

**Title of Project : Fabrication and Characterization of Carbon  
Nanotubes Encapsulating Atomic Nanowires**



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Research Area : Nanoscience and nanotechnology of nano-carbons

Keyword : carbon nanotubes, nanowires, metallofullerenes, peapods, HRTEM

**【Purpose and Background of the Research】**

Based on our past achievements and background in nano-peapods studies, it is not until relatively recently that we discovered very fascinating materials, *i.e.*, **metal-nanowires encapsulated carbon nanotubes** (cf.Fig.1). We found that metal-nanowires (whose size varies from single-chain nanowires to several hundreds-chain nanowires depending upon the diameter of host carbon nanotubes) can easily be fabricated during a high-temperature annealing of metallofullerene-peapods. This is the first example that pure metal-nanowires of various sizes are prepared within carbon nanotubes, in which electronic and magnetic properties are expected to exhibit some unique properties such as ferromagnetism and superconductivity due to substantial charge transfers between metal-nanowires and carbon nanotubes.

**【Research Methods】**

Of the most important targeted goals of the present projects is not only to fabricate the present novel nano-carbon materials but to characterize them in terms of simultaneous measurements of structures and electron transport properties. This can only be realized by a specially designed technique where HRTEM, FET and Raman spectroscopy measurements are performed on exactly the same individual nano-peapod and/or metal-nanowires carbon nanotubes (cf.Fig.2). Therefore, the present project investigates also the development and fabrication of such a combined experimental set-up.

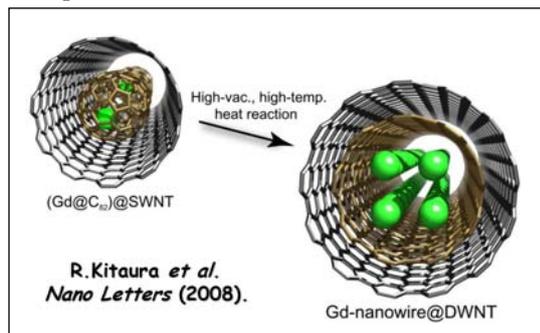


Figure 1 Gd-nanowires grown in nanot

**【Expected Research Achievements and Scientific Significance】**

The thicknesses of the resulting metal nanowires varied with the diameters of the host nanotubes forming the peapods. As a preliminary result, we already found that some metal-nanowires consist of a single chain, whereas other wires contained several chains of metal atoms (typically, various lanthanide atoms) and measured 3–4 nm across.

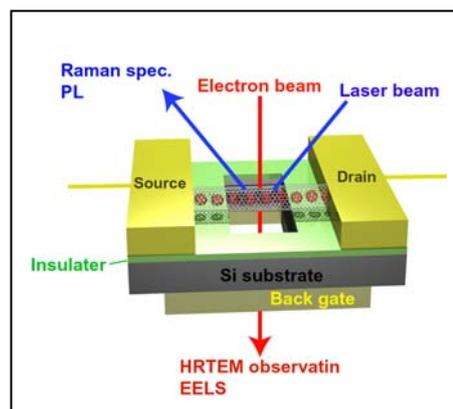


Figure 2 New observation system

Furthermore, since the bulk electronic and magnetic transport measurements of these new nanocarbon materials are also interesting in terms of size-dependent properties of metal-nanowires encapsulated in carbon nanotubes, we will employ the conventional bulk measurements such as SQUID and the four-probe conductivity measurement together with various optical spectroscopy.

**【Publications Relevant to the Project】**

1. R.Kitaura et al. *Angew.Chem.Int.Ed.* **48**, 8298 (2009).
2. R.Kitaura et al. *Nano Lett.* **8**, 693 (2008).

**【Term of Project】** FY2010-2014

**【Budget Allocation】** 176,000 Thousand Yen

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