# Stabilization and Thermal Properties of Carbon Nanotubes/Cu Nanocomposites Prepared by Molecular-Level Mixing

***Youn-Jeong Hong*, Chung-Hun Jung, Hye-Jin Kim, and Kyu-Mann Lee***

**Dept. of Advanced Materials Engineering, Korea University of Technology and Education, Chonan, Chungnam, Korea**

**Phone: 82-41-560-1320, e-mail: kmlee@kut.ac.kr**

## Abstract

*The CNTs are the most extensively studied material which are characterized by the complete property of matter, structure, and the large thermal conductivity (Thermal conductivity of CNTs ~ >2000W/mK vs. Thermal conductivity of Aluminum ~ >204W/mK). Thus, they are successfully applied to the various fields. However, due to the strong agglomeration caused by the van der waal's force, their applications are limited.*

*In the present study, a new method for CNTs dispersion was developed by using the mechanical dispersion, acid treatment, and then Cu was coated. This process produces CNTs/Cu nanocomposite powders, whereby the CNTs are homogeneously located within the Cu powders. The thermal properties of the CNTs/Cu nanocomposite were investigated.*

## 1. Introduction

Since the first discovery of CNTs in 1991, a window to new technological areas have been opened [1-2]. One of the emerging applications of CNTs is the enhancement of thermal conductivity. Due to the large thermal conductivity (thermal conductivity of CNTs ; ~ > 2000W/mK, vs. thermal conductivity of copper and Aluminum ; ~ 390 and ~ 204W/mK, respectively), they are most extensively studied to apply to the various fields, such as heat sink in LED and PDP panel, and lap-top computer, etc. However, due to the strong agglomeration caused by the van der waal's force, if CNT compositions are manufactured by conventional processes, most of the CNTs are located on surface of matrix [3]. This process inhibits the diffusion of matrix materials across or along the powder surface, resulting in decreasing electric and mechanical characteristics of CNT nanocomposite.

The purpose of the present study is to uniformly disperse the CNTs and to fabricate CNT/Cu nanocomposite powders [4-5]. A new method for CNTs dispersion was developed by using the mechanical dispersion, and acid treatment, and then Cu was coated. This process produces CNTs/Cu nanocomposite powders, whereby the CNTs are homogeneously located within the Cu powders. The thermal properties of the CNT/Cu nanocomposites were investigated.

## 2. Experimental procedures

CNTs were suspended in 3:1 mixture of concentrated $H_2SO_4/HNO_3$ and sonicated in a water bath for 24 hrs at 35$^o$ ~ 40 ℃.

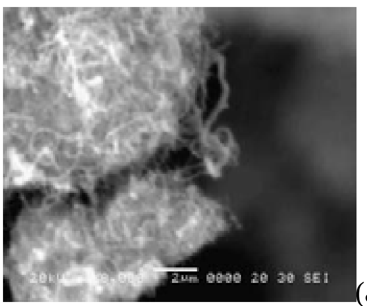
The resultant suspension was diluted with D.I. water, and the CNTs were collected on a 100nm size pore filter membrane. The ethanol and the $Cu(CH_3COO)_2{\bullet}H_2O$ were added to the CNT solution and were sonicated for 2 hrs. In this process, functional groups of CNT surface combine with Cu ions by chemical reaction. The solution was vaporized with magnetic stirring at 100℃. The powders are changed into stable CNT/CuO and then reduced to CNT/Cu composite powders by a reduction process under a hydrogen atmosphere at 400~800℃. The above processes gave homogeneously dispersed CNTs within Cu powders. The CNT/Cu powders were compacted in 10 ㎜ diameter under a pressure of 50 ㎏/㎟ and sintered under hydrogen atmosphere (4%$H_2$, 96% Ar) at 925℃ for 5 hrs. Density of samples was measured by the method of ASTM C2D.

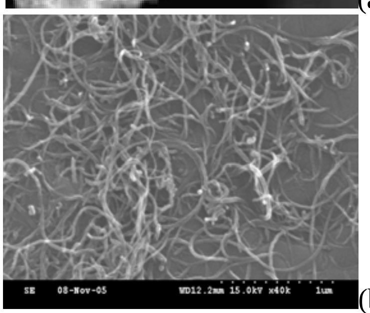
## 3. Results and Discussion

Figure 1 shows Microstructures of (a) MWNT (multi-wall nanotube) powder, (b) homogeneously dispersed CNT, (c) MWNT/CuO nanocomposite powder, and (d) MWNT/Cu nanocomposite powder. And Fig. 1(e) presents TEM micrographs of MWNT/CuO nanocomposite powder.

In order to make a stable suspension by attaching functional groups such as –C=O, -COOH, -OH onto the CNT surfaces and top, CNTs are dispersed in an acid solution. Once the functional groups are attached to CNTs surface, the electrostatic repulsive force between CNTs overcomes the van der walls' force, and thus, stable CNT suspensions are formed and no precipitation reaction is occurred.

These results clearly indicate that the CNTs and Cu ions are mixed with each other at the molecular level, and the CNTs are located within the Cu powders rather than on the Cu powder surfaces.


(a)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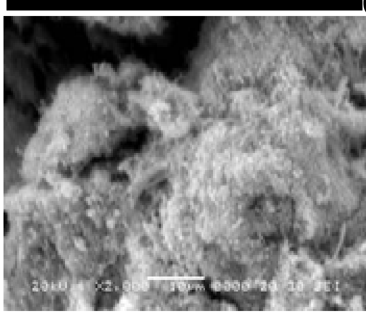
(c)


(d)


(e)

Figure 1. Microstructures of (a) MWNT (multi-wall nanotube) powders (b) dispersed CNT (c) MWNT/CuO nanocomposite powders (d) MWNT/Cu nanocomposite powders, and (e) MWNT/CuO nanocomposite powders (TEM).

XRD patterns of CNT, Cu, CNT/CuO, and CNT/Cu Specimens are presented in Fig. 2. In the figure 2, the observed XRD data of CNT/Cu nanocomposite reduced from the CNT/CuO nanocomposite well correlate with the data of pure Cu. But, small amount of CuO is still remained. These results indicate that the CuO nano-powders are uniformly coated with the dispersed CNT, and then, reduced to CNT/Cu composite powders by reduction process.

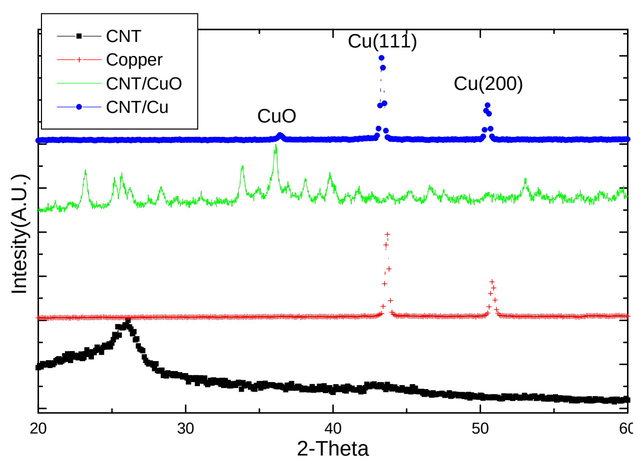


Figure 2. XRD patterns of CNT, Cu, CNT/CuO, and CNT/Cu

Table 1 shows the density of CNT/Cu nanocomposite and pure copper. The density of CNT/Cu nanocomposite was 6.266g/cc, and this is 70 % of pure copper. There are two possibilities that decrease the density of CNT/Cu nanocomposite. One is the addition of low density CNTs( 2.99g/cc). Since the amount of CNT is 5~10 vol. %, this is not likely to be the major that leads the decreased density. However, we cannot exclude this possibility. The other is the poor microstructure, forming pores, etc. Therefore, we have investigated the microstructure of sintered CNT/Cu nanocomposite.

| | The absolute Density(g/cc) |
|---|---|
| MWNT/Cu | 6.266 |
| Copper (99.9%) | 8.884 |
| Copper (99.99%) | 8.890 |

Table 1. Density of CNT/Cu nanocomposites and pure Cu.

Figure 3 show the polished microstructures of CNT/Cu nanocomposite and pure copper. The grain size of CNT/Cu nanocomposite is much smaller than that of pure copper. As shown in the Fig. 3(a), micro-pore is located within the grain boundary and triple junction. Therefore, one can conclude that the decreased density is mainly caused by the poor microstructure.

If the CNT/Cu composites are manufactured by conventional processes, most of the CNTs are located on surface of matrix. But, In this study, the agglomeration of CNTs was not observed.

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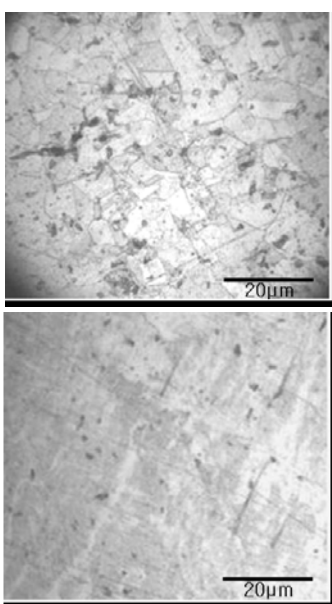

(a)
(b)

Figure 3. Polished microstructures of (a) the CNT/Cu nanocomposite with 5~10 vol.% of CNTs, and (b) the pure copper.

Table 2 shows the thermal conductivities of various materials. The conductivity of copper is 385W/mK and the conductivity of CNTs (SWNT and MWNT) is much higher than that of other materials.

| | Thermal conductivity (W/mK) |
|---|---|
| SWNT | >2000 |
| MWNT | 1800~6000 |
| Glass | 0.878 |
| Stainless steel | 19 |
| Iron | 73 |
| Al | 204 |
| Cu | 385 |
| Ag | 419 |
| Diamond | 2000 |

Table 2. Thermal conductivities of various materials.

Figure 4 indicates that the thermal conductivity of CNT/Cu nanocomposite was improved about 10% compared with pure copper. The increase of thermal conductivity can be interpreted in terms of the addition of 5~10 vol.% CNT of which thermal conductivity is quite high (thermal conductivity of CNTs ; ~ > 2000W/mK vs. thermal conductivity of Cu ; ~ > 390W/mK). However, for the systematic discussion of the thermal properties relevant to the present study, we should optimize the sintering condition to densify the microstructure of CNT/Cu nanocomposites.

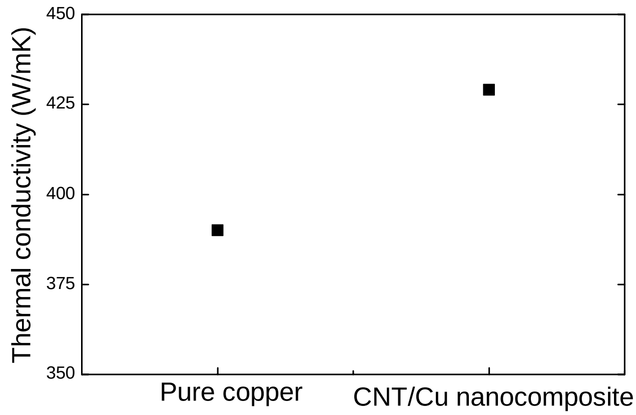


Figure 4. Thermal conductivity of CNT/Cu nanacomposites.

## 4. Conclusions

The following conclusions were made from the present study :

(1) CNTs were dispersed homogenously by introducing the functional groups.
(2) CNT/Cu nanocomposites were fabricated by molecular level method, it consists of Cu ion with CNTs of functional groups in a solvent.
(3) The thermal conductivity of the CNT/Cu nanocomposite was improved about 10% compared with pure copper. The increase of thermal conductivity can be interpreted in terms of the addition of CNT.

## 5. Acknowledgements

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## 6. References

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