Characterization of Carbon Nanotube-Silver Composite Yarn

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Owing to efforts of many researchers, carbon nanotube (CNT) is known to have many excellent properties. Therefore, CNT can be used for various applications. However, CNT based devices must be limited because of its nano size. Spinning CNT yarn is a technique to overcome the problem of size. If CNT yarn shows properties of the original CNT, CNT yarn is suitable for space elevator, light cable, wire harness, etc due to its lightness and toughness. However, there is a difficulty of contact resistance between each CNTs. Fabrication of composite (CNT and metal) yarn is a simple way to improve the electrical conductivity. In this paper, we demonstrate CNT-silver (Ag) composite yarn.

CNT yarn was spun from vertically aligned CNT forest (VACNF) synthesized by thermal chemical vapor deposition (CVD) [1]. CNT yarn passed through silver nitrate solution while it was spun. The morphology of CNT-Ag yarn was observed by scanning electron microscope (SEM, Hitachi S-3000H) and transmission electron microscope (TEM, JEOL JEM-Z2500). Energy dispersive X-ray spectroscopy (EDS) was employed for element analysis.

A SEM image of CNT-Ag yarn is shown in FIG. 1. In typical CNT yarn, the mark of twist was clearly observed in SEM image. However, the mark had almost disappeared after silver nitrate treatment. In case of ozone irradiation, graphite wall of CNT had been broken [2]. Ozone and silver nitrate are oxidizer, therefore it was considered that graphite wall of CNT had also been broken by silver nitrate treatment and changed into amorphous carbon. As amorphous carbon covered CNT-Ag yarn has been increased, the mark had almost disappeared.

Degree of silver extraction around CNTs was observed by TEM. As spun CNT yarn was difficult to observe, the sample in this experiment was prepared as follows; CNTs were dispersed in deionized water. Subsequently, a little amount of CNT dispersed in water was mixed with silver nitrate solution. This mixed solution was dropped onto TEM grid immediately, and dried in oven at 100 ^{o}C for 2 hours. FIG. 2 (a) shows a TEM image. As each CNTs were formed bundles, it was hard to observe individual CNT. Also, several nano particles adhered to CNT bundle could be observed. We found that nano particles were Ag from EDS spectrum as shown in FIG. 2 (b) (dashed circle inset). Other peaks, which were indicated under arrows, were due to TEM grid.

We also measured the electrical conductivity of CNT-Ag yarn. As the diameter of yarn was changed by the width of drawn CNTs from VACNF, resistivity ρ, which was not affected by cross section and length, was employed. Here, ρ is calculated with following formula;

$$\rho = \frac{RS}{L} \qquad (1)$$

R, S, and L are resistance, cross section, and length of sample, respectively. The resistivity of our typical CNT yarn without treatment was ~1-2x10^{-2} Ωcm, but that of CNT-Ag yarn was improved to 1.2x10^{-3} Ωcm.

In summary, we performed CNT-Ag composite yarn by passing through silver nitrate solution, which was simple way. Graphite wall of CNTs were destructed by oxidation, therefore the mark of yarn had almost disappeared. There were several Ag nano particles around CNT bundle by TEM observation and EDS spectrum. And resistivity was improved to ~1/10 with compared to pristine CNT yarn.

Acknowledgement

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References

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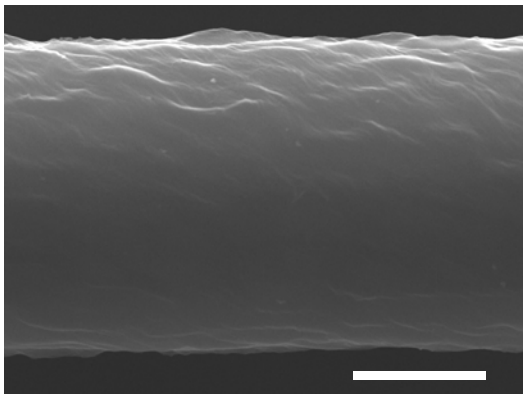

FIG. 1. A SEM image of CNT-Ag composite yarn. Scale bar is 5μm.

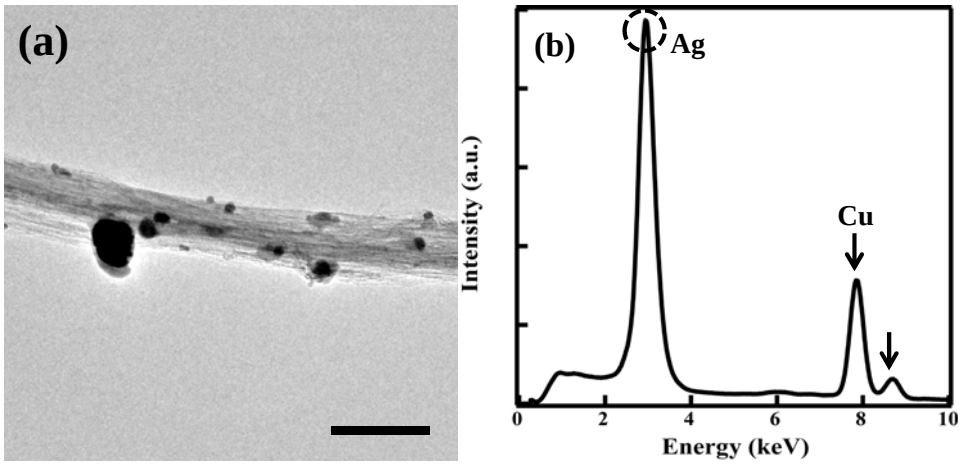

FIG. 2. (a) A TEM image of silver nitrate treated CNTs. Scale bar is 100nm.
(b) EDS spectrum at FIG. 2 (a)