Electrical transport properties in single-walled carbon nanotubes networks

K. Snoussi[a*], A. Vakhshouri[b], H. Okimoto[c], T. Takenobu[d], Y. Iwasa[e], S. Maruyama[f], K. Hashimoto[a,b] and Y. Hirayama [a,b]

[a]*JST-ERATO Nuclear Spin Electronics Project, 980-0845, Sendai, Japan*
[b]*Department of Physics, Tohoku University, 980-8578, Sendai, Japan*
[c]*Department of Polymer Science and Engineering, Yamagata University, Yamagata, 980-8577Japan*
[d]*Department of Applied Physics, Waseda University, Tokyo 169-8555, Japan*
[e]*School of Engineering, The University of Tokyo, Hongo, 113-8656, Japan*
[f]*Department of Mechanical Engineering, The University of Tokyo, Hongo, 113-8656, Japan*

The electrical transport properties in single-walled carbon nanotube (SWCNT) networks have attracted much attention since the last two decades, because of both their promising applications [1] and their intriguing physical properties [2]. In this work, we study the temperature (*T*) and the magnetic-field (*B*) dependences of electrical transport properties in single-walled carbon nanotube (SWCNT) networks.

SWCNTs were grown by no-flow alcohol catalytic chemical vapor deposition [3] and dispersed in dimethylformamide. They had a bundle diameter of about 15 nm, as characterized by scanning electron microscopy. They were printed on SiO_2 substrates by an ink-jet method [4] and palladium electrodes were subsequently patterned on the devices using a metallic mask and electron beam physical vapor deposition. The two-terminal transport measurements were carried out at T = 0.5 - 295 K using a variable-temperature cryogenic system and a dilution refrigerator.

First, we carefully checked the current-voltage (I-V) characteristics. The measured I-V curves are linear at temperatures down to T = 0.5 K, establishing the ohmic behaviors of both the samples and the electrical contacts. Figure 1 shows the temperature dependence of the resistance (*R*) estimated from the I-V curves: the natural logarithm ln(*R*) exhibits a linear relationship with $T^{-1/3}$, demonstrating that a 2D Mott variable-range hopping transport [5] is dominant in the SWCNT networks throughout the whole measurement temperature range.

Next, we measured the magnetoresistance *R*(*B*) at different *T*. The obtained *R*(*B*) curves are plotted in Figure 2. At T = 4.3 and 5 K, *R*(*B*) shows a minimum at about 2.5 - 3 T. We found that this minimum drastically moved down towards the low *B*-fields to approximately 0.5 T at T = 1 and 1.6 K. This can be interpreted as the suppression of the quantum-interference effects in the variable-range hopping regime of disordered systems at low *T* [6].

[1] S. J. Kang et al., *Nat. Nanotechnol.*, **2** (2007) 230.

[2] R. Tarkiainen et al., *Phys. Rev. B*, **69** (2004) 033402.

[3] R. Xiang et al., *Jpn. J. Appl. Phys.*, **47** (2008) 1971.

[4] H. Okimoto et al., *Jpn. J. Appl. Phys.*, **48** (2009) 06FF03.

[5] M. Jaiswal et al., *J. Phys.: Condens. Matter*, **19** (2007) 446006.

[6] W. Schirmacher, *Phys. Rev. B*, **41** (1990) 2461.

*Corresp. author: snoussi@ncspin.jst.go.jp, Phone: +81-22-217-7605, Fax: +81-22-217-7606

Figures

Fig. 1. Linear relationship between ln(R) and $T^{-1/3}$ observed in SWCNT networks and indicating a 2D Mott variable-range hopping transport mechanism.

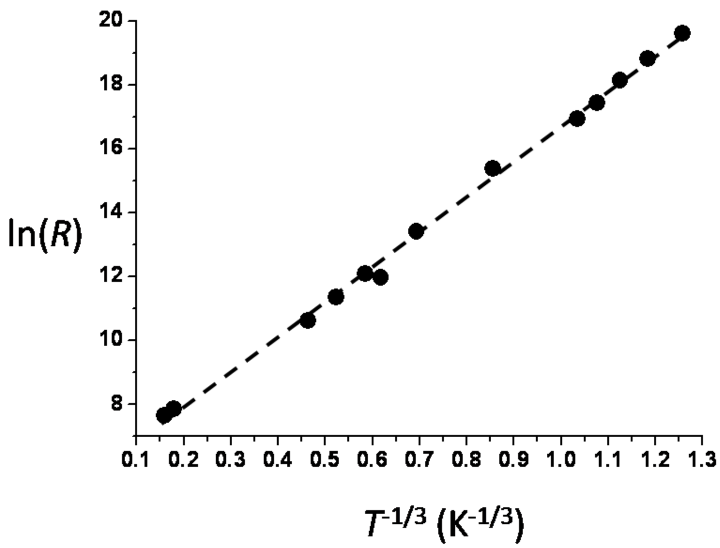

Fig. 2. Magnetoresistance *R(B)* in single-walled carbon nanotube network samples as a function of the magnetic field B: ln[$R(B)/R(0)$] is plotted *versus* B at various temperatures.