DNA Dissolves Single-walled Carbon Nanotubes in Water

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Transmission electron microscopy, atomic force microscopy, and UV-vis-NIR absorption spectroscopy have revealed that deoxyribonucleic acid (DNA) molecules dissolve single-walled carbon nanotubes in an aqueous solution.

Although carbon nanotubes have been in the forefront of nanoscience and nanotechnology because of their many unique properties,¹ chemical and biochemical approaches using this material have been very limited. Noncovalent sidewall-functionalized soluble carbon nanotubes are of interest,² because the study would lead to the chemical and biochemical design to create functional carbon nanotubes in solution systems.

The combination of carbon nanotubes and deoxyribonucleic acid (DNA) has been of interest to many chemical and biochemical areas in both fundamental and application.³ Very recently, Dwyer et al.⁴ and Baker et al.⁵ reported the synthesis of covalently bonded adducts of single-walled carbon nanotubes with DNA and oligonucleotide, respectively. Although carbon nanotubes have been solubilized in organic solvents and in water by i) chemical modification,⁶ ii) the adsorption of detergents⁷ or a π-aromatic compound,²a and iii) polymer wrapping,⁸ to our knowledge, no report has been published thus far describing the preparation of a carbon nanotube-DNA aqueous solution.

Here we describe the first finding that DNA molecules dissolve single-walled carbon nanotubes (SWNTs) in aqueous solutions.

Figure 1 shows a photo of p-SWNTs in water in the absence of DNA (left) and a solution/dispersion of p-SWNTs in water in the presence of DNA (right). DNA was used as a solubilizer. No precipitation was produced for the p-SWNT-DNA solution/dispersion even after two months upon storage at 5°C.

Transmission electron microscope (TEM) measurements for the aqueous solution/dispersion of p-SWNT-DNA were conducted on a Jeol JEM-100S electron microscope. A carbon-coated TEM grid (Ouken-Shoji, 200-A mesh) was immersed in the solution for ca. 1–2 s, and then air-dried. Figure 2 shows a typical TEM image, in which dispersed bundled SWNTs with molecular length of ca. 0.5–2 μm are clearly observed. It is in fact that p-SWNTs are solubilized/dispersed in the DNA aqueous solution.

Atomic force microscope (AFM) was used to reveal the structure of p-SWNTs in the DNA solution. A sample for AFM measurements was prepared by dipping a freshly cleaved...
mica substrate into the DNA-SWNT aqueous solution and of solution of DNA solely for a few seconds and then air-dried. A typical AFM image for a p-SWNTs-DNA solution recorded on a SPI3800N (Seiko Instruments Inc.) with a Si$_3$N$_4$ cantilever (SN-AF01) is presented in Figure 3. The height of the nanotubes indicated by lines a–f was 2.75, 2.35, 2.72, 2.24, 2.12 and 1.96 nm, respectively. An AFM image for the solely DNA solution g (height, 4.68 nm) and h (height, 5.03 nm).

The UV maximum for the nucleic base of the p-SWNT-DNA aqueous solution appeared at 266 nm, which is identical bylines a and c) and DNA (b). Optical cell solutions of p-SWNT-DNA (a and c) and DNA (b). Optical cell

Figure 4. UV-vis-NIR absorption spectra of aqueous solutions of p-SWNT-DNA (a and c) and DNA (b). Optical cell length, 1 mm.

Figure 3. A typical AFM image of an aqueous solution/dispersion of p-SWNT-DNA.

in a DNA aqueous solution. The carbon nanotube aqueous solution prepared by the present method would be useful for chemical, biochemical and biological designs to create functional carbon nanotubes in aqueous systems. Further studies along this line are currently underway in our laboratories.

References and Notes
9 The MW of DNA evaluated by polyacrylamide gel electrophoresis was 300-600 bp.
10 AFM images of DNA are usually measured in water containing magnesium ion.