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Mechanical Properties of Silicon Carbide Nanowires / Carbon Nanotubes / Rubber Composites

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ABSTRACT

In this work, 0-0-3 composites materials of silicon carbide nanowire (SiC NWs)/ carbon nanotube (CNTs)/ rubber were fabricated. The SiC NWs and CNTs reinforcement were prepared using the current heating technique (CHT) and infusion chemical vapor deposition (infusion CVD), respectively. The 0-10% by volume of CNTs + SiC NWs were mixed into rubber matrix phase to obtain 0-0-3 composites. Mechanical and physical properties of composite samples such as density, tensile strength and hardness were examined and compared with that of single phase of rubber. The results shown that tensile strength, hardness and density of composites were increased with adding reinforcement phase. Moreover, microstructure of sample was investigated by using scanning electron microscopy (SEM).

Keywords:silicon carbide nanowires (SiC NWs), carbon nanotubes (CNTs), rubber, composites

INTRODUCTION

In the recent years, polymer based composites reinforced with a small percentage of strong fillers can significantly improve the mechanical, thermal and barrier properties of the pure polymer matrix (Chisholm *et al*., 2005). Therefore, fiber reinforced composites (FRCs) are increasingly used as structural materials, due primarily to their excellent stiffness and weight characteristics. Additionally, the effectiveness can be increased in many applications including packaging, coating, sport, electronics, aerospace industries, aircraft and military, automotive, and marine engineering (Chisholm *et al*., 2005), (Walker and Smith, 2002), (Mel, 1994) and (Mallick, 1993).

Many types of fiber employed nowadays are glass-fiber, carbon-fiber and aramid-fiber or Kevlar. The traditional carbon fiber and glass fiber reinforced composites, both fiber and porous structures are at microscale and only a very small portion of the resin molecules are able to directly interact with reinforcement (Wang *et al*., 2004). Therefore, these fibers are still limited in some applications, especially, the aircraft engine and aerospace industries which need high temperature materials, high mechanical properties (Luthra and Park, 1992). So that, there are many works focus on the reinforcing polymer-based materials have incorporated various

particle/whisker-type fillers especially, the functionally graded materials (FGMs) to fabricate the high performance materials for space-planes (Chand, 2000) and (Krumova *et al*., 2001).

The new type filler phase, silicon carbide nanowires (SiC NWs) have been attracting considerable attention due to their excellent properties such as high thermal stability, high thermal conductivity, good mechanical properties and chemical inertness (Fu *et al*., 2006) and (Ying *et al*., 2004). Besides, it has been suggested as good reinforcement materials and suitable to be used as the reinforcing material for composites due to their much higher strength over their bulk counterparts and strong interfacial bonding (Yang *et al*., 2004).

Carbon nanotubes (CNTs), one graphene layer (SWNT) or many graphene layers wrapped onto themselves (MWNTs) are a novel crystalline carbon form which is another one of the novel materials which have been utilized as fillers in polymer matrix composites (Allaoui *et al*., 2002) because of their unique structure and remarkable mechanical properties such as high elastic properties, large elastic strain and fracture strain sustaining capability, exceeding those of any previously existing reinforcement materials of composites (Xie *et al*., 2005) and (Zou *et al*., 2004). Moreover, the CNTs also shows great flexibility compared to conventional fiber. Due to their exceptional mechanical, physical, thermal, optical and electrical properties, CNTs are being dispersed in polymer using variety of approaches.

In this work, composites samples between SiC NWs, CNTs and rubber were fabricated using casting techniques. The reinforced fiber, SiC NWs and CNTs were synthesized by current heating technique (CHT) and infusion chemical vapor deposition (infusion CVD). Physical and mechanical properties such as hardness, tensile strength and density of the composites samples were investigated. Moreover, microstructure of samples was determined using SEM technique.

METHODOLOGY

The SiC NWs were synthesized via current heat technique (CHT) (Jintakosol and Singjai, 2007) and (Nhuapeng *et al*., 2008). SiC NWs were taken out from surface were ground by using agate mortar for 10 min to get rid of hard agglomeration. The CNTs were synthesized by the infusion chemical vapor deposition (infusion CVD) (Singjai *et al*., 2007). CNTs were milled for 3 h to get rid of the agglomeration. A matrix phase of the composites was natural rubber. The density of the matrix is 0.928 g/cm^3. The SiC NWs and CNTs were used as the reinforcement phase (Figure 1). The SiC NWs and CNTs were added into rubber with the different ratios varying from 1 to 10 percents by volume.

To fabricate the composites, firstly, the mixture of SiC NWs and CNTs was ground for 10 min. Second, the mixture of reinforcements was added into the water and mixed in ultrasonic bath for 5 min. Thereafter, mixture of rubber filled with SiC NWs and CNTs was then poured into the plastic mould with thickness of 1 mm. Finally, the composite samples were left to settle for 3 day at room temperature and then removed from the mould.

Density of the samples was measured by Archimedes method. The mechanical properties, tensile strength were investigated by using the universal testing machine with a cross-head rate at 50 mm/min. The composites samples were cut into the dog-bone shapes (Figure 2). The hardness was examined by Shore durometer hardness testing technique (SHORE A). Furthermore, the microstructure of the samples was determined by scanning electron microscopy (SEM).

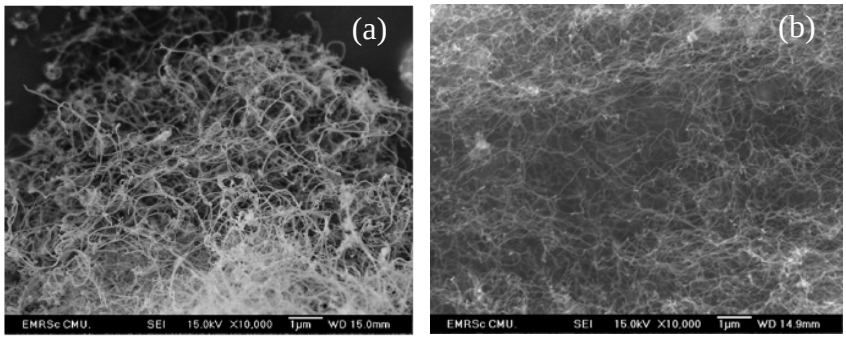

Figure 1 SEM micrographs of (a) SiC NWs and (b) CNTs

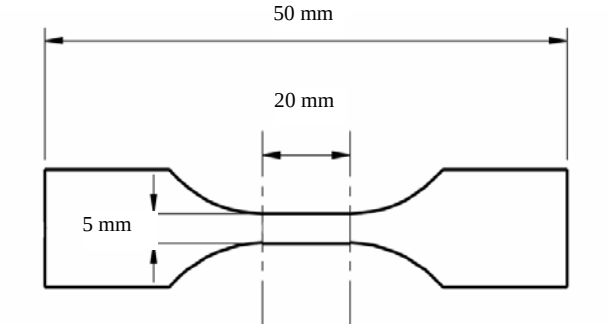

Figure 2 The standard sample for tensile testing.

RESULTS AND DISCUSSION

The results of the physical and mechanical properties testing of of SiC NWs/ CNTs/rubber composites sample were shown in Table 1. The density of composite samples is in the range of 0.938-1.006 g/cm^3. It was also found that the density of the composites is close to that of the rubber (0.928 g/cm^3). It may be due to adding small quantity.

The tensile strength and hardness of the composite samples are in the ranges of 6.31-17.63 MPa and 42.9-50.6 (type A), respectively. It can be noted that tensile strength of composite samples is decreased, where as the hardness of elastic rubber composite samples is increased with increasing the volume percentage of SiC NWs and CNTs. This result shows the effect of ceramics filler characteristics. However,

the SiC NWs and CNTs filler can promote the hardness property of rubber composites.

Moreover, SEM micrographs of the samples are shown in Figure 3. It has been seen that the dark phase is rubber phase and the bright phase is belong to SiC NWs and CNTs phase. Besides, it is also interesting to note that SiC NWs and CNTs are entirely wrapped by rubber. This result indicated that very well distribution and adhesion between SiC NWs and CNTs reinforcement phase and rubber matrix phase obtained from composites samples.

Table 1 The physical and mechanical properties of SiC NWs/CNTs/rubber Composites

SiC NWs + CNTs (Vol%)	Density (g/cm^3)	Tensile strength (MPa)	Hardness (Type A)
0.0	0.928	13.32	42.9
1.0	0.956	11.88	44.8
2.0	0.938	16.36	46.8
3.0	0.972	17.46	47.7
4.0	0.954	17.63	47.8
5.0	0.962	16.13	48.2
6.0	0.988	11.99	49.1
7.0	0.995	11.88	49.4
8.0	0.987	13.38	49.5
9.0	0.986	14.48	49.7
10.0	1.006	6.31	50.6

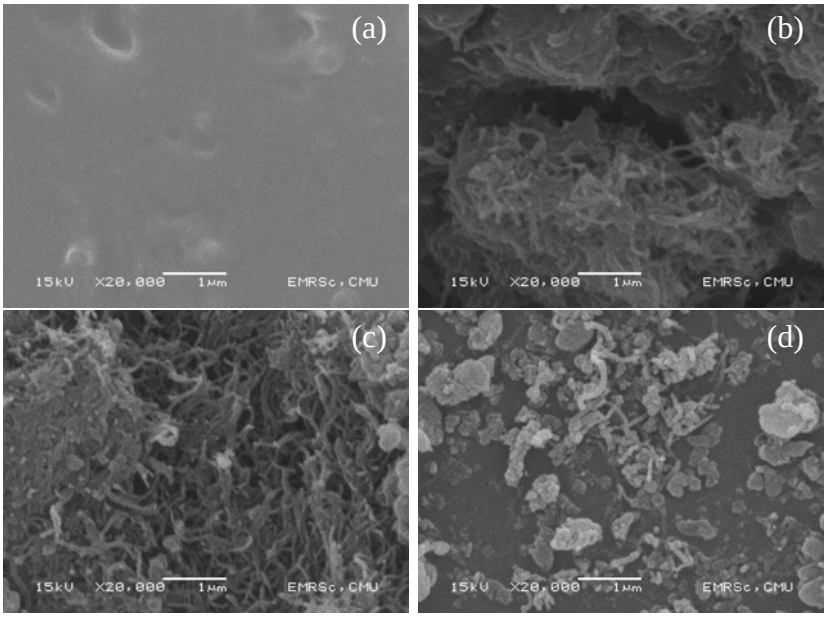

Figure 3 SEM micrographs of (a) 0.0, (b) 2.0, (c) 6.0 and (d) 10.0 Vol%

CONCLUSION

SiC NWs/CNTs/rubber composites were fabricated using the ultrasonic mixing and casting technique. The SiC NWs and CNTs were used as the reinforcement to promote the mechanical properties (hardness) of the composites. The results revealed that the well distribution and adhesion between SiC NWs and CNTs reinforcement phase and rubber matrix phase were obtained.

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REFERENCES

Allaoui, A., Bai, S., Cheng, H.M. and Bai, J.B. (2002). Mechanical and electrical properties of a MWNT/epoxy composite. *Compos. Sci. Technol., 62,*1993-1998.

Chand, S. (2000). Review carbon fiber for composites. *J. Mater. Sci. 35*, 1303–1313.

Chisholm, N., Mahfuz, H., Rangari, V.K., Ashfaq, A. and Jeelani, S. (2005). Fabrication and mechanical characterization of carbon/SiC-epoxy nanocomposites. *Comp. Struct., 67(1),* 115-127.

Fu, Q.G., Li, H.J., Shi, X.H., Li, K.Z., Wei, J. and Hua, Z.B. (2006). Synthesis of silicon carbide nanowires by CVD without using a metallic catalyst. *Mater. Chem. Phys., 100*, 108–111.

Jintakosol, T. and Singjai, P. (2007). Synthesis of Silicon Carbide Nanowires Doped with Al_2O_3. *Key Eng. Mater, 353–358*, 2171–2174.

Krumova, M., Klingshirm, C., Haupert, F. and Friedrick, K. (2001). Microhardness studies on functionally graded polymer composites. *Compos. Sci. Techno., 61*, 557–5563.

Luthra, K.L. and Park, H.D. (1992). Chemical Considerations in Carbon-Fiber/Oxide-Matrix Composites. *J. Am. Ceram. Soc., 75* (7), 1889–1898.

Mel, M.S. (1994). *Composite Materials, Vol. 1: Properties, Nondestructive, Testing and Repair*, New Jersey: Prentice-Hall, NJ.

Mallick, P.K. (1993). *Fiber-reinforced Composites: Materials, Manufacturing and Design, Revised and Expanded*, second ed., Marcel Dekker, Inc., NY.

Nhuapeng, W., Thamjaree, W., Kumfu, S., Singjai, P. and Tunkasiri, T. (2008). Fabrication and mechanical properties of silicon carbide nanowires/epoxy resin composites. *Curr. Appl. Phys., 8*, 295-299.

Singjai, P., Changsarn, S. and Thongtem, S. (2007). Electrical resistivity of bulk multi-walled carbon nanotubes synthesized by an infusion chemical vapor deposition method. *Mater. Sci. Eng. A., 443*, 42-46.

Walker, M. and Smith, R. (2002). A computational methodology to select the best material combinations and optimally design composite sandwich panels for minimum cost. *Comp. Struct., 80*, 1457-1460.

Wang, Z., Liang, Z., Wang, B., Zhang, C. and Kramer, L. (2004). Processing and property investigation of single-walled carbon nanotube (SWNT) buckypaper/epoxy resin matrix nanocomposites *Comp. Part A, 35.* 1225-1232.

Xie, X.L., Mai, Y.W. and Zhou, X.P. (2005). Dispersion and alignment of carbon nanotubes in polymer matrix: A review. *Mater. Sci. Eng. R., 49,* 89-112.

Yang, W., Araki, H., Kohyama, A., Thaveethavorn, S., Suzuki, H. and Noda, T. (2004). Fabrication in-situ SiC nanowires/SiC matrix composite by chemical vapor infiltration process. *Mater. Lett., 58,* 3145–3148.

Ying, Y., Gu, Y., Li, Z., Gu, H., Cheng, L. and Qian, Y. (2004). A simple route to nanocrystalline silicon carbide. *J. Solid State Chem., 177,* 4163–4166.

Zou, Y., Feng, Y., Wang, L. and Liu, X. (2004). Processing and properties of MWNT/HDPE composites. *Carbon, 42,* 271-277.