" Developing Standard Measurements to allow comparisons across experiments "

Howard Fairbrother

Department of Chemistry

Johns Hopkins University

NNI Workshop - Nanomaterials and the Environment & Instrumentation, Metrology, and Analytical Methods,

October 6 – 7, 2009.

nanoEHS

What is the state of research in this area of research at the current time?

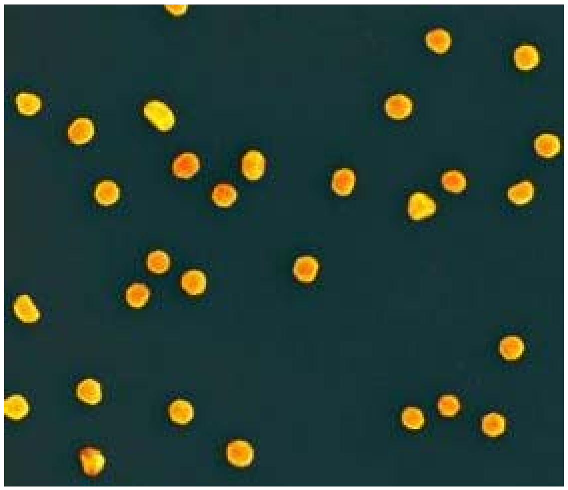
All over the place!

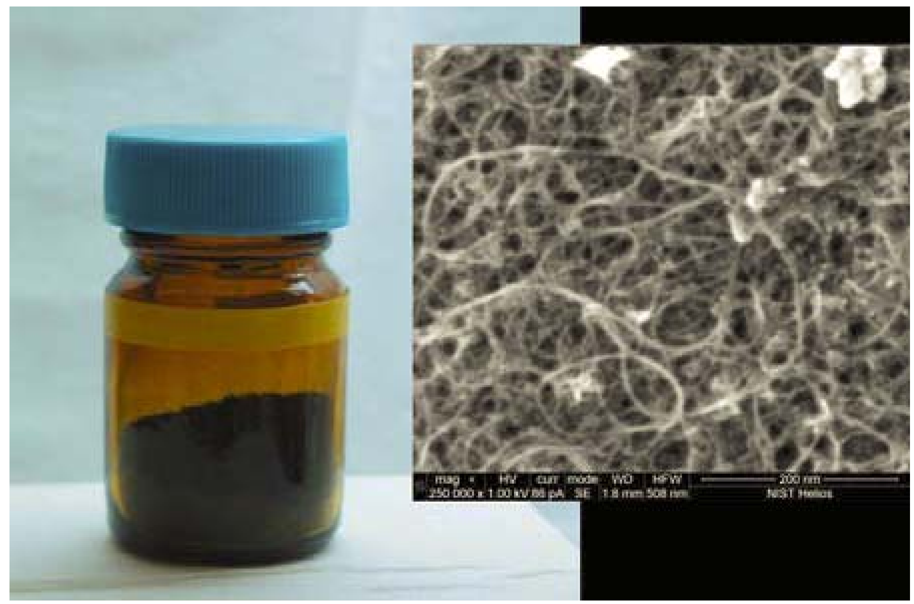
NANOTUBE -SUPPLIERS .COM

42 nanotube suppliers (Courtesy of Alex Starr)

Manufacture	Product Type	Product Method	Product Id	%C(purity)	Diameter (nm)	Length (µm)	Cost $/g
NanoLab Inc	MWCNT	CVD	PD15L5-20	>95%	15	5 – 20	110
Mercorp	MWCNT	CVD	MRCMW	>90%	35(±10)	30	60
Helix	MWCNT	CVD	MWNT	95%	10 – 30	0.5 – 40	28
Nanocs	MWCNT	CVD	CNTM0001	High?	20	1 – 100	160
Nanocyl	MWCNT	CVD	NC3100	95%	9.5	1.5	53
SES Research	MWCNT	CVD	900-1201	95%	10 – 30	5 – 15	70
Arkema	MWCNT	CVD	Graphistrength C100	90%	10 – 15	0.1 – 10	??
Arkema	MWCNT	CVD	Graphistrength U100	97%	10 – 15	0.1 – 10	??
Bayer	MWCNT	CVD	baytubes C 150 P	95%	5 – 20	1 – 10	??
Bayer	MWCNT	CVD	baytubes C 150 HP	99%	5 – 20	1 – 10	??
Helix	MWCNT	CVD	SD-MWNT	95%	<10	0.5 – 40	75
Helix	MWCNT	CVD	SD-MWNT	95%	10 – 20	0.5 – 40	40
Helix	MWCNT	CVD	MWNT	95%	10 – 30	0.5 – 40	28
Helix	MWCNT	CVD	MWNT	95%	20 – 40	0.5 – 40	28
Helix	MWCNT	CVD	MWNT	95%	40 – 60	0.5 – 40	28
Helix	MWCNT	CVD	MWNT	95%	60 – 100	0.5 – 40	28
Carbon Solutions	SWCNT	Arc	Ap-SWNT	40-60%	1 – 10	1 – 5	50
NanoLab Inc	SWCNT	Arc	D1L1-10J	40%	1 – 1.5	10	225
Carbon Solutions	SWCNT	Arc	P2-SWNT	70-90%	4 – 5	0.5 – 1.5	400
SweNT	SWCNT	CoMoCat		90%	1	1	500
Unidym	SWCNT	HipCo					
SES Research	SWCNT	CVD	900-1351	90%	<2	1 – 5	250
Nanocs	SWCNT	Arc	CNTM0002		2 – 1 0	50 nm – Many	250
Helix	SWCNT	CVD	HP-SWNT	90%	1.3	0.5-40	210
Helix	SWCNT	CVD	LC-SWNT	50-70%	1.2 - 1.5	0.5-3	83
Mercorp	SWCNT	Arc	MRSW	12%	1.2 - 1.4	10-50	60
Nanocyl	SWCNT	CCVD	NC1100	70%	2	Many	??

Development of Reference Materials is Emerging - NIST





Au NPs

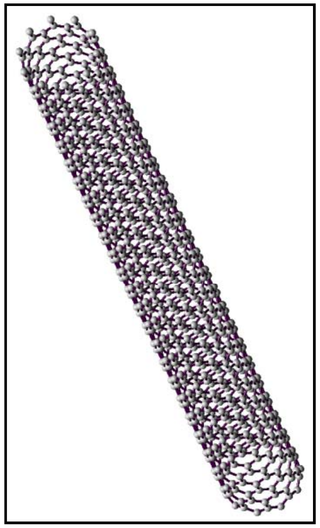
CNTs

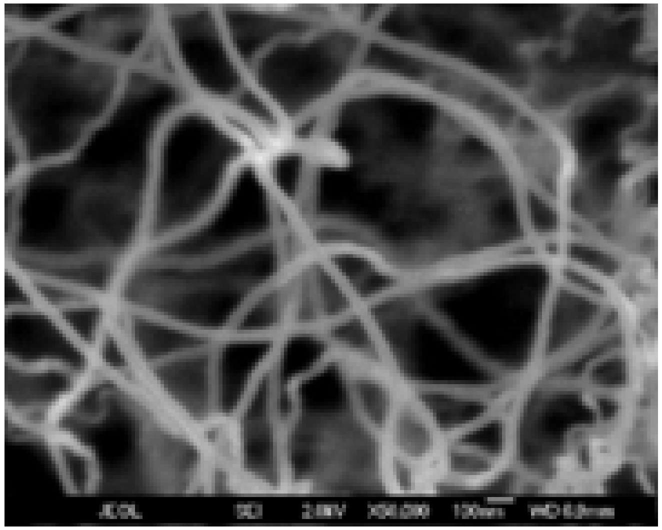
But… It is probably unrealistic and unreasonable to expect that all research on EHS effects of nanomaterials (engineered or otherwise) is going to use sole source reference materials (RMs), so…

I would advocate a policy of minimum characterization requirements for studies to be suitable for publication.

These requirements would obviously depend on the nanomaterial under consideration.

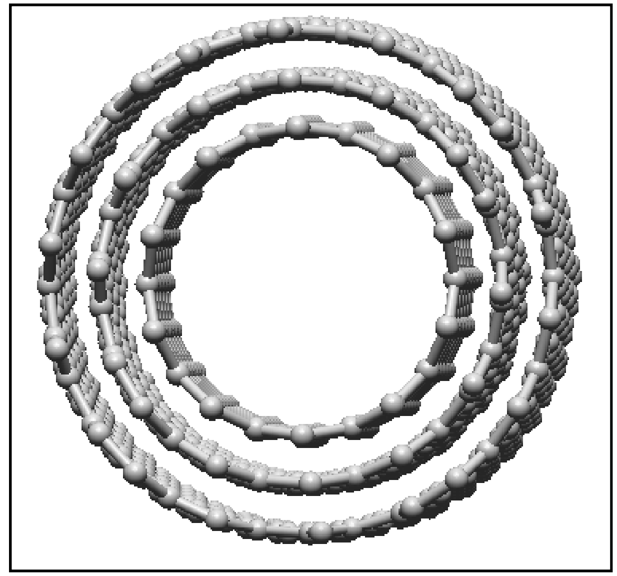
Using CNTs as an example





Showing a SEM

Image is not sufficient

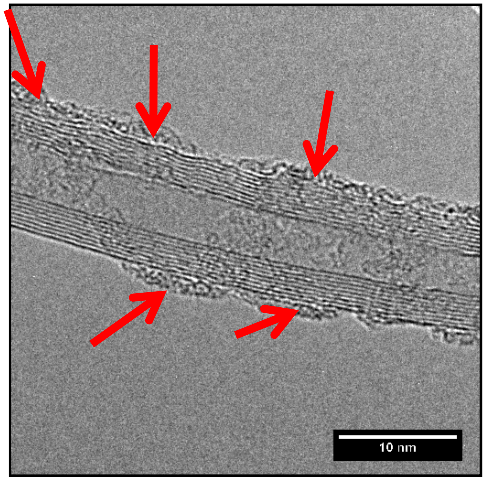


Key Materials Properties (for CNTs)

Structure - Length distribution (AFM, TEM)

Chemical Composition (EDS, Elemental Analysis)

Purity (Raman for a:C and Elemental Analysis for metal content)



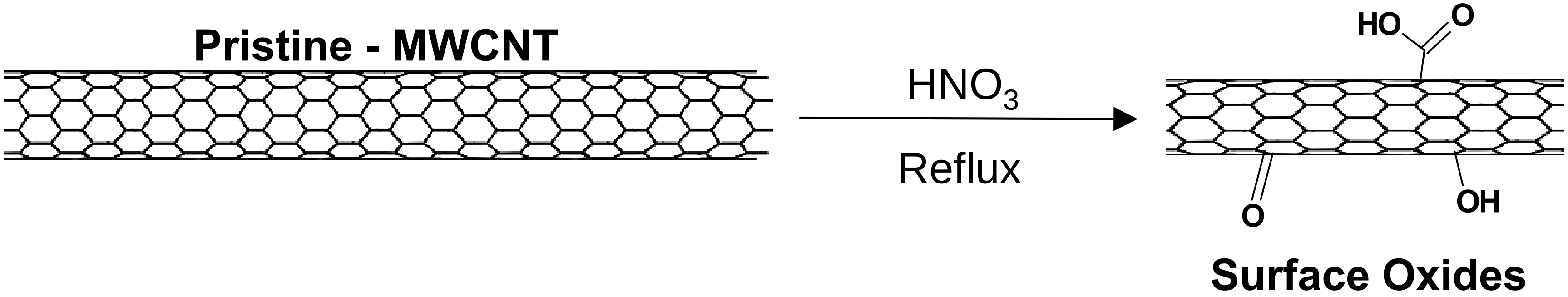
For Colloidal Suspensions:

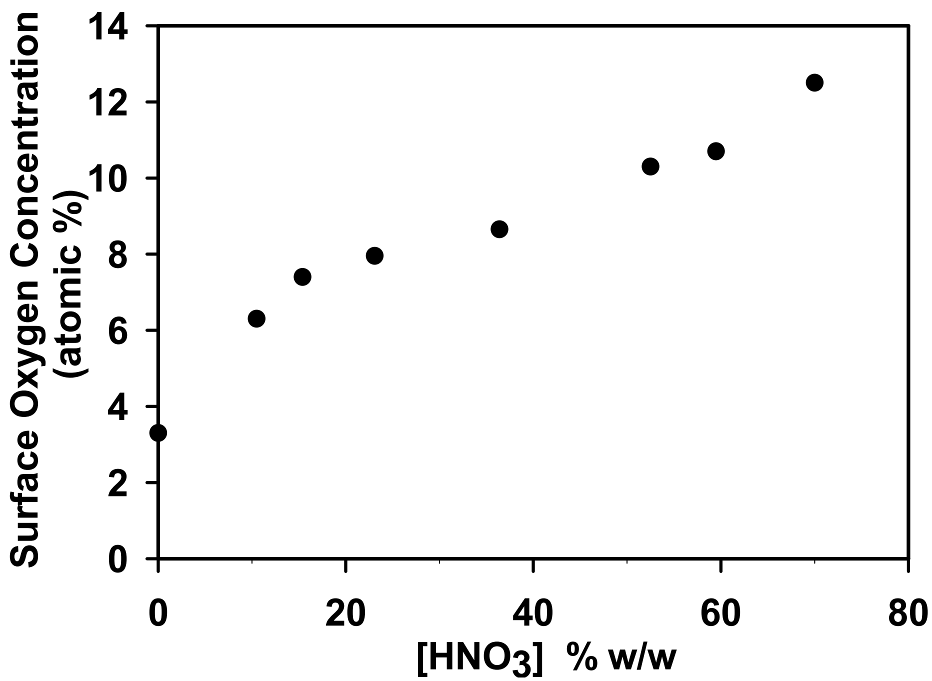
Particle Size (DLS)

Surface Properties (EM, Chemical Composition)

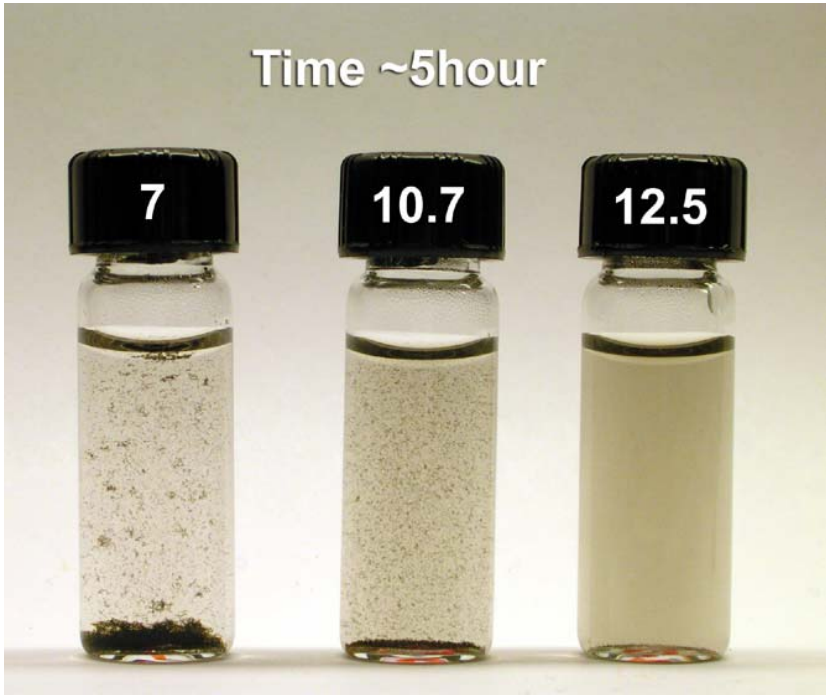
Verification that you are studying what you think you are studying

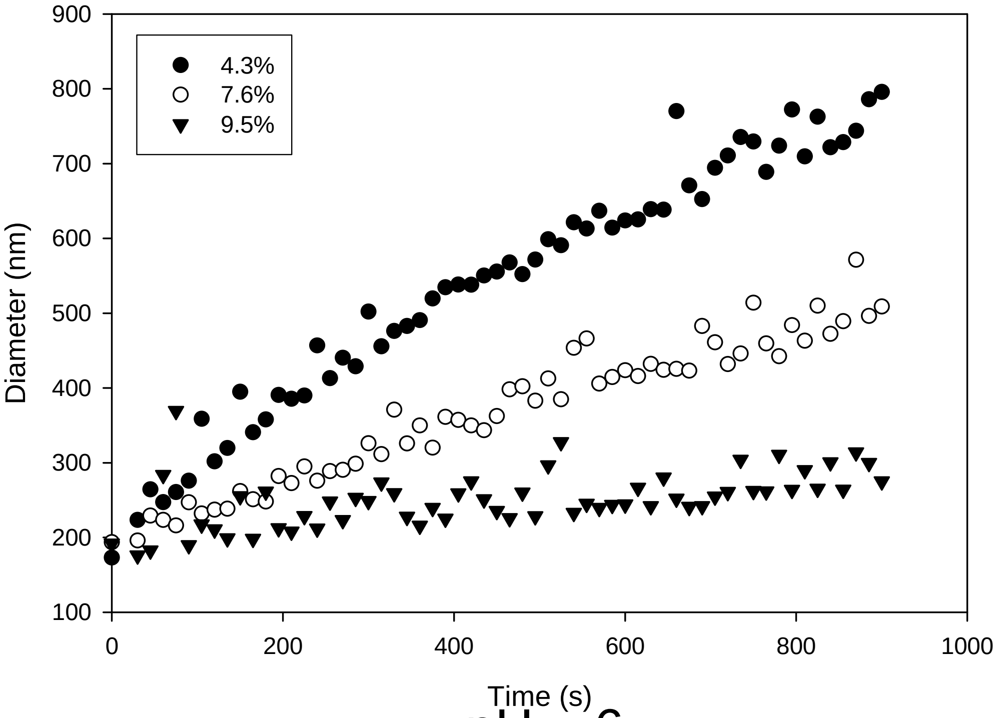
Effect of Oxidation on MWCNTs





More Oxidized CNTs are more stable towards Aggregation



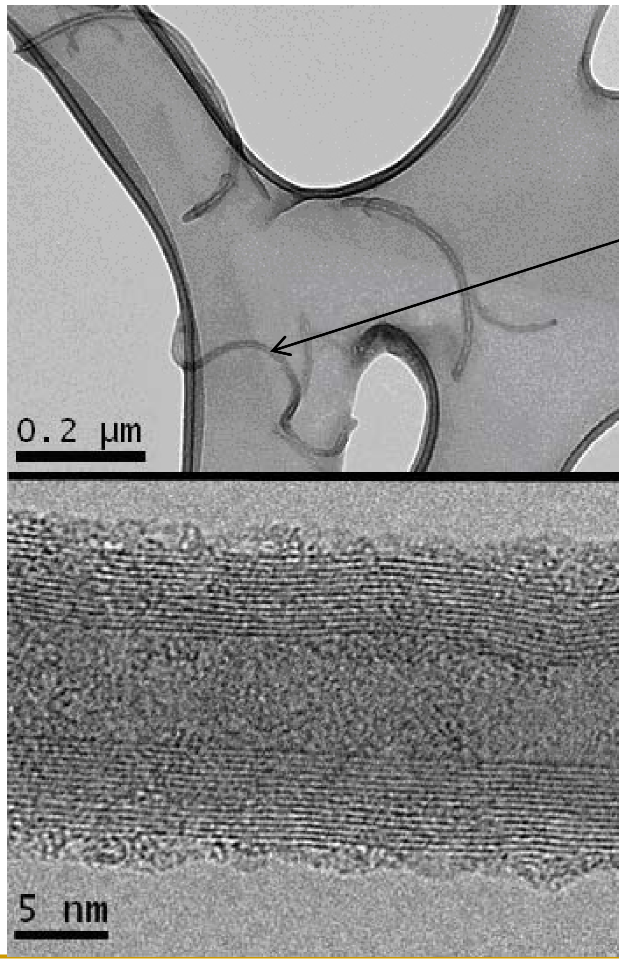


pH = 6

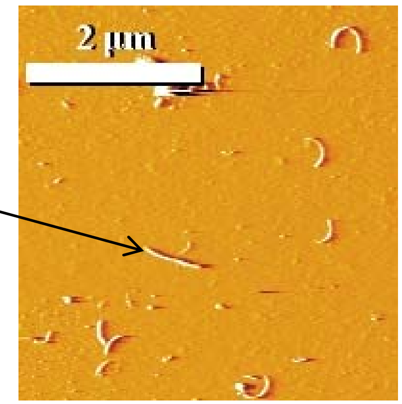
64 mM NaCl

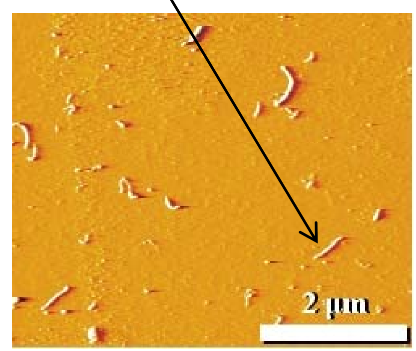
7.5 mg CNT/L

Oxidized MWCNTs in Suspension



Individual nanotubes

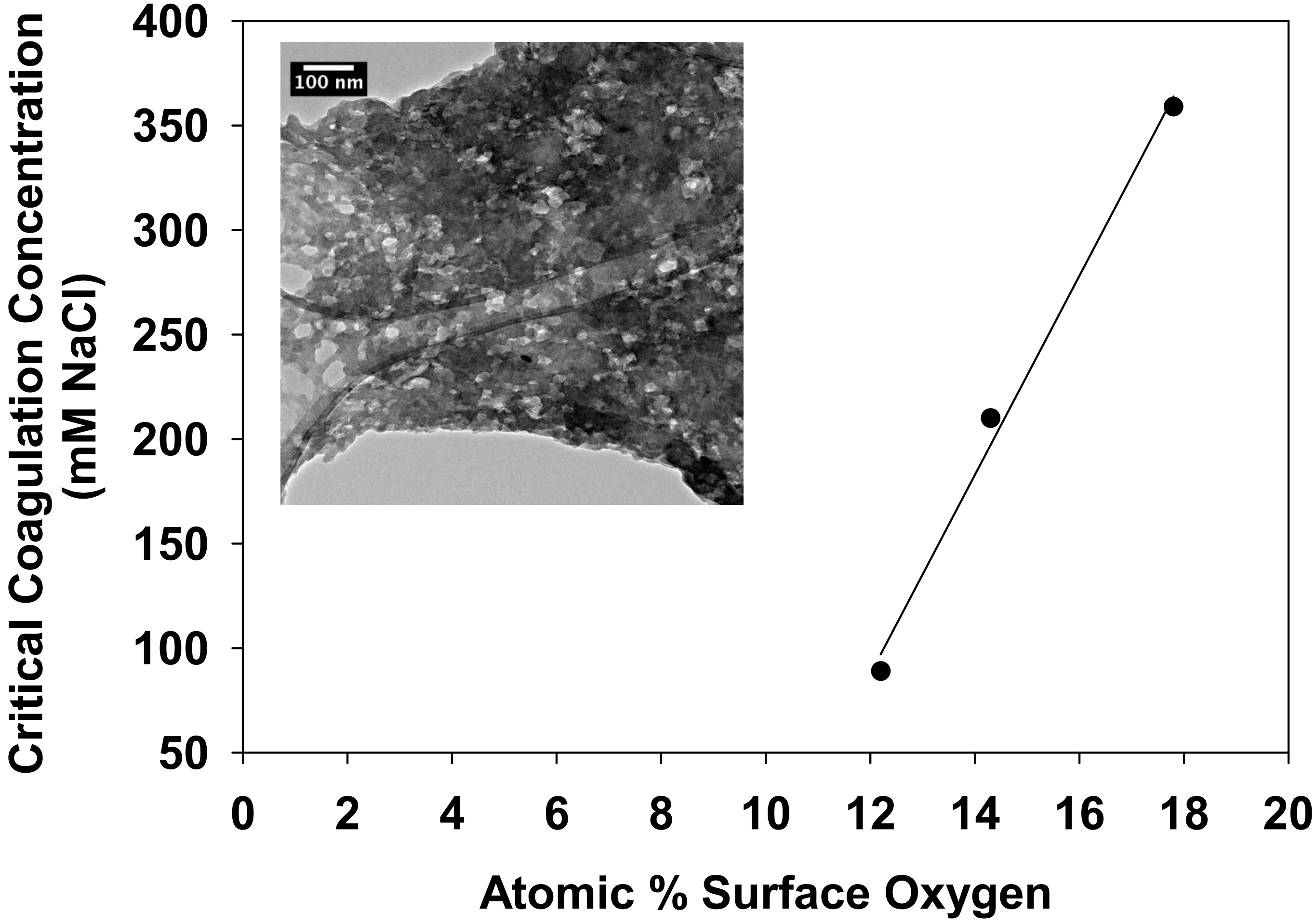




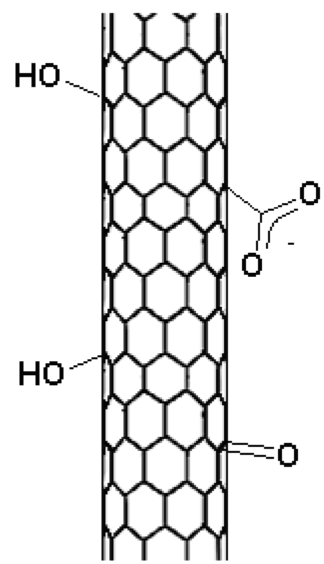
TEM

AFM

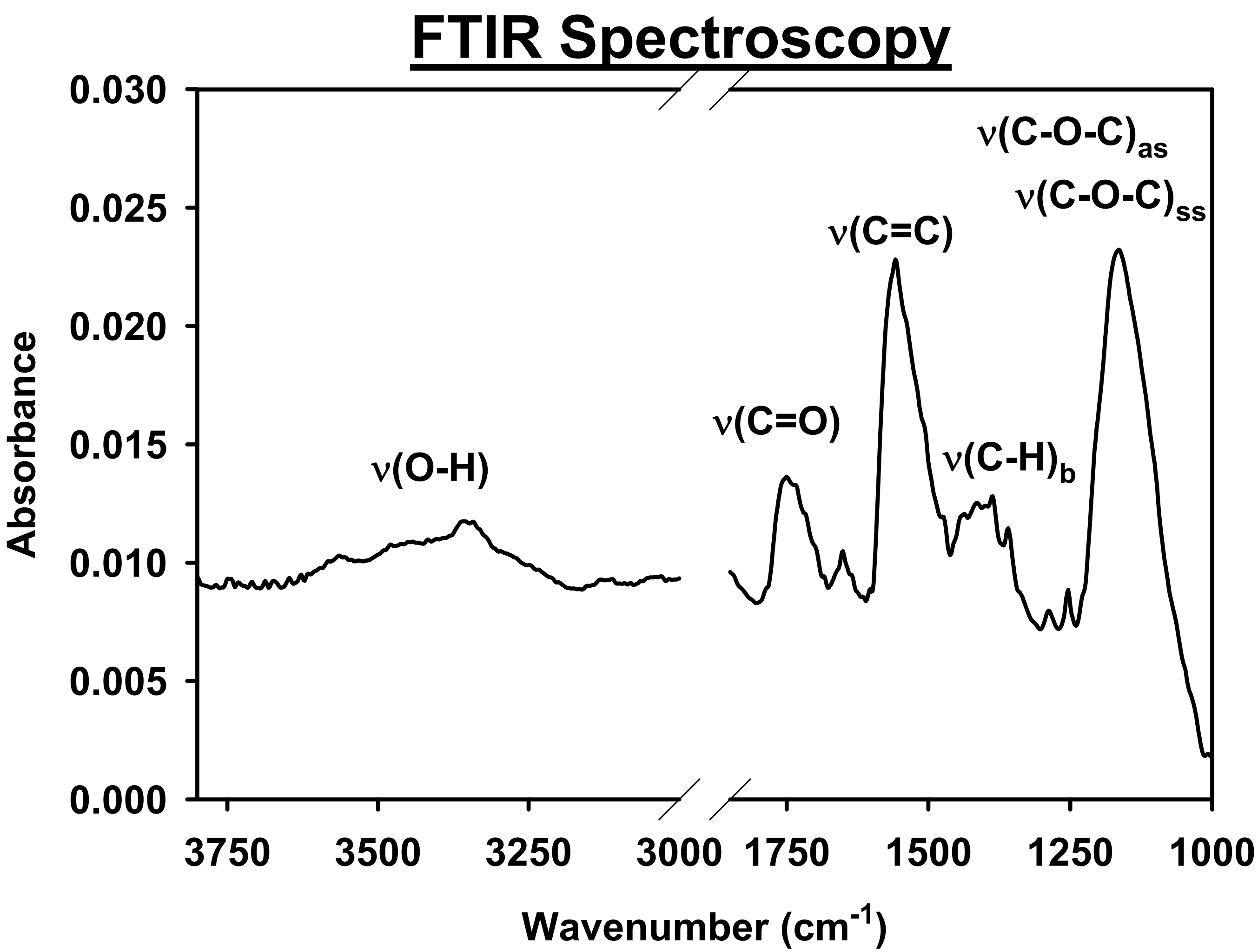
Effect of Surface Oxidation on SWCNTs



If you are going to make quantitative claims use quantitative techniques



Characterization of Oxides on CNTs



FTIR identifies oxygen functional groups but provides no quantification

Chemical Derivatization of Surface Oxides?

- Reagent selectively reacts with specific functional groups
  - Reagent contains a CF_3 tag.
  - Vapor phase chemical process
  - Label chemical quantified by XPS