

SiO₂/MgO coated multiwalled carbon nanotubes in polymer composites

Krisztian Nemeth¹, Balazs Reti¹, Mark Posa², Karoly Belina², and Klara Hernadi^{*1}

¹Department of Applied and Environmental Chemistry, University of Szeged, Rerrich Béla tér 1, Szeged 6720, Hungary

²Faculty of Mechanical Engineering and Automation, Kecskemét College, Izsáki út 10, Kecskemét 6000, Hungary

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* Corresponding author: e-mail hernadi@chem.u-szeged.hu, Phone: +36 62 544 619, Fax: +36 62 544 619

The aim of this work was to develop a talc-like inorganic coating on the surface of the multiwalled carbon nanotubes (MWCNTs) to facilitate their mixing into the polypropylene and polyethylene matrix. Precursor compounds such as MgCl₂ · 6H₂O, Mg(NO₃)₂ · 6H₂O, MgO₂C₄H₁₀ and tetraethyl-

orthosilicate (TEOS) were used to cover the surface of the MWCNTs. As prepared, coverages and polymer composites were characterized by transmission electron microscopy and X-ray diffraction techniques.

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1 Introduction Since their discovery [1] carbon nanotubes (CNTs) have been in the center of the scientific interest due to their excellent mechanical [2, 3] and electric [4, 5] properties. Because of these attributes, multiwalled carbon nanotubes (MWCNTs) are often used in chemical sensors [6, 7], electronic devices [8, 9], and as reinforcing material in polymer composites [10–12]. The preparation of uniform MWCNT/polymer composite is a huge challenge, because MWCNTs do not disperse homogeneously in the polymer matrix because of the van der Waals forces between the MWCNTs and poor surface wetting properties. To assist the interaction between the MWCNTs and the polymer the key may be to coat the surface of the MWCNTs with inorganic coating. Previous works have considered the inclusion of CNTs solely in the single-phase systems such as TiO₂ [13], V₂O₅ [14], Al₂O₃ [15], SiO₂ [16, 17]

Since the inorganic-oxide coating on the MWCNTs surface can facilitate the stronger attach between the MWCNT and polymer and also can influence the physical and chemical properties, the aim of present work is the fabrication and characterization SiO₂-MgO/polymer nanocomposites using three different magnesia precursors and two preparation techniques.

2 Experimental

2.1 Materials The synthesis of MWCNTs was carried out via chemical vapor deposition (CVD) method at 720 °C in a rotary oven using Fe,Co/CaCO₃ catalyst [18], nitrogen

atmosphere and acetylene as carbon source. Using this synthesis method and catalyst MWCNTs were selectively formed without carbonaceous particles or amorphous carbon. The average diameter of MWCNTs is about 20–60 nm. The following precursors were used to form SiO₂-MgO without further purification: MgCl₂ × 6 H₂O (Molar), Mg(NO₃)₂ × 6 H₂O (Molar), MgO₂C₄H₁₀ (Aldrich) and tetraethyl orthosilicate (Aldrich). Methanol (Reanal) was used as solvent without purification.

2.2 Preparation of composite materials

2.2.1 Sol-gel method In the first step, MWCNTs were dispersed in methanol with ultrasonic treatment for 15 min. After that calculated amount of precursors (molar ratio Mg:Si = 3:4) was sonicated for 10 min and was added dropwise to the MWCNT mixture under continuous stirring. NaOH (0.5 M) was added to the solution to keep the pH between 8 and 10. The MWCNT/precursor mixture was stirred for 2 h at 25 °C. The prepared samples were dried at 65 °C for 24 h then annealed at 400 °C for 4 h.

2.2.2 Hydrothermal method Predetermined amount of MWCNTs were dispersed in 60 ml methanol solvent via ultrasonication. After that calculated amount of silica and magnesia, precursors (molar ratio Mg:Si = 3:4) were dissolved in methanol and NaOH was added. These two mixtures were added to each and were sonicated for 45 min.

1 Finally, the solution was put in a 150 ml teflon-lined
2 autoclave and applying hydrothermal synthesis for 24 h at
3 120 °C in order to prepare SiO₂-MgO/MWCNT nanocom-
4 posite. At the end of the synthesis, samples were filtered,
5 washed with methanol and dried for 24 h at 65 °C and
6 annealed in static furnace in air for 4 h at 400 °C.

7 **2.2.3 Preparation of MWCNT/polymer**
8 **nanocomposites** Polyethylene (PE) (8000 F HDPE,
9 TVK, Hungary) and polypropylene (PP) (H 781 F homo-
10 polymer, TVK, Hungary) were used as matrix materials.
11 Composites were prepared in a co-rotating internal mixer
12 (Brabender type). Polymer granules (55 g) was placed into
13 the chamber, previously heated up to 180 °C. Calculated
14 quantity of nanotube was also added. Rotation of the rotors
15 was 80 rpm, mixing time was 10 min in every experiments.
16 The mixed compound was removed from the chamber and
17 pressed into sheet at the same temperature. Cooling rate of
18 the samples was ballistic.

19 **2.3 Sample characterization** To verify the for-
20 mation of the silica-magnesia oxide layer on the surface of
21 the MWCNTs transmission electron microscopy (TEM) was
22 used (Philips CM10). Samples were grinded into fine powder
23 in an agate mortar. A small amount of the samples were
24 added into ethanol and after short sonication the suspension
25 was dropped onto a carbon coated Cu TEM-grid. The
26 MWCNT/polymer composites were investigated by scan-
27 ning electron microscopy (SEM)(Hitachi S-4700 Type II
28 FE-SEM). Crystal structure was investigated by X-ray
29 diffraction (XRD) (Rigaku Miniflex II Diffractometer).

30 **3 Results and discussions**

31 **3.1 Samples synthesized via sol-gel method**
32 After annealing process, the quality of composite materials
33 were investigated by TEM method. Table 1 shows the

Table 1 Summary of SiO₂-MgO coating on MWCNT's surface in various magnesia precursors.

| precursors | MWCNT content (wt%) | coating |
|--|---------------------|---------|
| Si-MgCl ₂ | 1 | + |
| | 5 | - |
| | 10 | - |
| | 15 | - |
| Si-Mg(NO ₃) ₂ | 1 | + |
| | 5 | + |
| | 10 | + |
| | 15 | ++ |
| Si-MgO ₂ C ₄ H ₁₀ | 1 | + |
| | 5 | + |
| | 10 | ++ |
| | 15 | ++ |

-, no coverage; +, rudimentary coverage with some segregated particles; ++, nearly homogenous coverage.

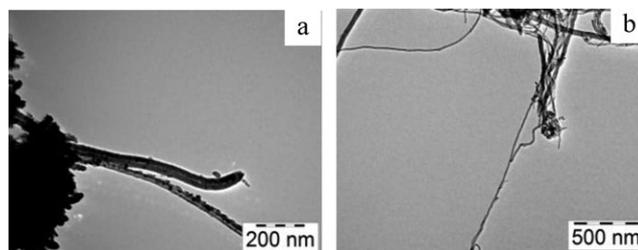


Figure 1 Transmission electron microscopy (TEM) images of SiO₂-MgO/MWCNT nanocomposites using MgCl₂ precursor (a) with 10 wt% MWCNT (b) with 5 wt% MWCNT.

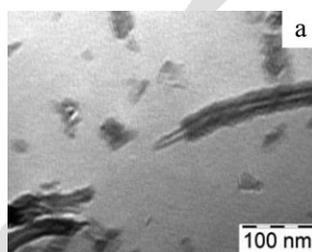


Figure 2 TEM image of SiO₂-MgO/MWCNT nanocomposite using Mg(NO₃)₂ precursor with 15 wt% MWCNT.

summary of SiO₂-MgO coating of MWCNT's surface in case of various magnesia precursors.

Table 1 shows that using MgCl₂ × 6 H₂O precursor SiO₂-MgO/MWCNT nanocomposites were not successful. Homogenous coating was not observed only segregated particles on the surface of the MWCNTs (Fig. 1a). In case of samples containing 5 and 15 wt% (Fig. 1b) MWCNTs only bare MWCNTs were observed.

Using Mg(NO₃)₂ × 6 H₂O as precursor, TEM observations revealed that inorganic layers were formed on the surface of some MWCNTs, however sample containing 15 wt% MWCNT nearly homogenous coating was observed (Fig. 2).

The preparation of SiO₂-MgO/MWCNT nanocomposite was also successful using MgO₂C₄H₁₀ as magnesia precursor. TEM images revealed that samples containing 1 wt% (Fig. 3a) and 5 wt% MWCNT have irregular coverage.

TEM images in Fig. 3b and c illustrates a nearly homogenous coverage on the MWCNTs surface using 10 and 15 wt% MWCNT content.

3.2 Samples synthesized via hydrothermal method Table 2 and TEM images (Fig. 4a-d) show using hydrothermal method and magnesium-ethoxide precursors to coat MWCNTs. The obtained samples contained segregated particles and MWCNTs were rudimentary coverages.

Applying magnesia-ethoxide as precursor various quality of coating were synthesized. TEM images have revealed (Fig. 5a and b) that from bare to nearly homogeneously coated MWCNTs were prepared.

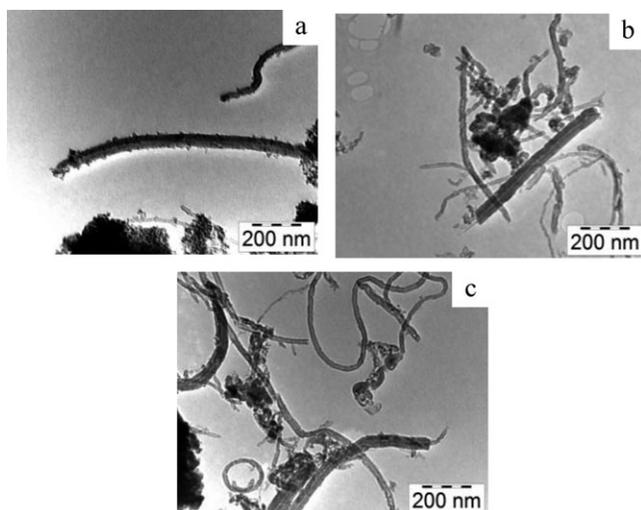


Figure 3 TEM images of Si–MgO/MWCNT nanocomposites using $\text{MgO}_2\text{C}_4\text{H}_{10}$ precursor (a) with 1 wt% MWCNT (b) with 10 wt% MWCNT and (c) with 15 wt% MWCNT.

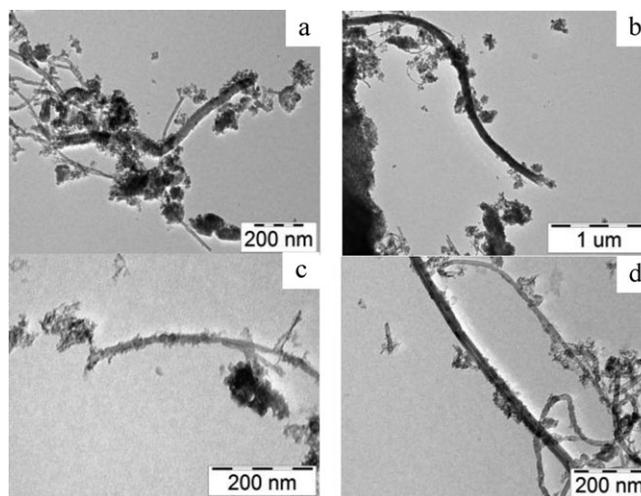


Figure 4 TEM images of SiO_2 –MgO/MWCNT nanocomposites using $\text{Mg}(\text{NO}_3)_2$ precursor (a) with 1 wt% MWCNT (b) with 5 wt% MWCNT (c) with 10 wt% MWCNT and (d) with 15 wt% MWCNT.

Table 2 Summary of SiO_2 –MgO coating on MWCNT's surface using various magnesia precursors.

| precursors | MWCNT content (wt%) | coating |
|---|---------------------|---------|
| Si– $\text{Mg}(\text{NO}_3)_2$ | 1 | + |
| | 5 | + |
| | 10 | + |
| | 15 | + |
| Si– $\text{MgO}_2\text{C}_4\text{H}_{10}$ | 1 | ++ |
| | 5 | + |
| | 10 | ++ |
| | 15 | – |

–, no coverage; +, rudiment coverage with some segregated particles; ++, nearly homogenous coverage.

3.3 Scanning electron microscopy analysis of MWCNT/polymer composites

The coated MWCNT samples were mixed into PE and PP matrix. The MWCNT/PE and MWCNT nanocomposite/PP composites as well as pristine polymers were investigated by SEM. SEM images in Fig. 6 shows significant difference between pristine PE (Fig. 6a) and fractured surface of MWCNT nanocomposite/PE composite containing 0.01 wt% of MWCNT (Fig. 6b). From Fig. 6b, it can be seen that MWCNTs are embedded in the PE matrix, and smooth interfaces between MWCNT and PE are observed.

3.4 XRD analysis All samples were annealed at 400°C for 4 h in air to convert the amorphous inorganic coating into a crystalline phase so characteristic reflexions are identifiable by XRD technique. This temperature is low enough to evolve oxide form without burning CNTs. As an

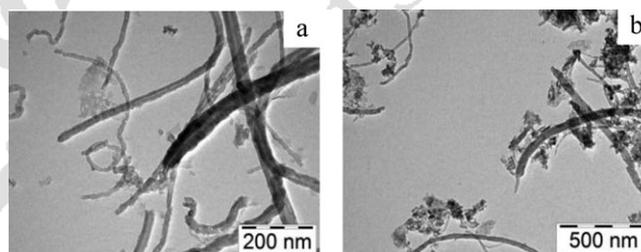


Figure 5 TEM images of SiO_2 –MgO/MWCNT nanocomposites using $\text{MgO}_2\text{C}_4\text{H}_{10}$ precursor (a) with 1 wt% MWCNT (b) with 10 wt% MWCNT.

example XRD diffraction pattern Si– $\text{MgO}_2\text{C}_4\text{H}_{10}$ /MWCNT (a) nanocomposite and a reference sample without MWCNT (b) are shown in Fig. 7.

The most important reflexions are at $2\theta = 21.52^\circ$ (200, SiO_2), $2\theta = 25.9^\circ$ (002, MWCNT) and $2\theta = 32.84^\circ$ (220), 37.22° (311), 42.98° (400), 62.58° (422, MgO).

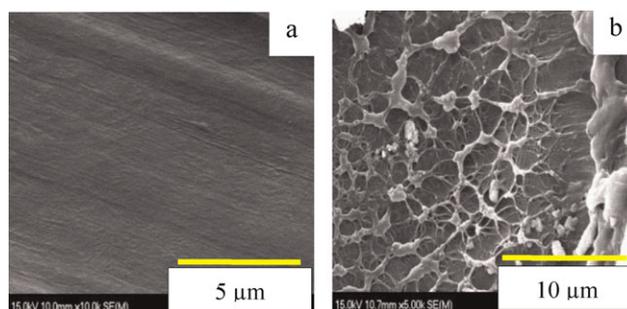


Figure 6 (online color at: www.pss-b.com) Scanning electron microscopy (SEM) images of (a) pristine polyethylene and (b) 0.01 wt% MWCNT nanocomposite/PE composite.

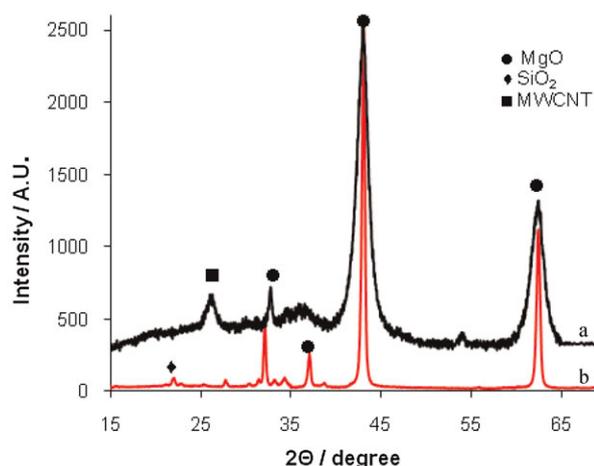


Figure 7 (online color at: www.pss-b.com) XRD diffraction of SiO₂-MgO/MWCNT using MgO₂C₄H₁₀ precursor (a) and reference (b) sample.

4 Conclusion Comparing the coated materials, it can be concluded that using magnesium-nitrate hexahydrate and magnesium-ethoxide precursors resulted more homogeneous coverage compared to the MgCl₂ × 6H₂O. In the presence of magnesium-chloride hexahydrate, homogeneous coating could not be observed.

It has been shown that by varying the content of MWCNT, the more homogeneous coating can be prepared by higher CNT content. Reinforcing effect of CNTs in a polymer matrix strongly depends on surface interaction between them. Using MWCNT of highly graphitic character and “smooth” surface can hinder this influence. Thus, coverage with SiO₂-MgO layer (chemically similar to commercially used talc-like filler) might have a significant role in conveying mechanical properties of MWCNTs. With controllable formation of inorganic coating, we hope to prepare new type of nanocomposite-polymer materials having incredible mechanical properties.

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References

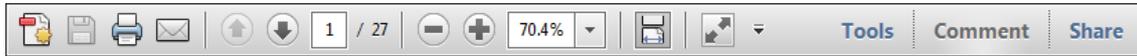
- [1] S. Iijima, *Nature* **354**, 56–58 (1991).
- [2] E. W. Wong, P. E. Sheehan, and C. M. Lieber, *Science* **277**, 1971–1975 (1997).
- [3] J. P. Salvetat, G. D. Briggs, J. M. Bonard, R. R. Bacsa, A. J. Kulik, N. A. Burnham, and L. Forro, *Phys. Rev. Lett.* **82**, 944–947 (1999).
- [4] P. Calvert, *Nature* **357**, 365–366 (1992).
- [5] W. A. D. Heern, A. Chatelain, and D. Ugrate, *Science* **270**, 1179–1181 (1995).
- [6] I. Lopes, A. Gohier, D. Porterat, P. Chenevier, G. Denian, S. Palacin, M. Mayne-L’Hermite, and C. Reynaud, *Key Eng. Mater.* **495**, 298–301 (2012).
- [7] Q. Zhao, Z. Gan, and Q. Zhang, *Electroanalysis* **14**, 1609–1613 (2002).
- [8] D. R. Kauffman, Y. Tang, P. D. Kichambare, J. F. Jackovitz, and A. Star, *Energy Fuels* **24**, 1877–1881 (2010).
- [9] H. Dong and K. Lu, *Int. J. Appl. Ceram. Technol.* **6**, 216–222 (2009).
- [10] J. N. Coleman, U. Khan, and Y. K. Gun’ko, *Adv. Mater.* **18**, 689–706 (2006).
- [11] M. Cadek, J. N. Coleman, K. P. Ryan, V. Nicolosi, G. Bister, A. Fonseca, J. B. Nagy, K. Szostak, F. Béguin, and W. J. Blau, *Nano Lett.* **4**, 353–356 (2004).
- [12] E. T. Thostenson and T. W. Chou, *J. Phys. D* **35**, 77–80 (2002).
- [13] Z. Nemeth, C. Dieker, A. Kukovecz, D. Alexander, L. Forro, J. W. Seo, and K. Hernadi, *Compos. Sci. Technol.* **71**, 87–94 (2011).
- [14] J. S. Sakamoto and B. Dunn, *J. Electrochem. Soc.* **149**, A26–A30 (2002).
- [15] Z. Németh, K. Markó, A. Erdőhelyi, L. Forró, and K. Hernádi, *Phys. Status Solidi B* **248**, 2480–2483 (2011).
- [16] K. Hernadi, E. Ljubovic, J. W. Seo, and L. Forró, *Acta Mater.* **51**, 1447–1452 (2003).
- [17] T. Seeger, Ph. Redlich, N. Grobert, M. Terrones, D. R. M. Walton, H. W. Kroto, and M. Rühle, *Phys. Chem. Lett.* **339**, 41–46 (2001).
- [18] E. Couteau, K. Hernadi, J. W. Seo, L. Thien-Nga, Cs. Miko, R. Gaál, and L. Forró, *Chem. Phys. Lett.* **378**, 9–13 (2003).

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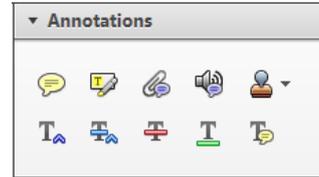
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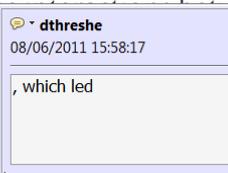


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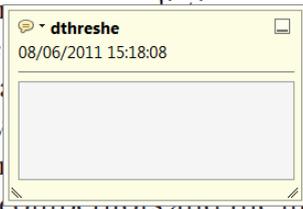


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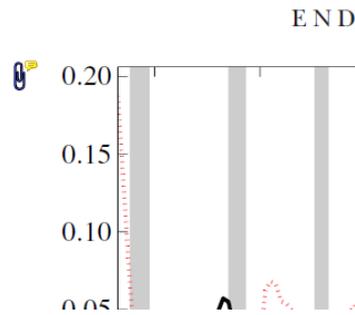
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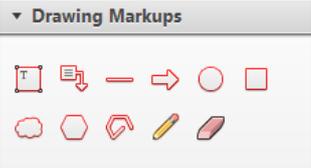


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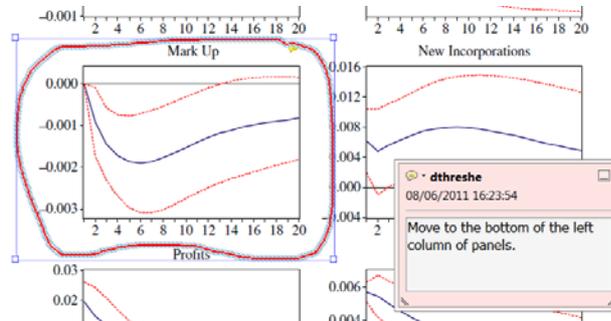


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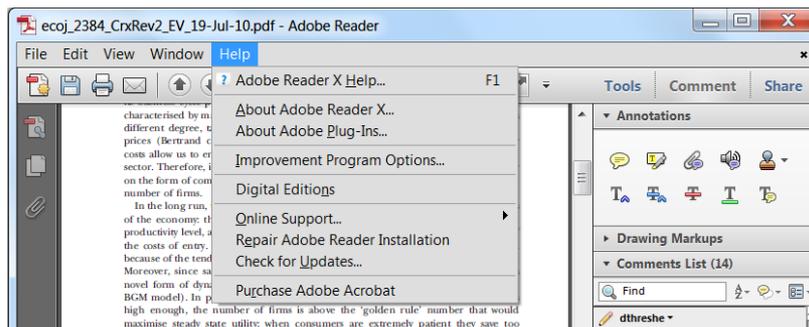
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