Carbon Nanotube Tips for Atomic Force Microscopy

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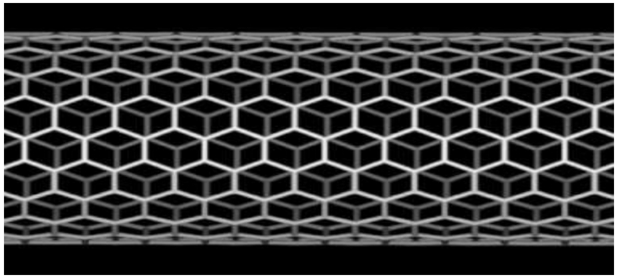
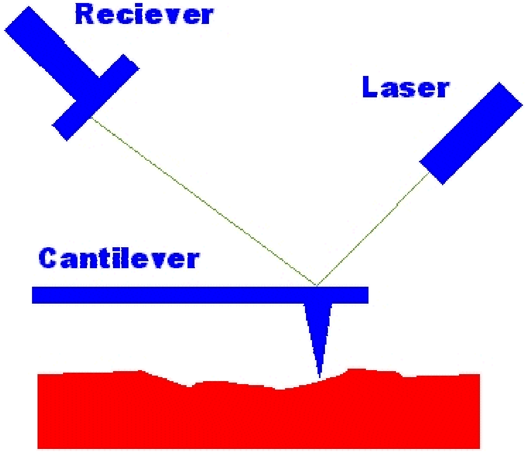
Overview

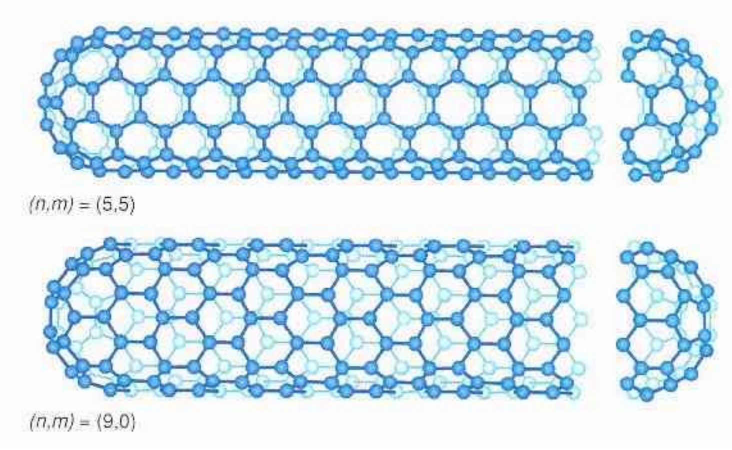
- What is a carbon nanotube?
- What is Atomic Force Microscopy?
- Why put the two together?
- What did I do this summer?

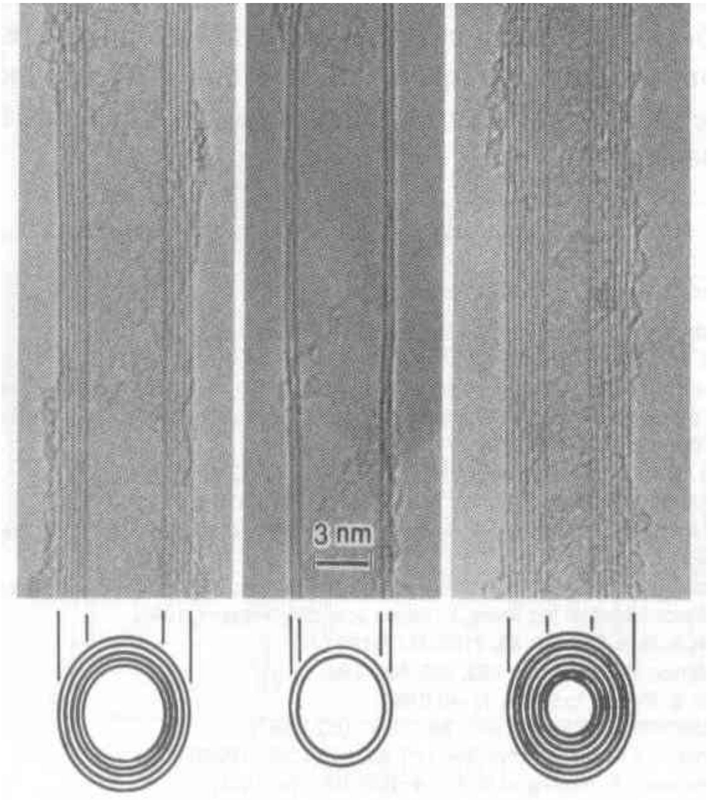




Carbon Nanotube Basics

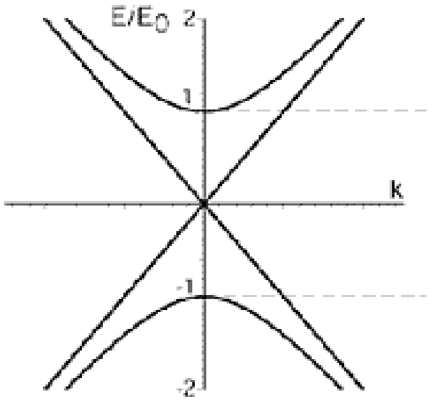
- Single atomic layer of graphite rolled into cylinder
- Single Walled Carbon Nanotubes (SWNT): radius = 0.35 – 2.5 nm, Multi Walled Carbon Nanotubes (MWNT): radius = 3 – 50 nm



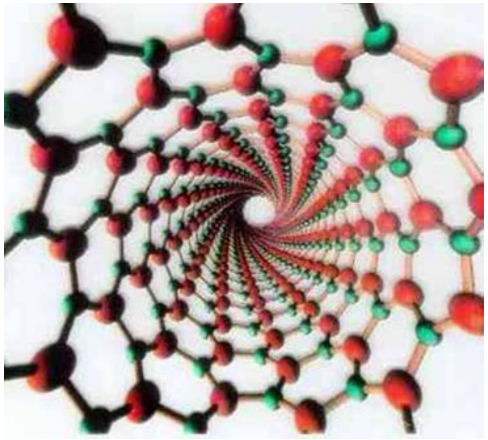


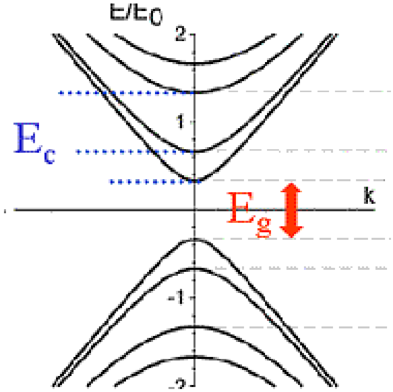
Electrical Properties

- Metallic or semiconducting, depending on direction
- Semiconducting tubes generally act as p-type, depending on chemical environment and metal attachment
  - Conduction is highly sensitive to changes in the chemical environment



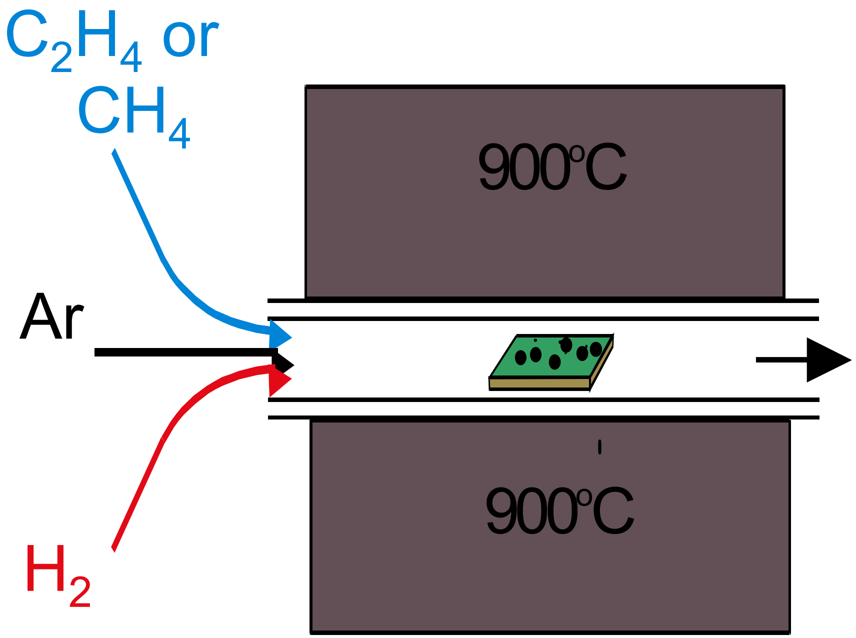
Type I – metals

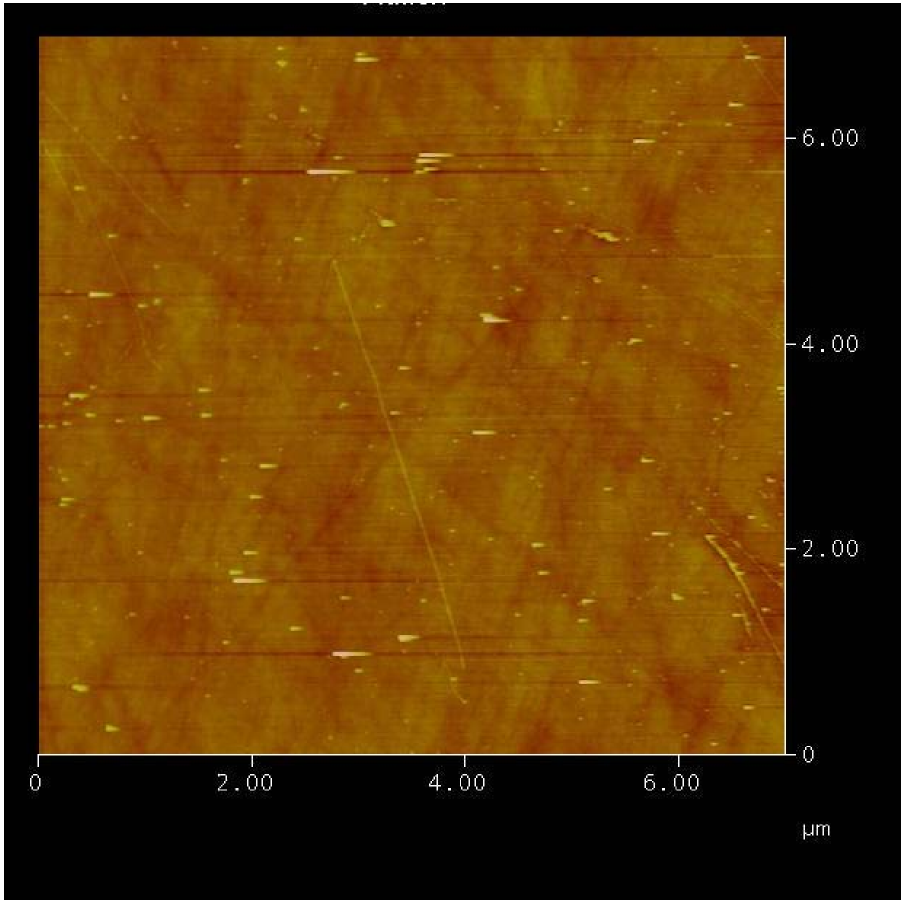




Type II – semiconductors

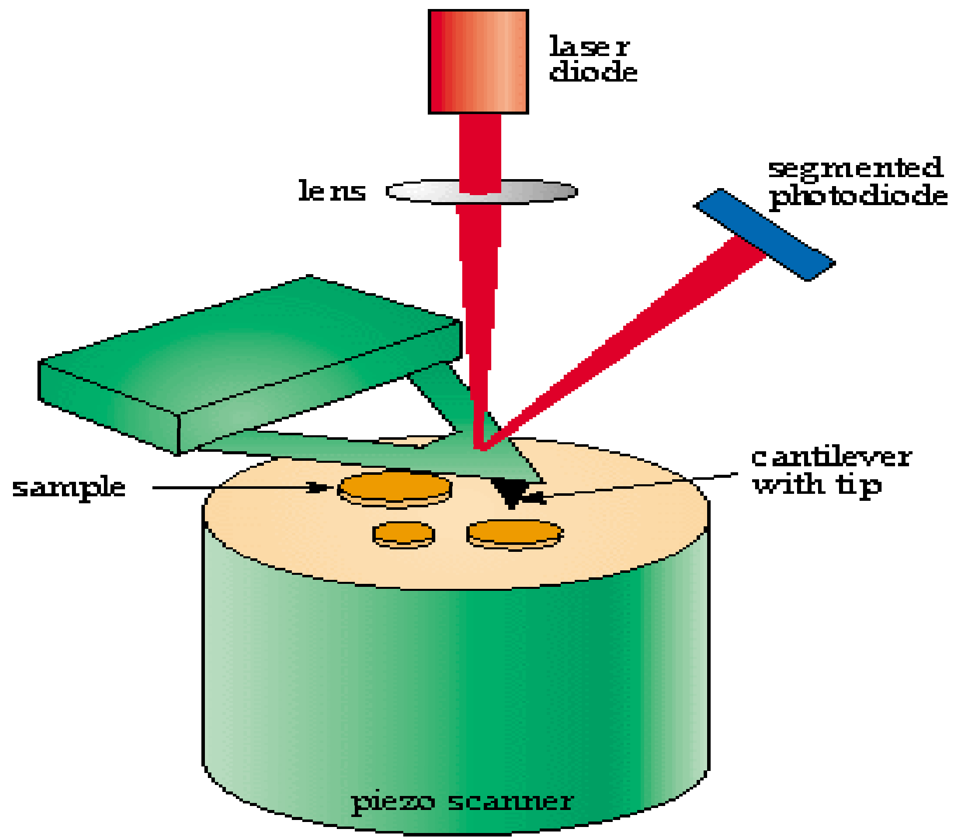
Nanotube growth using Chemical Vapor Deposition (CVD)





Atomic Force Microscopy:

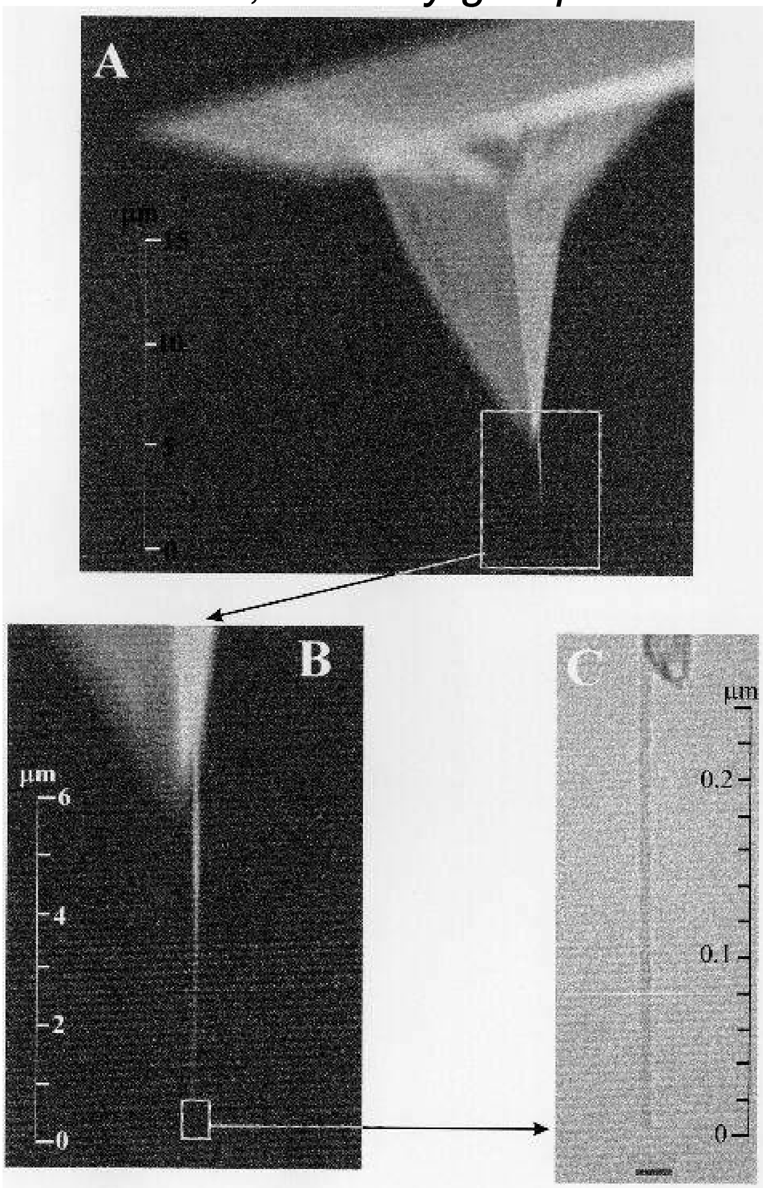
- Piezoelectric unit controls movement with angstrom precision
- 10 pN forces on the tip can be detected
- Contact vs. tapping mode
- Can apply voltage across the tip
- Different parameters can be controlled to obtain an image



Nanotubes on AFM tips - ‘tube tips’

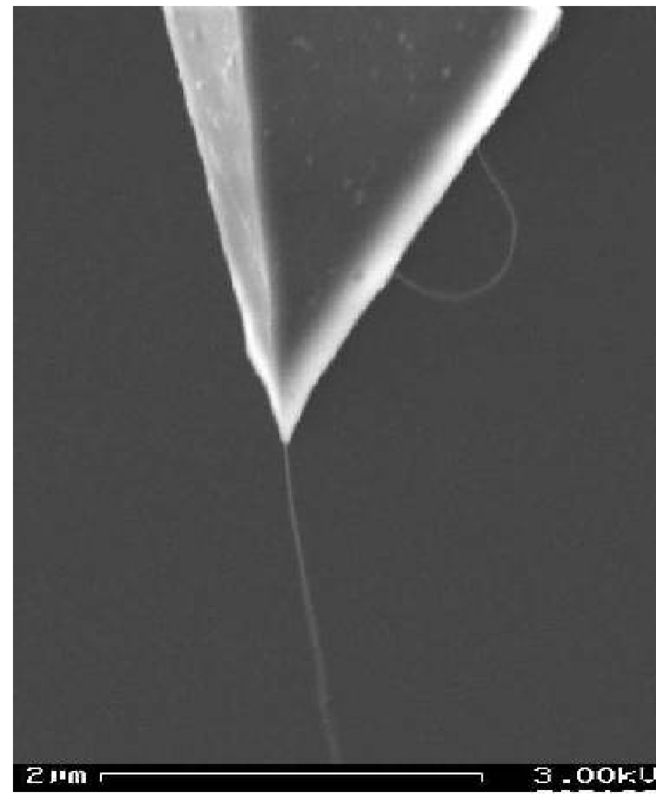
Multi-wall tube tips

Rinzler, Smalley group 1997



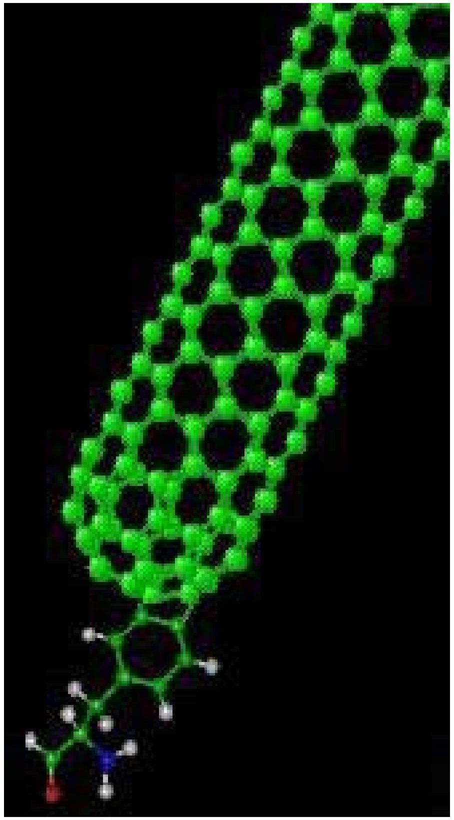
Single-wall tube tips

Hafner, Lieber group 2000

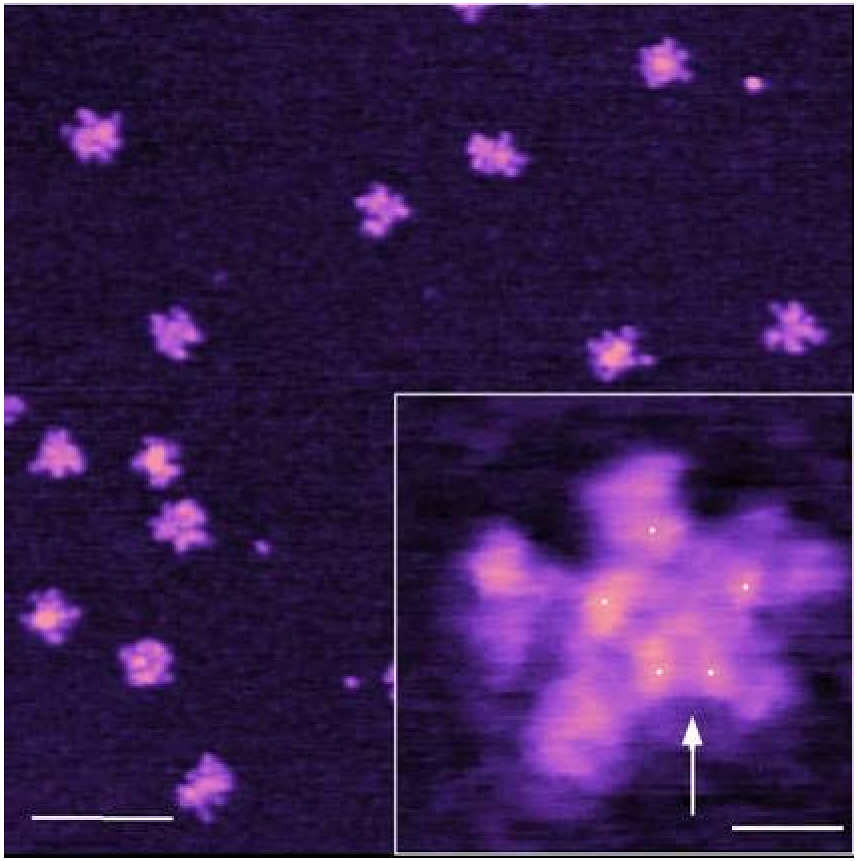


Applications of ‘tube tips’

- High aspect ratio
- Ultra-high resolution
- Very robust



Chemical probe – derivatize end only



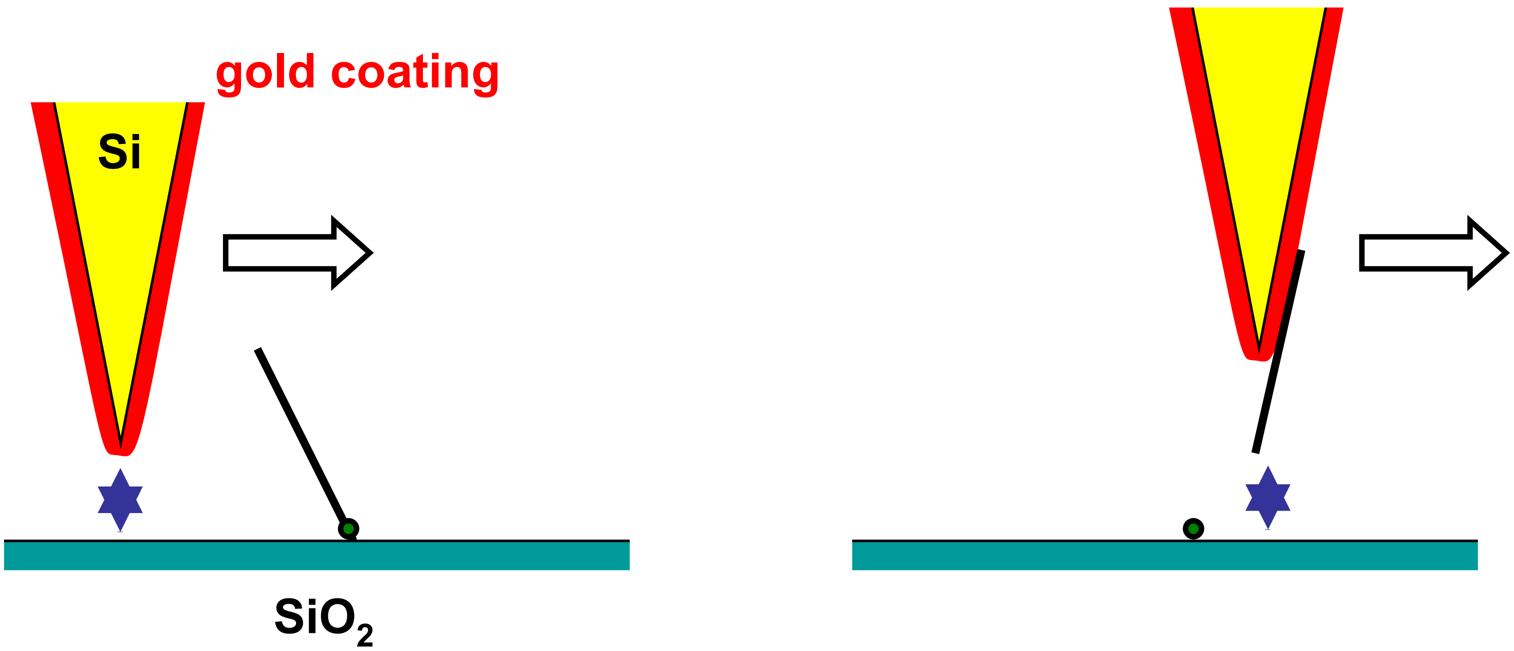
Immunoglobulin M molecules
(from Lieber group)

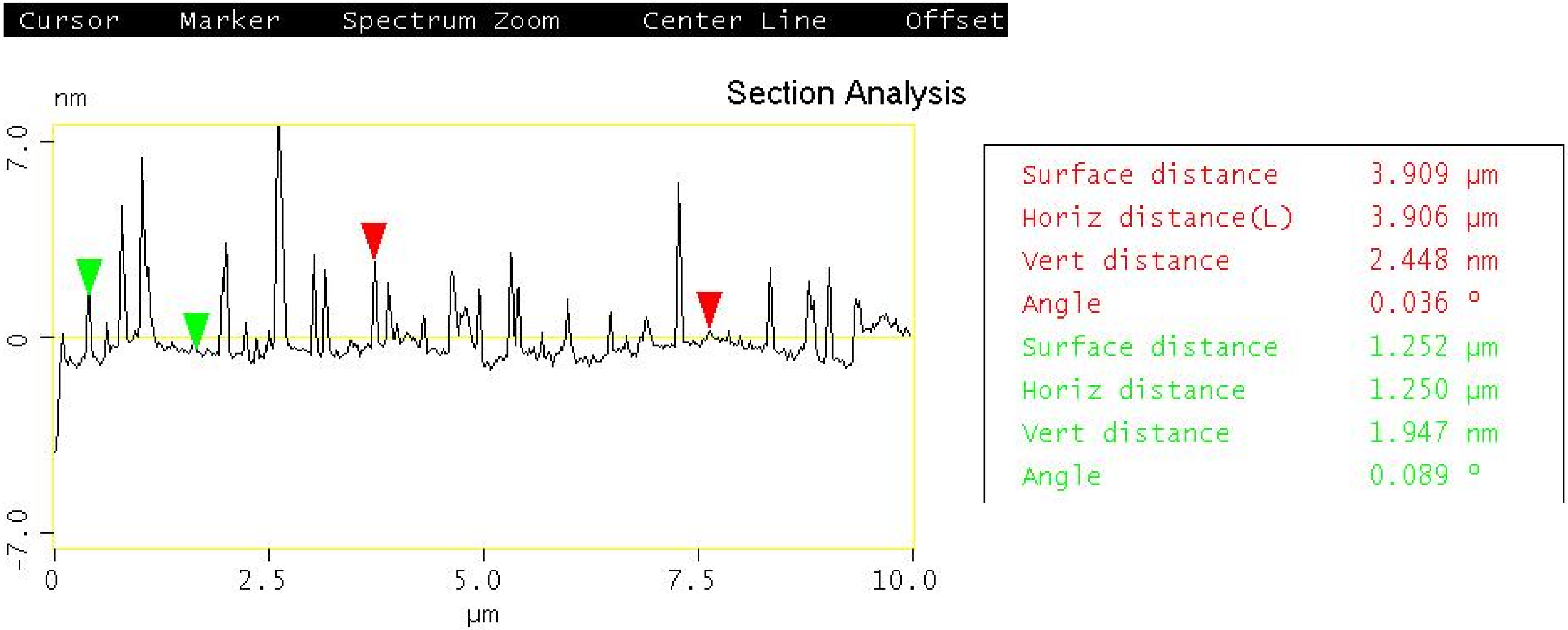
Other proposed uses:
•Ideal nano-electrode for probing membranes
•For electronic force microscopy

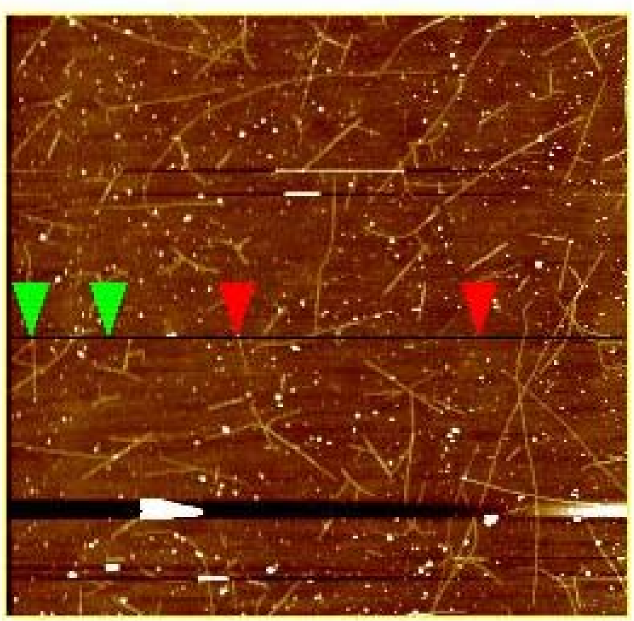
How to pick up a tube

Jason Hafner *et al*, J. Phys. Chem. B **2001**, *105*, 743

tapping-mode AFM scan



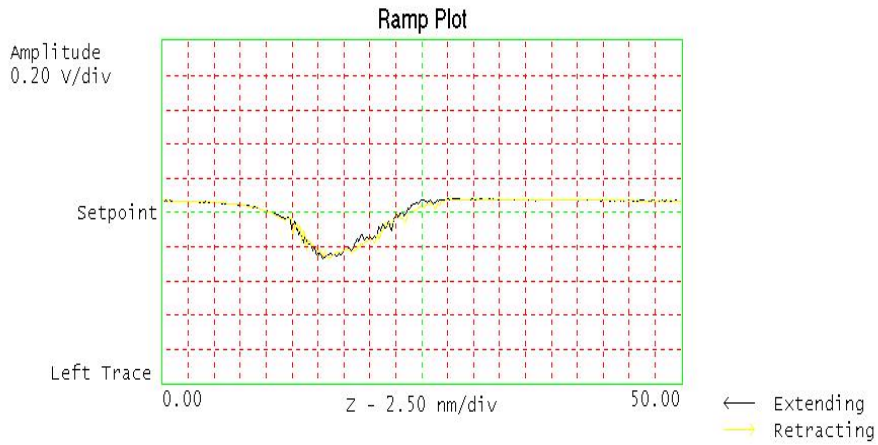


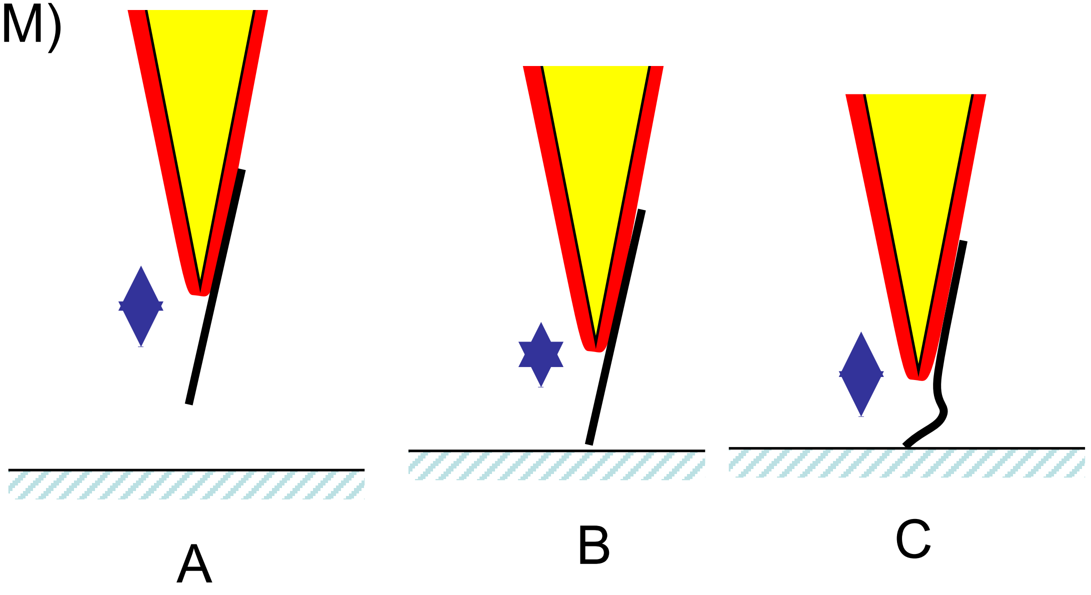


A good pick-up sample has a high density of short tubes

How do you know if you've picked up a tube?

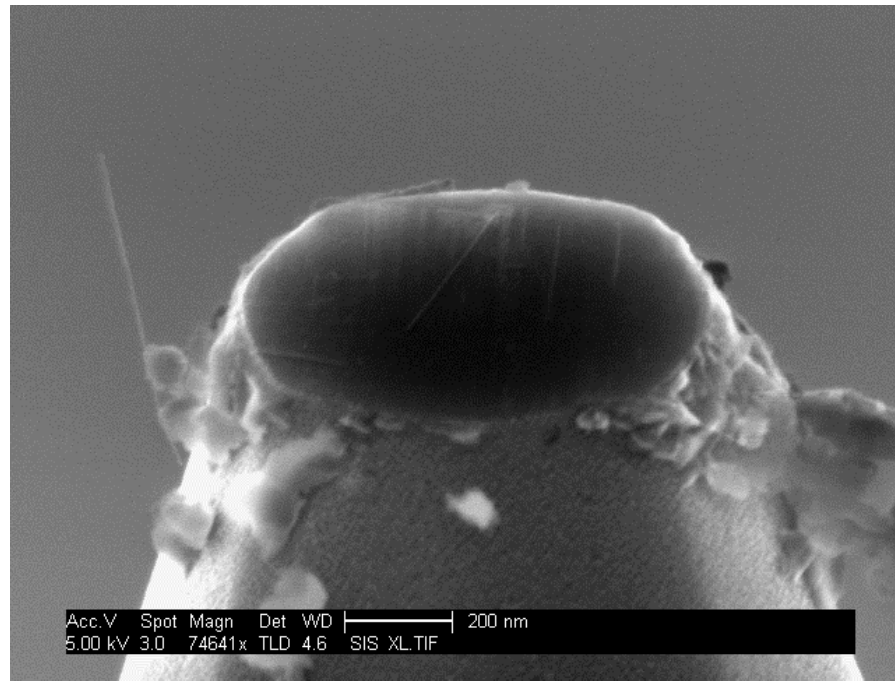
- The image changes
- Do a force plot to determine elastic buckling behavior
- Image tip with the Scanning Electron Microscope (SEM)





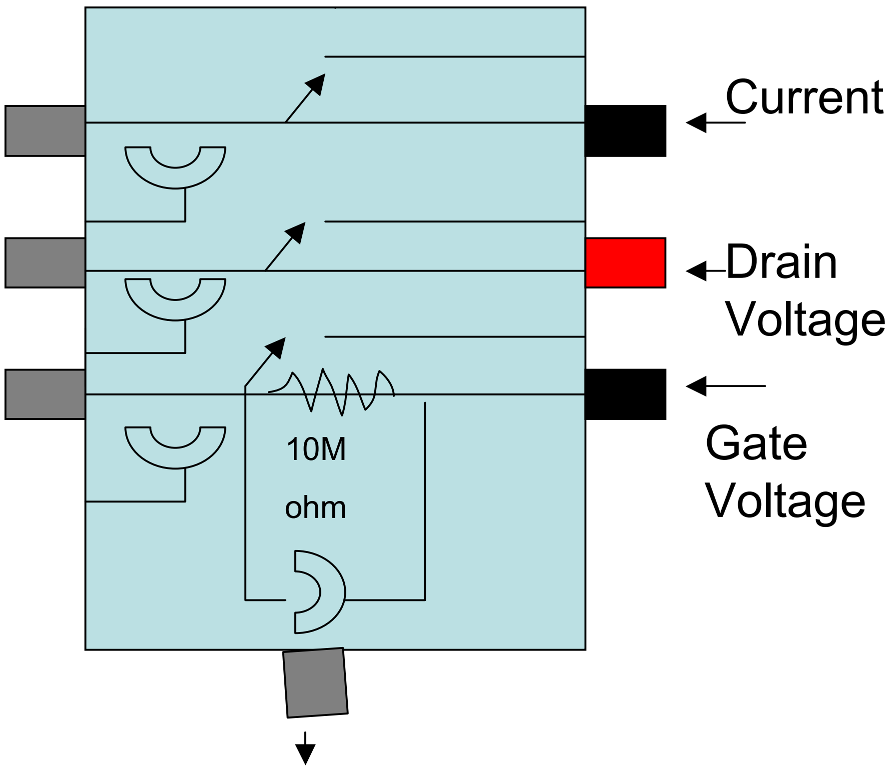
In Development . . .

- To improve pick-up we have switched to using sharp, new tips
- We are trying to get high density growth on unoxidized silicon in order to be able to shorten the tips
  - Tips are shortened by applying potential pulses between the AFM tip and the sample



Other Nanotube Things I Did . . .

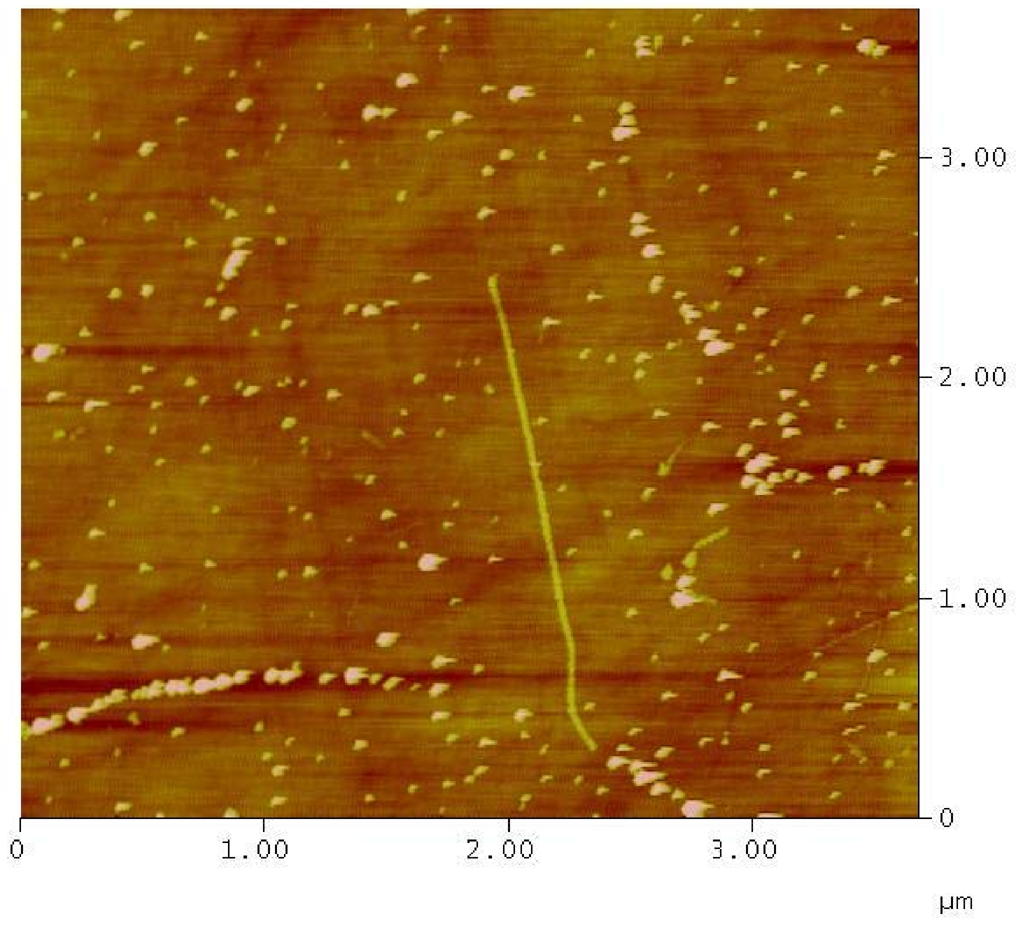
Built an electrical box to improve the probe station to measure gate voltage dependence



Nanotube growth on Quartz

-high density catalyst (1 grain: 20 ml IPA)

-leave at 900 degrees for 10 minutes before addition of methane



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