Measurements of Thermodynamic Properties on Nano-Scale by Single Carbon Nanotube Spectroscopy

Homma Y[1] and Chiashi S[2]
[1]*Department of Physics, Tokyo University of Science, Tokyo, Japan*
[2]*Department of Mechanical Engineering, The University of Tokyo, Tokyo, Japan*

Measurements of thermodynamic properties on nano-scale are important in nano- and bio-technologies. However, different from electrical and optical properties, measurements of the thermal properties and the phase of a nano-material are usually difficult to implement. We have applied spectroscopic measurements of a suspended single-walled carbon nanotube (SWNT) to probe the phase of molecules confined in the SWNT or the temperature of the SWNT. The quasi 1D electronic structure of SWNT allows highly resonant optical transitions, enabling the detection of signals from a single SWNT. In addition, because a SWNT is a monolayered material composed of all surface atoms, optical transitions in the SWNT are sensitively affected by the surrounding or encapsulating materials of the SWNT.

Using a singly suspended SWNT between a pair of silica pillars (Fig. 1), we measured photoluminescence (PL) or Raman scattering from it [1-4]. Water molecules confined in the inner space of a SWNT affect the optical transition energy in the SWNT depending on the dielectric constant of water that varies with its phase. Thus, the phase diagram of water confined inside of a SWNT could be constructed from the temperature and water vapor pressure dependent spectra. With the spectroscopic PL imaging, the temperature distribution along the tube axis under laser irradiation could be obtained based on the temperature dependent PL spectrum change. From the temperature distribution, the temperature dependence of thermal conductivity was derived by solving heat equation. The single SWNT spectroscopy provides fruitful information on molecules on/in SWNT as well as the properties of SWNTs.

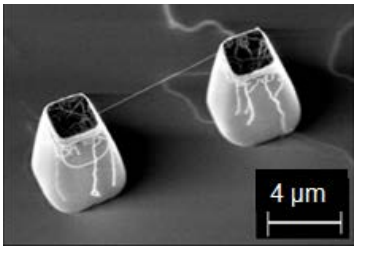

Fig. 1. Scanning electron micrograph of a singly suspended SWNT between micropillars.

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Email: homma@rs.tus.ac.jp