Chitosan for Suspension Performance and Viscosity of MWCNTs

Yi-Hsuan Hung and Wen-Chieh Chou

***Abstract*—This study prepared the MWCNTs/water nanofluid with chitosan as a dispersant by the direct-synthesis method. The main purpose of this paper is to experimentally investigate the suspension performance variations influenced by the additive concentrations of the multi-walled carbon nanotubes (MWCNTs) as well as the chitosan in the water. The feasibility study of the nanofluid using the MWCNTs and chitosan is carried out. Experimental results demonstrate that the additive concentration of chitosan showed the proportional relationship for suspension performance. However, adding chitosan will increase the viscosity and decrease the thermal conductivity of nanofluids. The chitosan concentration of 0.4 wt% can provide good suspension performance for all concentration range of MWCNTs in this study. As the nanofluids containing MWCNTs and chitosan with concentrations of 1.5 wt% and 0.4 wt.%, the thermal conductivity will increase 9.0% and enhance 233% of the viscosity compared with deionized water.**

***Index Terms*—Chitosan, MWCNTs, nanofluid, viscosity, thermal conductivity.**

I. Introduction

Carbon nanotubes (CNTs) has inherently special physical and chemical properties such as the unique optical, thermal and magnetic performance, etc.. Hence, the CNTs can be regarded as one of the most promising materials in all nanomaterials [1]. The most commonly used CNTs are single-walled carbon nanotubes (SWCNTs) and multi-wall carbon nanotubes (MWCNTs). The CNTs has excellent thermal conductivity and mechanical properties. By mixing it in the solid [2]-[8] or fluid [9]-[15], the mixture can effectively enhance the thermal performance and mechanical properties of the base materials. Therefore, the CNTs employed in the field are evaluated with great potential for the heat transfer applications.

When the CNTs nanofluid is with high thermal conductivity used in a heat exchange (heat dissipation) system, the suspension performance is the most concern. Low suspension performance will cause the decrease of heat exchange capacity and the choke of the flow pipes. Therefore, in addition to the mechanical stir, appropriate adding a dispersant or surfactant is the most common and effective method to improve the suspension performance. The commonly used dispersant contains nitric/sulfuric acid mixture, potassium hydroxide group [11]-[15] and a wide range of using surfactants such as sodium dodecylbenzene sulphonate (SDBS), sodium dodecyl sulfate (SDS), and gum arabic (GA) [16], [17]. Although adding dispersants to promote dispersion of nano-materials in the base fluid can maintain a good suspension performance in a long period, it may thus reduce the thermal conductivity of nanofluid due to the lower thermal conductivity of these dispersants.

This study prepared the MWCNTs/water nanofluid with chitosan as a dispersant by the direct-synthesis method. We investigate the influences of the additive concentrations of the MWCNTs and chitosan in the deionized water on suspension performance variations. By appropriate experiments, the feasibility was evaluated. Finally, we conducted the measurements of thermal conductivity and viscosity to search for the optimal additive concentration of dispersant in MWCNTs/water nanofluids.

II. Experimental

A. Preparation of Nanofluid

The MWCNTs/water nanofluid adopted in this study contains MWCNTs (20-30 nm, Cheap Tubes Inc.). Fig. 1 shows a photograph of MWCNTs with a transmission electron microscope (FEI-TEM, Tecnai G2 F20, Philips). The aggregation of MWCNTs appears, and the outside diameter approximately met the specifications provided by the manufacturer. A cationic dispersant: chitosan, with the advantages of non-toxic and biodegradable properties, is widely employed in medicine, agriculture, chemical and food processing areas [14], [18]-[20]. Therefore, this study adopted it as a dispersant for MWCNTs/water nanofluids. The base liquid was prepared by adding 0.1, 0.2 and 0.4 wt. % of water-soluble chitosan in the deionized water to obtain the good suspension for nanofluid. The MWCNTs/water nanofluid produced by the direct-synthesis method was then used as the experimental sample. An electromagnetic agitator (PC-420D, Corning) and an ultrasonic vibrator (D400H, TOHAMA) were alternately used to disperse the MWCNTs into four weight fractions (0.25, 0.5, 1.0, 1.5 wt. %) in the base liquid (Table I).

B. Experimental Process

Firstly, the zeta potential (Vzp) of MWCNTs/water nanofluid was measured by a dynamic light scattering (DLS) analyzer (SZ-100, HORIBA) to determine suspension performance. Then, all the completed experimental samples were statically placed for 7 days to confirm suspension performance, and to be identified the changes of transmittance of MWCNTs/water nanofluid by using the UV/VIS spectrometer (BRC112E, B&W) with a set of fixed time. Finally, the thermal conductivity and viscosity were measured by thermal properties analyzer (KD-2 Pro,

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The authors are with the Department of Industrial Education, National Taiwan Normal University, No. 162, Sec. 1, He-ping E. Rd., Da-an District, Taipei City 10610, Taiwan (e-mail: hungyh@ntnu.edu.tw, n_p803@hotmail.com).

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Decagon) and viscometer (T15, Hydramotion) to evaluate the effect of concentration of chitosan and MWCNTs for thermal conductivity (k) and viscosity (μ) of MWCNTs/water nanofluid at the room temperature, respectively.

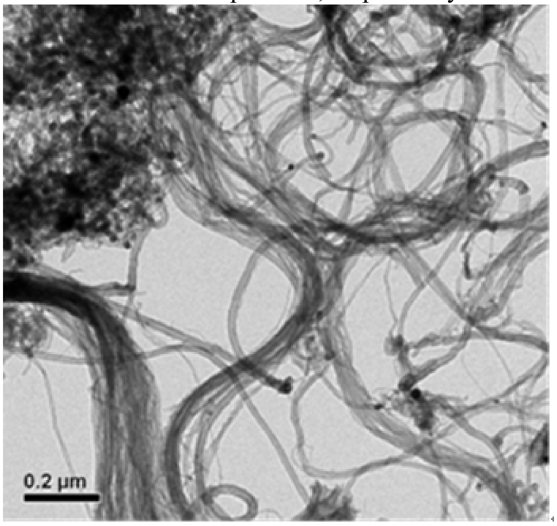

Fig. 1. TEM image of MWCNT.

TABLE I: CONCENTRATIONS OF EXPERIMENTAL SAMPLES.

Sample No.	1	2	3	4
MWCNTs (wt.%)	0.25	0.5	1.0	1.5
Chitosan (wt.%)	0.1	0.1	0.1	0.1
Sample No.	5	6	7	8
MWCNTs (wt.%)	0.25	0.5	1.0	1.5
Chitosan (wt.%)	0.2	0.2	0.2	0.2
Sample No.	9	10	11	12
MWCNTs (wt.%)	0.25	0.5	1.0	1.5
Chitosan (wt.%)	0.4	0.4	0.4	0.4

C. *Data Analysis*

All experimental data obtained with the deionized water as the baseline values is defined as, while experimental data of the nanofluid as adding the MWCNTs and chitosan to deionized water is. The differences before and after adding the MWCNTs and chitosan to deionized water were presented as proportions (R), calculated as follows:

$$R = D_n / D_w \quad (1)$$

III. RESULTS AND DISCUSSIONS

Fig. 2 demonstrates the measurement results of all samples listed in Table 1. The value of zeta potential closer to zero will more lead to the sedimentation of MWCNTs. It can be seen that the increase of the concentration of chitosan raises the zeta potential. On the other hand, the higher concentration of MWCNTs will reduce the value of zeta potential. To remain good suspension, the concentration of dispersant must be proportional to the concentration of MWCNTs. From the result of Fig. 2, it can be concluded that No. 1-2, No. 5-7 and No. 9-12 have better suspension performance.

Fig. 3-5 illustrates the measurement results of transmittance of the samples which were statically placed 7 days measured by a UV/VIS spectrometer. Once the sedimentation occurs, the transmittance of the samples will rise so that the suspension performance decreases. The variation tendencies are consistent between the zeta potential and the transmittance from the UV/VIS spectrometer. Since the samples with poor suspension performance are unsuitable for related applications, their experiments for thermal conductivity and viscosity were ignored.

Fig. 6 exhibits the thermal conductivity of samples with good suspension performance. It can be seen that the thermal conductivity ratio (R_k) will rise with respect to the increase of the concentration of MWCNTs. The ratio is defined as the thermal conductivity of the nanofluid divided by the deionized water according to Eq. (1). It is interesting that more dispersant lowers the thermal conductivity due to the fact that the nanoparticles will be surrounding by chitosan; however, the raise of suspension performance will contrarily increase the thermal conductivity. Hence the optimal value of the concentration of dispersant is the most concerned issue in this research. From the viewpoint of, samples with adding 0.4 wt.% (No. 9-12) contain better performance. The thermal conductivity ratios increase with respect to the increase of concentrations of MWCNTs. The optimal condition occurs at 0.4 wt.% of MWCNTs and 1.5 wt% of chitosan, where the thermal conductivity will enhance 9.0% compared with that of deionized water.

Fig. 7 plots the viscosity improvement of samples with good suspension performance. The viscosity ratio, , is defined as the viscosity of the nanofluid divided by that of the water according to Eq. (1). It can be investigated that will rise with respect to the increasing concentrations of MWCNTs and chitosan. It shows that the larger value of concentration lead to the larger viscosity. The maximum enhance ratio occurs at the condition that the concentration of MWCNTs is 1.5 wt.% while the concentration of chitosan is 0.4 wt%. The viscosity will increase 233% compared with deionized water.

It is noted that though the case with MWCNTs and chitosan at concentrations of 1.5 wt.% and 0.4 wt% owns the maximal thermal conductivity ratio, it contains the maximal viscosity ratio at the meantime. Larger viscosity may cause significant energy consumption in a heat exchange system via the pipe energy loss and the larger pumping power. Therefore, when considering the overall efficiency of a heat exchange system, selecting the case that is with lower concentration of MWCNTs (i.e. No. 6 or 7) but is with good suspension performance (less chitosan with lower viscosity) might gain the maximal benefit of the whole heat exchange system.

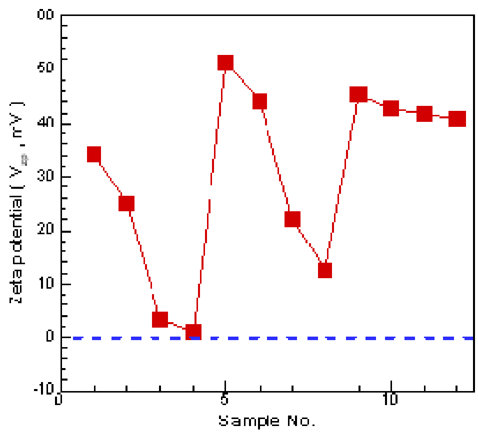

Fig. 2. Zeta potential of MWCNTs/water nanofluid for no. 1 to no. 12.

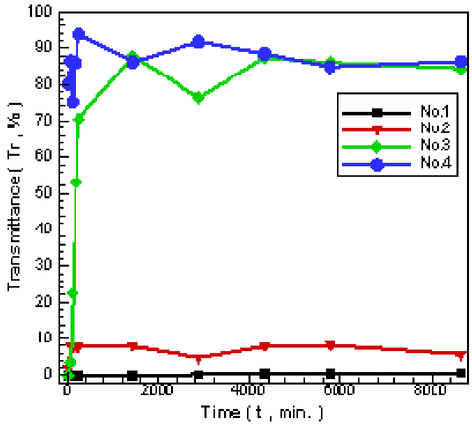

Fig. 3. Transmittance of MWCNTs/water nanofluid for no. 1 to no. 4.

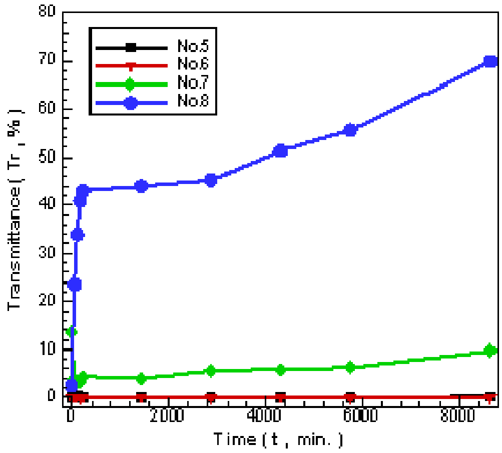

Fig. 4. Transmittance of MWCNTs/water nanofluid for no. 5 to no. 8.

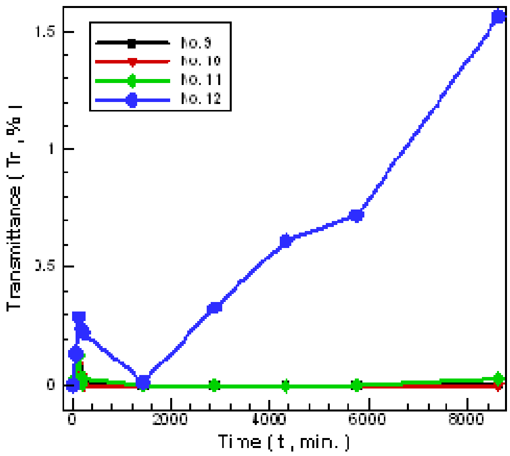

Fig. 5. Transmittance of MWCNTs/water nanofluid for no. 9 to no. 12.

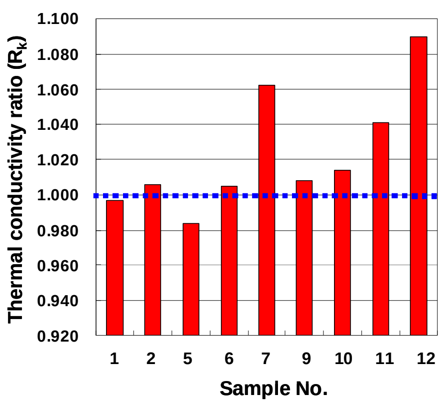

Fig. 6. Thermal conductivity ratio of MWCNTs/water nanofluid.

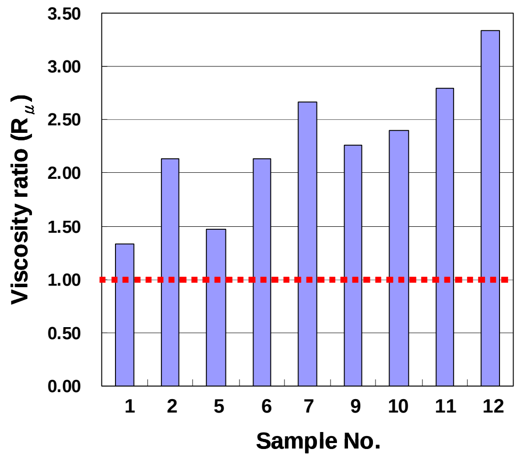

Fig. 7. Viscosity ratio of MWCNTs/water nanofluid.

IV. Conclusions

This study prepared the MWCNTs/water nanofluid employing chitosan as a dispersant by the direct-synthesis method. Experiments have been conducted to investigate the variation of suspension performance influenced by 12 combinations with various concentrations of the MWCNTs as well as the chitosan in the deionized water. Experimental results demonstrate that the additive concentration of chitosan showed the proportional relationship for suspension performance. However, adding chitosan will increase the viscosity as well as decrease the thermal conductivity of nanofluids. The chitosan concentration of 0.4 wt% can provide good suspension performance for all concentration range of MWCNTs in this study. As the nanofluids containing MWCNTs and chitosan with concentrations of 1.5 wt.% and 0.4 wt%, the thermal conductivity will increase 9.0% and enhance 233% of the viscosity compared with deionized water. The results will guide us how to select the concentrations of MWCNTs and dispersant at the meantime for a heat exchange system in the near future.

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Yi-Hsuan Hung was born in Taipei, Taiwan, in Nov. 12, 1974. He received the BS degree, MS degree and PhD degree in Department of Power Mechanical Engineering at National Tsing Hua University, Hsinchu, Taiwan, in 1997, 1999, 2004 respectively. His major research fields were in system dynamics, green power sources, and heat dissipation system. He has worked in Industrial Technology Research Institute (ITRI). He was a researcher, project manager, department manager in the electric propulsion department, intelligent vehicle division, Mechanical and System Lab. from 2005 to 2009. His research interests focus on technologies of green vehicles (hybrid, fuel cell, plug-in hybrid, battery, etc..), key components (engines, motors, energy storage systems), and system modeling. He is currently an assistant professor in Dept. of Industrial Education, National Taiwan Normal University, Taipei, Taiwan from 2009. The studies mainly focus in nanofluid/nanoparticle performance, heat dissipation systems, green power sources, advanced vehicles, etc.. Dr. Yi-Hsuan Hung has been a local committee member for 21st international symposium of transport phenomena in 2010. He was also a session (co)chair in: international symposium on advanced vehicle control (AVEC), international symposium of transport phenomena (ISTP), and 2010 International Symposium on Computer Communication Control and Automation (IEEE 3CA).

Wen-Chieh Chou was born in Keelung, Taiwan, in Nov. 29, 1985. He received the BS degree in Department of Industrial Education at National Taiwan Normal University, Taipei, Taiwan, in 2008. He is now a master degree student in Department of Industrial Education at National Taiwan Normal University, Taipei, Taiwan since 2011. His research directions focus on nanoparticles/nanofluid, heat dissipation system, biofuels, etc.