異なる半導体性純度のカーボンナノチューブシートの熱電特性

Thermoelectric Properties of SWNT Sheets with Different Semiconducting SWNT Ratio

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Abstract Figure of merit (*ZT*) values of semiconducting (s-), metallic (m-) and their mixture of single-walled carbon nanotube (SWNT) together with unsorted SWNT were evaluated by measuring their electrical conductivity (σ), Seebeck coefficient (S) and thermal conductivity (κ).

Introduction SWNTs have attracted strong attentions as thermoelectric (TE) material due to their extremely high electrical conductivity (σ), light weight, mechanical toughness and flexibility. Especially, s-SWNT sheet is proved to have large S theoretically and experimentally [1, 2]. However, the improvement of *ZT* value by separating s-SWNT from the as-produced SWNT mixture is still uncertain. In this study, we characterized the TE properties of s-SWNT sheets with different s-SWNT ratio and compared their *ZT* values with that of the unsorted SWNT sheet.

Experiment s-SWNTs 2.4 mg (98% Nanointegris) and m-SWNT 0.6 mg (98% Nanointegris) were added to 0.5% SDBS solution and dispersed by bath sonicator (BRANSON, 1 hr) and probe sonicator (TOMY UD-200). The dispersion were filtrated and the free-standing s-:m-SWNT=4:1 sheet was obtained (80% s-SWNT). 98% s-SWNT sheet, s:m-SWNT=2:1 sheet (67% s-SWNT), s:m-SWNT=1:2 sheet (33% s-SWNT), and 2% s-SWNT sheets were made in the same fashion. In-plane σ and S of the sheets were measured by ZEM-3 (ADVANCE RIKO) from 30 to 100 ºC. The specific heat capacity (C_p) was measured by differential scanning calorimetry (DSC) method using EXSTAR DSC 6200 (SII Nanotechnology) at the heating rate of 10 K min^{-1}. In-plane thermal diffusivity (α) were evaluated using a Thermowave Analyzer TA (Bethel Co., Ltd.,). Density (ρ) was calculated from the weight and volume of the sheets.

Results and discussion Table 1 summarized the in plane σ, S, power factor (*PF*), κ and *ZT* of the unsorted SWNT, 2%, 33%, 67%, 80% and 98% s-SWNT sheets at 30 ºC. Unsorted SWNT sheet exhibited nearly 1.7 times higher σ than the 2% s-SWNT sheet. This was due to the defects induced during the separation process of the m-SWNTs, which was confirmed by the larger D band of m-SWNTs than that of unsorted SWNT in Raman spectra (data not shown). As s-SWNT ratio increased, S increased leading to higher *PF*, which was the same as previous report [3]. No significant difference was observed in the average κ values as the s-SWNT ratio increased, which was in accordance with the literature [4,5]. Mixed SWNT sheets showed lower κ than unsorted SWNT probably due to the higher defect of m- and s-SWNTs [6]. In conclusion, as s-SWNT ratio increased, *PF* increased while κ stayed the same, leading to an increasing *ZT*. The result was practically quite informative when considering the advantage of the s-SWNTs for TE applications.

Table 1. TE properties of various SWNT sheet (Values inside the ( ) is the error bar)

	Unsorted SWNT	2% s-SWNT	33% s-SWNT	67% s-SWNT	80% s-SWNT	98% s-SWNT
σ (S m^{-1})	5.03×10^4	2.89×10^4	1.54×10^4	2.12×10^4	1.24×10^4	1.04×10^4
S (µV K^{-1})	35.0	11.9	26.1	47.9	58.6	76.0
PF (µW m^{-1}K^{-2})	61.62	4.090	10.47	48.49	42.64	60.28
κ (W m^{-1} K^{-1})	17.90 (1.88)	9.16 (0.95)	9.34 (0.98)	10.16 (2.17)	11.41 (2.14)	9.57 (0.63)
ZT	1.04 (0.12) $\times10^{-3}$	1.36 (0.16) $\times10^{-4}$	3.40 (0.39) $\times10^{-4}$	1.45 (0.34) $\times10^{-3}$	1.13 (0.27) $\times10^{-3}$	1.91 (0.18) $\times10^{-3}$

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