Thermoelectric Properties of Graphene and Carbon Nanotube

Ghosh, Sampad
Interdisciplinary Graduate School of Engineering Sciences, Kyushu University

Harish, Sivasankaran
International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University

Saha, Bidyut Baran
Mechanical Engineering Department, Kyushu University

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Thermoelectric Properties of Graphene and Carbon Nanotube

Sampad Ghosh[1,2], Sivasankaran Harish[2], and Bidyut Baran Saha[1,2,3,*]
[1]Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan
[2]International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University, Japan
[3]Department of Mechanical Engineering, Kyushu University, Japan
*Corresponding author email: saha.baran.bidyut.213@m.kyushu-u.ac.jp

Abstract: *Graphene (GNP) and carbon nanotube (CNT) filled composites have great potential for making cheaper thermoelectric materials which can be used in building energy harvesting applications. In this paper, the thermoelectric performance of GNP and CNT powders are investigated. The as-received powders were compressed and subsequently cured at room temperature to make it bulk. On bulk samples, the electrical conductivity, Seebeck coefficient and thermal conductivity were measured. Semiconductor like behavior of the electrical conductivity as observed in both samples. As a consequence of high electrical conductivity and Seebeck coefficient, GNP had better result of thermoelectric efficiency. The largest dimensionless figure of merit (ZT) equals to ~0.004 was obtained for the graphene sample.*

Keywords: Carbon nanotube; Energy harvesting; Figure of merit; Graphene; Thermoelectric properties.

1. INTRODUCTION

Depletion of natural fuels and the socio-economic threat to nuclear energy has a quest for alternative sources of energy generation. Thermoelectric (TE) system is very promising for the conversion of heat into electricity which utilizes the temperature gradient. The traditional TE materials such as Bi_2Te_3 exhibits a high figure of merit [1]; however, they are expensive and toxic. Improvement in the figure of merit for structural materials based nanocomposites may be of interesting due to their availability, low cost, non-toxicity and ease of production. Graphene (GNP) and carbon nanotube (CNT) have been considered as promising candidates for various fields like electronic, optical and solar cells due to their outstanding electrical properties. GNP and CNT also have been used as fillers in polymer composites and the electrical conductivities of such composites are of the order of magnitude higher than other polymer composites containing different conductive fillers. These kinds of applications triggered to incorporate GNP and CNT into the structural materials for building energy harvesting. In addition, both GNP and CNT has gained interest in the field of TE materials due to its one dimensional (1D) structure. It has been reported that the lower dimensional, i.e., one or two dimensional TE materials can perform better than bulk materials [2].

The goal of this study was to investigate the thermoelectric properties of graphene and carbon nanotube since they can enhance the TE properties of structural materials when used as a filler. Promising results were obtained which is represented by the figure of merit (ZT) based on thermoelectric properties measurement.

2. EXPERIMENT

In this work, Graphene (H-grade nanoplatelets, average particle diameter 25 µm from XG Sciences, USA), Carbon nanotube (multi-wall, outer diameter : < 8 nm, inner diameter : 2-5 nm from Raymor – Nanotubes for Electronics, Canada), Polyvinyl alcohol (molecular weight - 44.05 g/mol from Kanto Chemical Co., Japan), and deionized water were used. To prepare the graphene (GNP) composite samples, graphene nanoplatelets were loaded in a metallic die and compressed at around 40 MPa pressure (See Fig.1). For carbon nanotube (CNT) composite samples, CNT was mixed with a water-binder solution followed by compressed at about 40 MPa. Finally, the composite samples were dried to remove the water and moisture contents. The thermoelectric properties of the samples were measured by RZ2001i from Ozawa Science, Japan [3] at ambient condition within the temperature range between 25 and 100 °C. The thermal conductivity was studied using the laser flash method. Thermal conductivity value was obtained from thermal diffusivity and specific heat capacity measured by NETZSCH LFA 457 [4] and a differential scanning calorimeter (DSC-60A) [5], respectively.

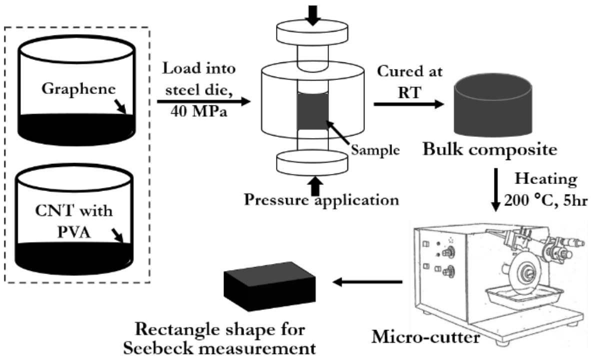

Figure 1 Sample preparation flows

3. RESULTS AND DISCUSSION

The results shown in Fig.2 suggest that the samples derived from graphene exhibited higher electrical conductivity in comparison to the carbon nanotube, with the largest difference of almost two orders of magnitude between GNP and CNT. The electrical conductivity observed on both samples was semiconductor like since conductivity increases with temperature. As shown in Fig.5, the thermal conductivity of CNT was lower than those of GNP, and the difference was 90% which is maintained throughout the temperature range. This would be attributed to a much smaller average particle diameter in CNT. All samples exhibited Seebeck coefficient around 15 μVK^{-1} as seen in Fig.3. The best result (23 μVK^{-1}) that combined with high conductivity of GNP sample (890 Scm^{-1}) gave a rise to considerable (0.0035) figure of merit. In the case of the CNT, best obtained thermoelectric figure of merit was ~0.2×10^{-3} (Fig.6). The Seebeck coefficient for both samples gradually increased with increase in temperature. However, GNP samples exhibited the highest Seebeck coefficient at around 60 °C. (Fig.3). The Seebeck coefficient values for all samples are positive which confirmed the composites are p-type semiconductor and hole carriers play an important role in them. Power factor (Fig.4) that describes electrical contribution to the ZT shows that GNP was electrically superior to CNT. This gives basis to conclude that higher ZT of the GNP though CNT had lowered thermal conductivity.

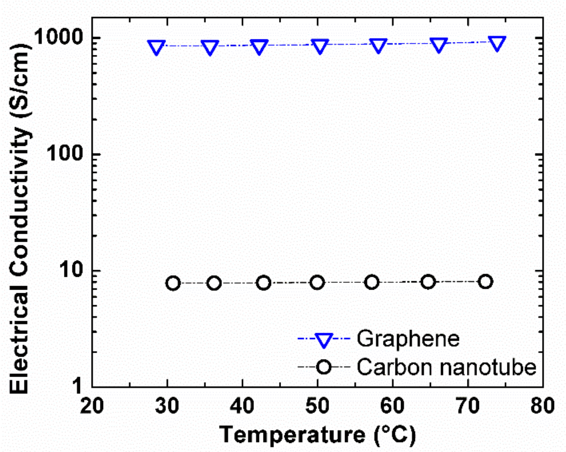

Figure 2 Electrical conductivity

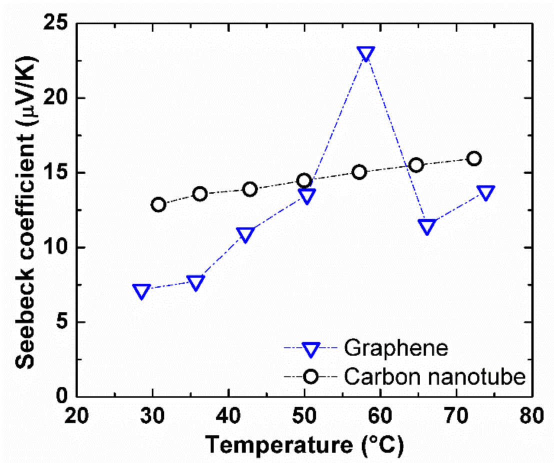

Figure 3 Seebeck coefficient

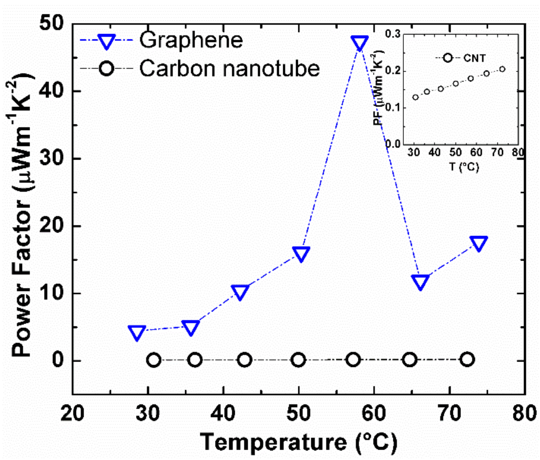

Figure 4 Power factor

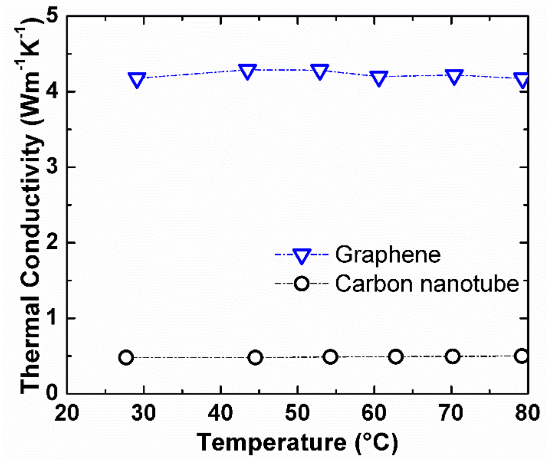

Figure 5 Thermal conductivity

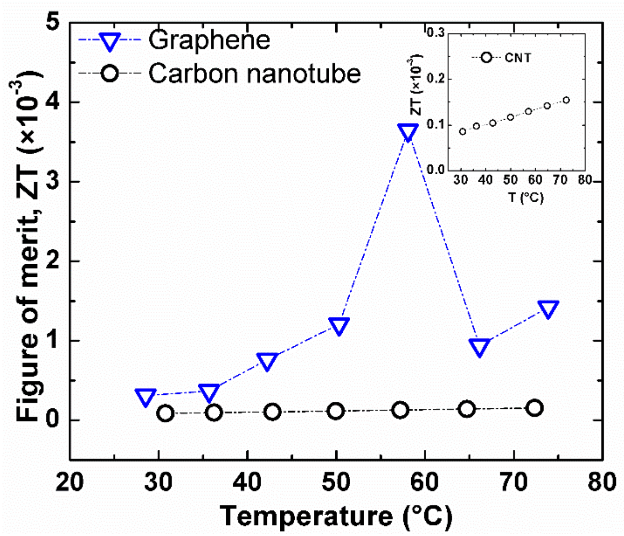

Figure 6 Figure of merit

4. CONCLUSION

Thermoelectric performances of graphene and carbon nanotube were evaluated to use them as nano-filler in the building energy harvesting technology. Graphene exhibits higher values of electrical and thermal conductivity than carbon nanotube. However, their Seebeck coefficient values are comparable. The figure of merit equals to 4×10^{-3} is obtained for graphene samples.

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