Bionanotechnology Approach in Nanoscale Device Fabrication: Protein Nanotubes as Smart Building Blocks

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Non-lithographic fabrications of devices such as electronics and sensor have been studied extensively by assembling nanometer-sized building blocks into the device configurations. While various nanocomponents have been applied as building blocks to construct nanodevices, the more reproducible methods to assemble them onto precise positions are desirable. We have been fabricating peptide-based nanotubes (antibody) and functionalizing them with various recognition components (antigen), and our strategy is to use those functionalized peptide nanotubes, which can recognize and selectively bind a well-defined region on patterned substrates, as building blocks to assemble three-dimensional nanoscale architectures at uniquely defined positions (Figure 1) and then decorate the nanotubes with various materials such as metals and quantum dots for electronics and sensor applications. We have also demonstrated that the nanotubes can be selectively immobilized on surfaces using a host-guest molecular recognition. Ferrocene-functionalized nanotubes (host) were also observed to recognize an exact ring size of cyclodextrin SAMs (guest) on Au surfaces and the attachment/detachment of nanotubes was controlled electrochemically due to the control of redox states of the ferrocene nanotubes, which may be applied as switches.

We have been functionalizing assembled nanotubes by metals, nanocrystals, and porphyrins for photonics, electronics, and sensor applications. Recently, we have synthesized nanotubes with certain peptide sequences that can selectively grow specific nanocrystals on nanotubes via biomineralization (Figure 2). By controlling the peptide conformation on the nanotubes, the nanocrystal size, packing density, and shape were controlled. This sequence peptide-incorporated nanotube is expected to become a conductivity-tunable building block for nanodevices. The electric and magnetic properties of the nanocrystal-coated peptide nanotubes were studied by a conductive atomic force microscope and an alternating gradient magnetometer.

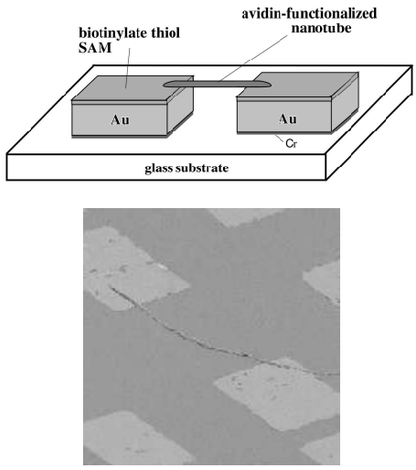

Figure 1. Immobilization of the avidin-coated nanotube on biotinylated thiol-SAM/Au surfaces. [Matsui, H.; Porrata, P.; Douberly, G. E, Jr., *Nano Lett.* **1**, 461, (2001)].

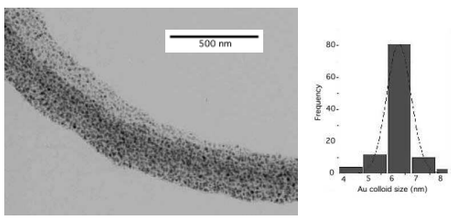

Figure 2. (left) TEM image of Au nanocrystals on the nanotube coated with the sequenced histidine-rich peptide. (right) Size distribution of Au nanocrystals on the nanotube. [Djalali, R.; Chen, Y-F.; Matsui, H., *J. Am. Chem. Soc*., **124**, 13660 (2002), Djalali, R.; Chen, Y-F.; Matsui, H., *J. Am. Chem. Soc*., **125**, 5873 (2003)]