Toward Fabrication of Nanoscale Sensors Using “Divining Rod” Carbon Nanotubes

Abstract:
Due to their unique structure, branched nanostructures such as carbon nanotube Y-junctions are theoretically estimated to have large piezoresistive coefficients, which in turn could be used for electronic or electromagnetic sensing of nanoscale displacement. Here, we report the fabrication of such a nanoscale sensor using a “divining rod”, branched nanotube structures.

Summary:
The Y-junction carbon nanotubes (YCNT) employed have a unique “fishbone” structure, with typical diameters of 20 to 50 nm, and length ranging from 1 to 15 µm. The typical resistivity of a straight segment of a fishbone CNT is of the order of 10^5 Ω/µm, similar to that of the graphite along its c-axis.

To fabricate a nanoscale sensor, we start by making a suspension with YCNTs and dichloride methylene, a small drop of which is placed onto a silicon substrate (the substrate has a 1 µm layer of thermally-grown silicon oxide, prepatterned with micron-size alignment marks for nanofabrication), and carefully allowed to dry in the marks area. SEM is then used to search for a typical YCNT, locating its coordinates relative to the fiducials. Nanofabrication is done with the CNF Leica VB6, forming at least 4 wires across 2 branches of the Y-junction (nanopatterns are designed in L-Edit with coordinates given by SEM).

To make good electrical contacts, we’ve tested a few different metal depositions. We found the best combination to be 50 nm (or more) Ti + 10nm Au. Here, Ti is the one to contact the YCNTs, Au is used only to prevent Ti from getting oxidized. Other metals, like Pd/Au, may work in some way, but we found Pd/Au didn’t stick to the YCNTs well, as it is so brittle that many times it cracked and shifted away from the nanotubes.

Now, if every step is successful, we should come out with a structure that has at least 4 Ti/Au wires across 2 of the 3 branches of the YCNT. The next step is to suspend the 3rd branch to form a divining rod. This is realized by another round of nanofabrication, followed up by BOE (buffered oxide etching, etchant: 6 parts 40% NH₄F and 1 part 49% HF) and a critical point dry.

Finally, we did a rapid thermal anneal [1] at 650°C for 30 s. With this step, the contact resistance of (Ti & YCNT) drops sharply from ~1 GΩ range to the order of 1kΩ, and becomes very stable.

In conclusion, we have made nanoscale sensors with individual Y-junction CNTs, using photolithography, nanolithography and other techniques. We are now measuring the piezoresistivity of these divining rod YCNTs to low temperatures and in high magnetic fields [2].

References:
Figure 1:
SEM picture of a Y-junction CNT suspending above a well (~400 nm deep, etched by BOE). The nanotube is contacted by 4 metal leads (50 nm Ti + 10 nm Au).