STM/STS studies on Europium nanowires encapsulated in carbon nanotubes

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The discovery of carbon nanotubes (CNTs) and their fascinating properties have ignited intense research interests on one-dimensional nanosystems. Although metal nanowires, whose diameter is one to several atoms, are one of the most ideal one-dimensional nanosystems, the preparation and characterization of these have been difficult because of their high reactivity towards air. Previously, we have reported the synthesis of Europium (Eu) nanowires in the interior space of CNTs and characterization of their structure with transmission electron microscopy.[1-2] Here, we present the preparation and investigation of spatially-resolved electronic structure of Eu nanowires encapsulated in CNT (EuNW@CNT) by scanning tunneling microscopy/spectroscopy (STM/STS).

EuNW@CNT was synthesized by the direct nano-filling method[1] and dispersed in THF with ammonium carbonate by sonification. Figure 1 shows a STS spectrum of EuNW@CNT. At the location where EuNW are expected to exist (the position ranging from 3 to 15 nm in Fig. 1), we observed that the conduction and valence bands are shifted downward and that bandgap shrinks with the appearance of two localized states in the gap region. These drastic change in electronic structure indicates that EuNW strongly interact with CNT, presumably, via the charge transfer from EuNW to CNT. [3] The results obtained in this work strongly suggest that one can drastically change CNT's band structures by encapsulation of metal atomic wires.

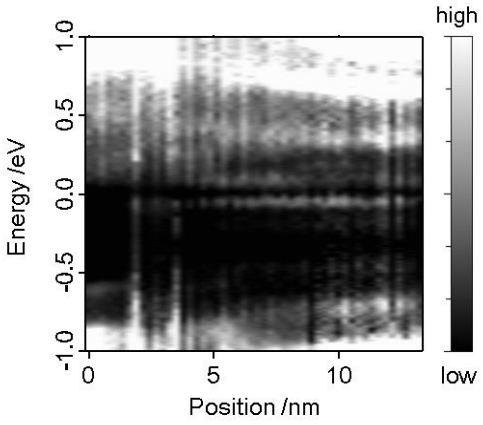

Figure1. STS spectrum of EuNW@CNT. d*I*/d*V* mapping taken along CNT axis. The left side is empty CNT area and right side is EuNW encapsulated area.

[1] R.Kitaura *et al*. Angew.Chem.Int.Ed. **48**, 8298, (2009).
[2] R.Nakanisihi *et al*. Phys. Rev. B**, 86**, 115445, (2012).
[3] J. Zhou *et al*. J. Phys. Chem. C, **114**, (2010),

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