Characterizing thermal conductivity of vertically-aligned single-walled carbon nanotube films

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Single-walled carbon nanotubes (SWNTs) are expected to possess high thermal conductivity. Thermal conductivity of individual SWNTs has been measured to be around 3000 $Wm^{-1}K^{-1}$ [1,2]. Detailed heat conduction characteristics of SWNTs have been widely investigated numerically [3,4]. On the other hand, there are only a few reported works on the thermal conductivity of vertically-aligned SWNTs (VA-SWNTs); experimental measurements using laser flash method [5,6] and thermoreflectance method [7], and thus the property is far from being fully exploited.

In this work, thermal conductivity of VA-SWNTs has been measured by utilizing the 3-omega method, which is commonly used for thin-films [8,9]. The obtained film thermal resistance 1 ~ 10 $\times 10^{-6}$ m^2KW^{-1} is in fairly good agreement with the previous work [7]. Substituting the film thickness and neglecting the thermal resistance at the boundary, the film thermal conductivity is obtained to be around 1 $Wm^{-1}K^{-1}$. The thermal conductivity of an individual SWNT estimated based on the filling ratio of the VA-SWNT film is 10^1 ~ 10^2 $Wm^{-1}K^{-1}$. This value is quite low compared with that of the experimentally measured values of individual SWNTs [1,2].

The current result suggests that heat conduction through the VA-SWNT film is limited by the thermal resistance at the nanotube-substrate boundary and/or the metal-nanotube boundary. In order to characterize the thermal boundary resistance, we propose and discuss a new measurement method utilizing the temperature dependence of the Raman spectrum of SWNTs.

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