functionalized silica nanoparticles. *Composites Science and Technology*, 75, 62-69.