Carbon Nanotubes and Desalination

Patrick Stetz

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Zettl Group Meeting

Carbon nanoparticle-modified multi-wall carbon nanotubes with fast adsorption kinetics for water treatment

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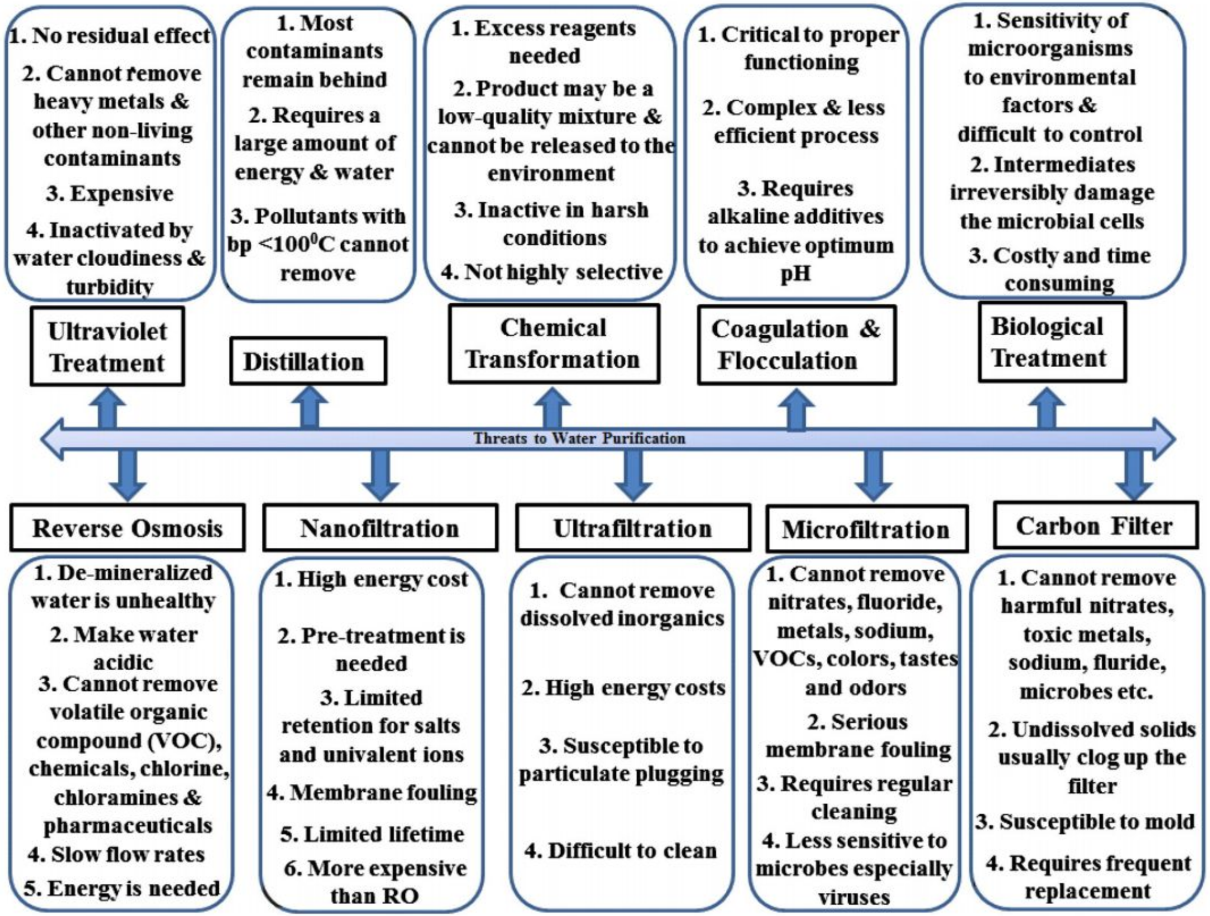
Journal: Nanotechnology

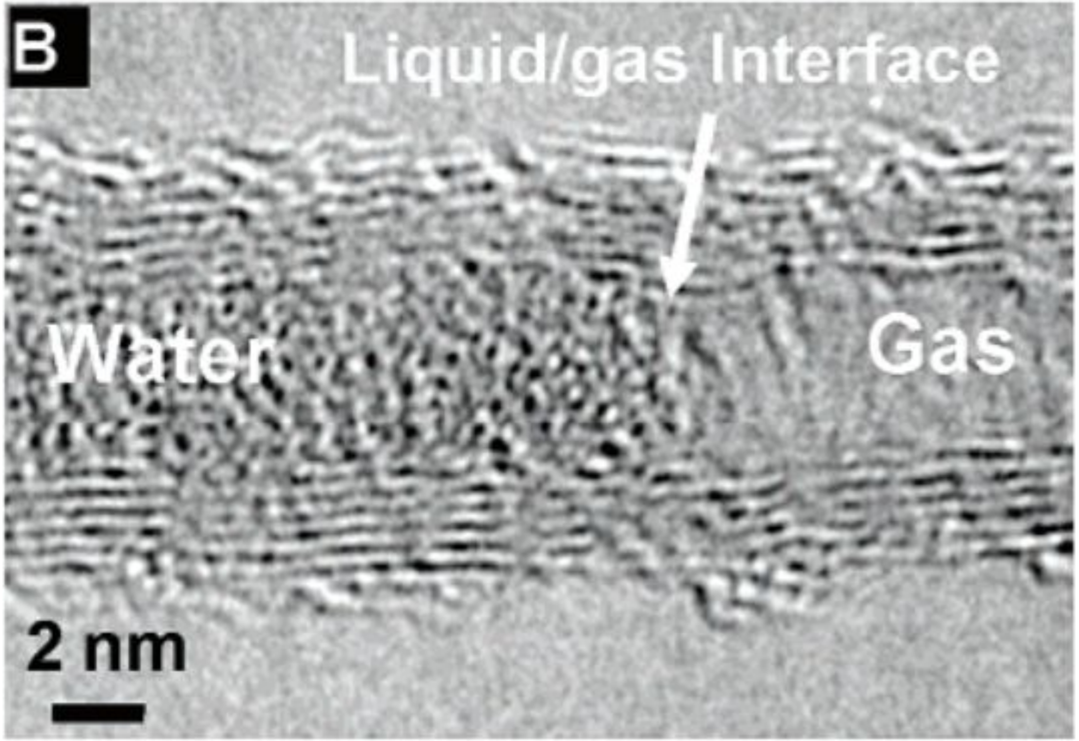
Textile Dye Pollution

Water Treatment Methods

R. Das et al. / Desalination 336 (2014) 97–109



Water in CNT



(2004) N. Naguib
Nano Letters

CNT Desalination

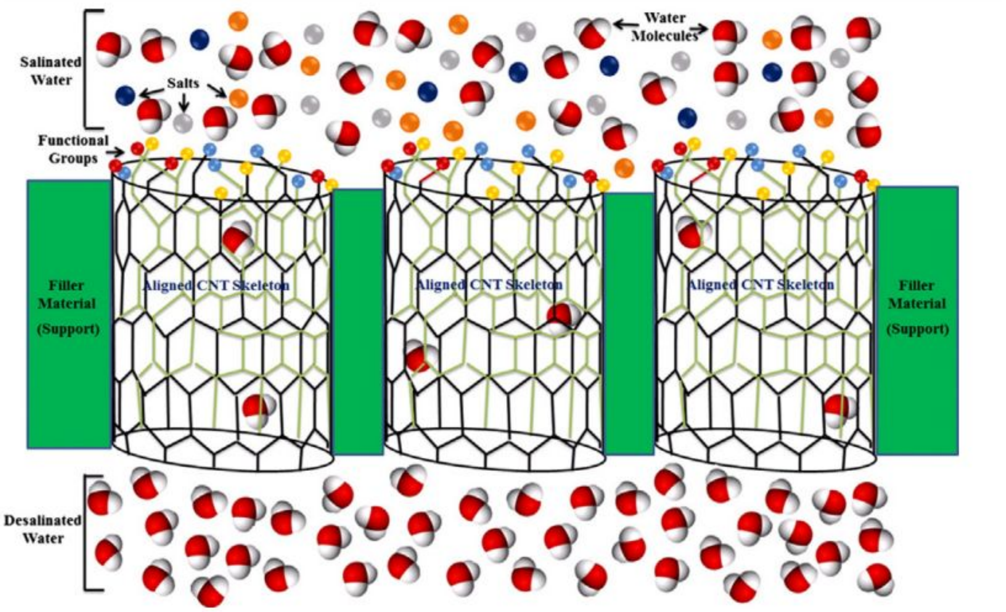
-CNT walls are hydrophobic

-Very little friction

-Water moving up to 43cm s^{-1} bar^{-1}

-Low energy cost

GRAPHICAL ABSTRACT



R. Das et al

Papers on “Desalination”

Field: Publication Years	Record Count	% of 13859	Bar Chart
2016	1893	13.659 %	
2015	1597	11.523 %	
2014	1227	8.853 %	
2013	1179	8.507 %	
2012	931	6.718 %	
2011	856	6.176 %	
2010	675	4.870 %	
2009	653	4.712 %	
2008	410	2.958 %	
2007	406	2.930 %	
Field: Publication Years	Record Count	% of 13859	Bar Chart

Papers on “CNT Desalination”

Field: Publication Years	Record Count	% of 108	Bar Chart
2016	31	28.704 %	
2015	19	17.593 %	
2014	15	13.889 %	
2011	13	12.037 %	
2012	10	9.259 %	
2013	10	9.259 %	
2010	6	5.556 %	
2007	2	1.852 %	
Field: Publication Years	Record Count	% of 108	Bar Chart

Information provided through Web of Knowledge

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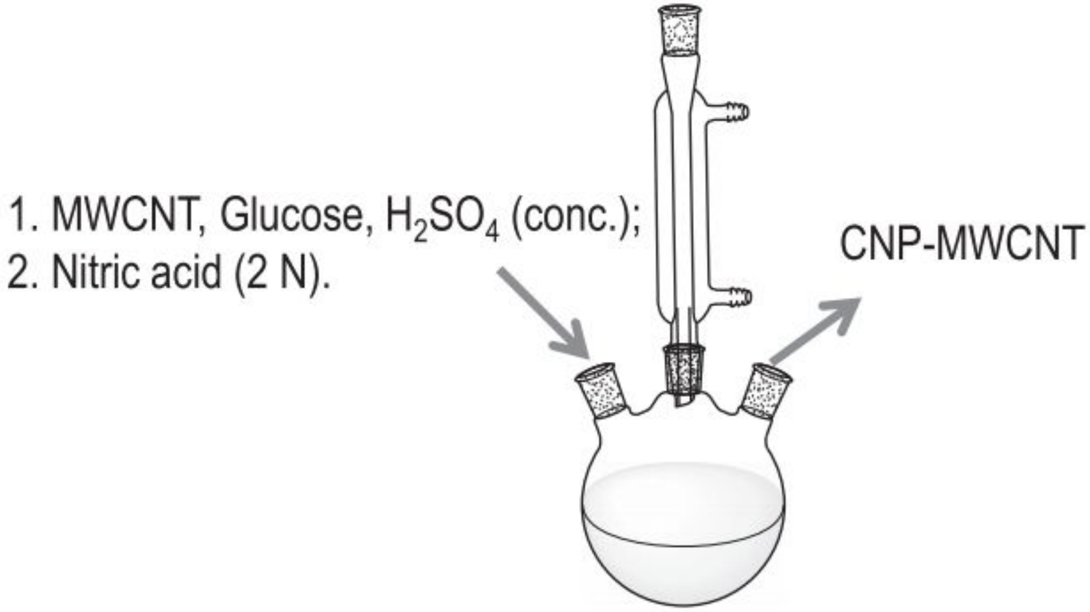
Synthesis



Scheme 1 Synthesis of CNP-MWCNT. Conditions: 1. 100 °C, 1 h; 2. 120 °C, overnight.

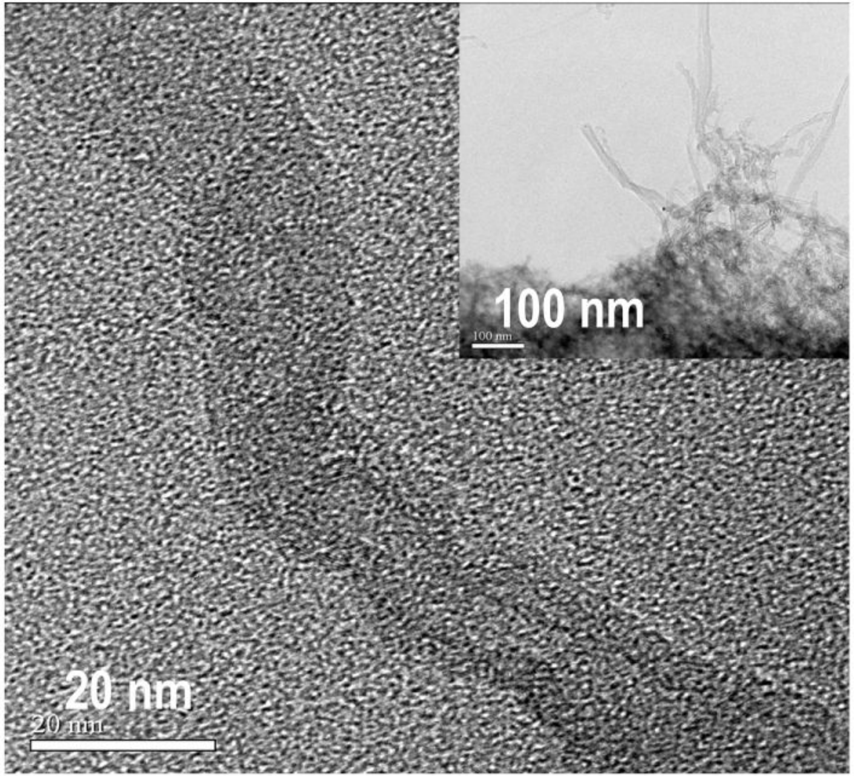
Synthesis

- MWCNTs (0.5g), glucose (1g in 5ml water), then sulfuric acid (98%, 10ml) were added to a flask and heated to 100^{o}C for 1hr

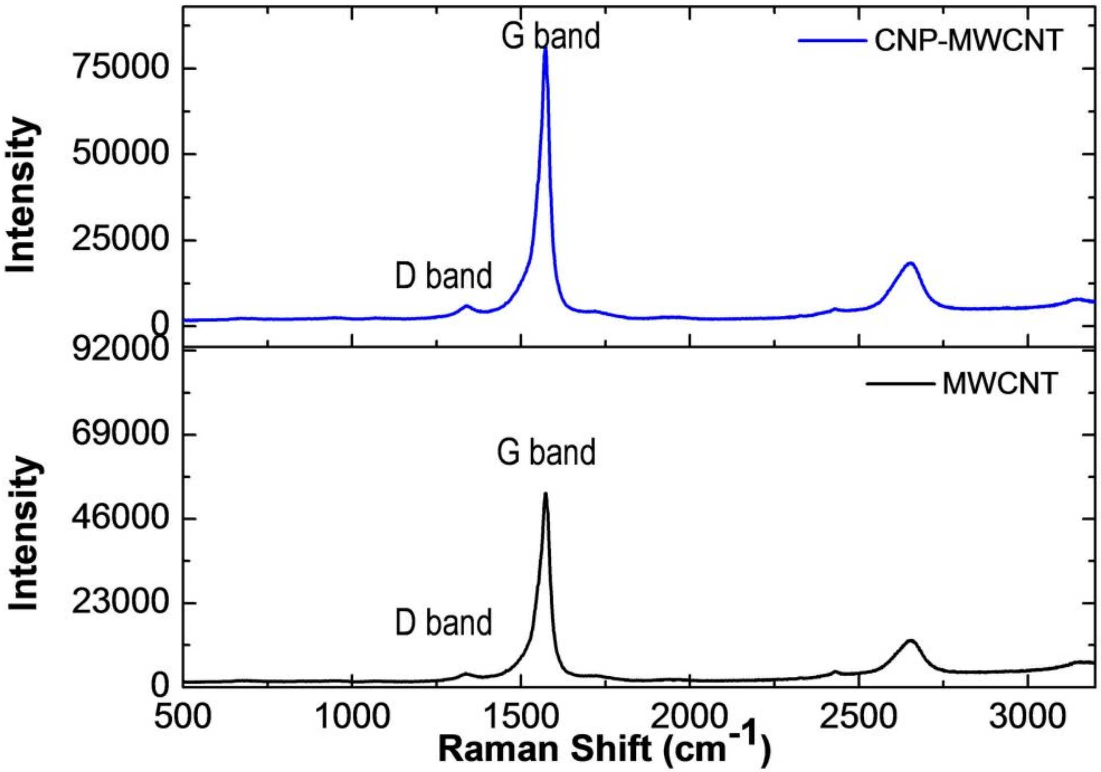
-Next nitric acid (2N, 50ml) was added, then the flask was heated to 120^{o}C and left overnight

-CNP-MWCNTs were collected by centrifuge at 6,000 RPM, then washed with Milli-Q water six times

CNP MWCNT



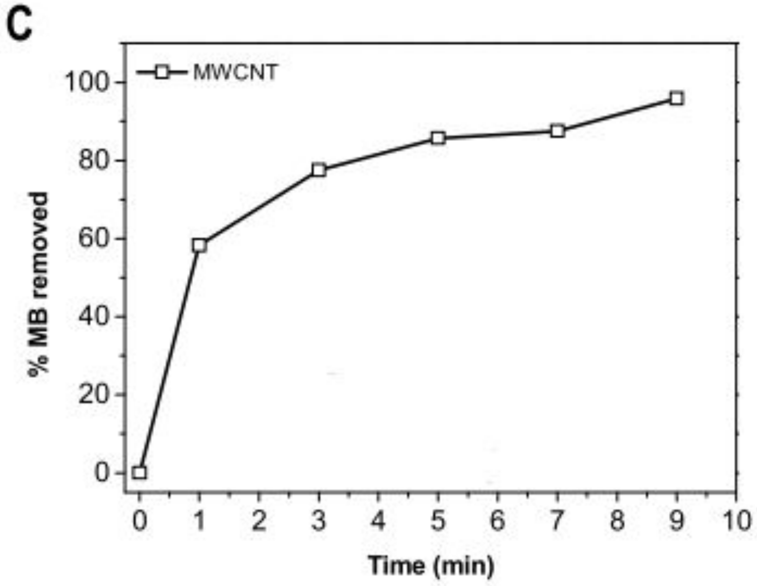
CNP-MWCNT Raman image

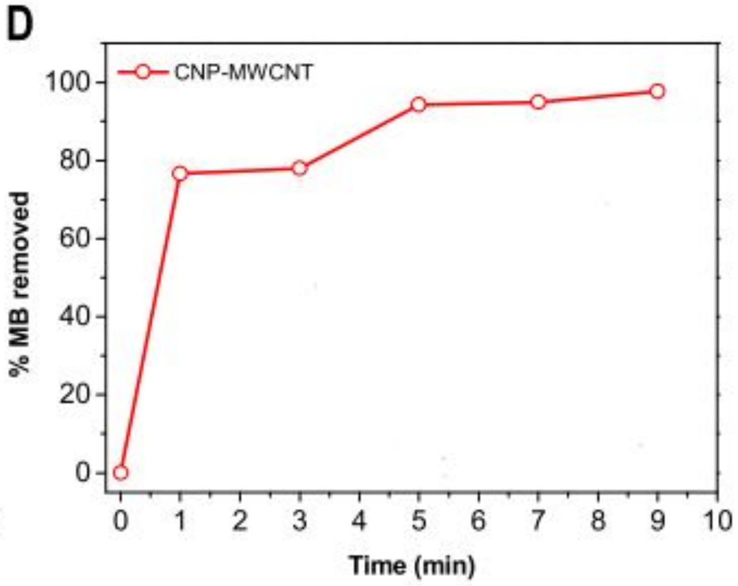


I_D/I_G = 0.07

I_D/I_G = 0.08

Results


C
MWCNT
% MB removed
Time (min)
0
20
40
60
80
100
0
1
2
3
4
5
6
7
8
9
10


D
CNP-MWCNT
% MB removed
Time (min)
0
20
40
60
80
100
0
1
2
3
4
5
6
7
8
9
10

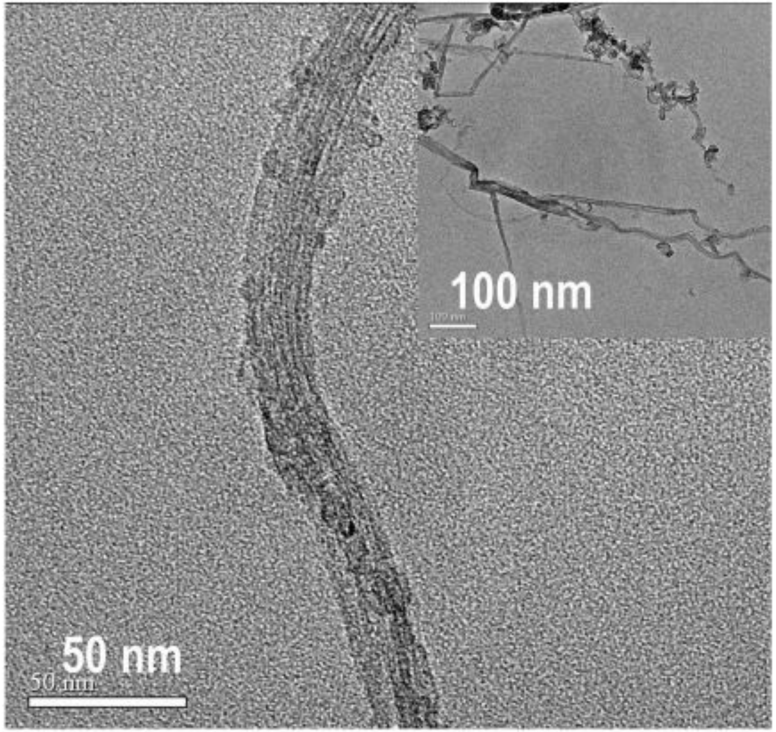
Results

CNP-MWCNTs have faster kinetics.

Attributed to:

-Smaller pore size

-Improved crystalline structure



Current problems in CNT Desalination

-Uniform pore size and distribution

-CNTs frequently have blockages

-Functional groups slow water passage

-CNT growth with proper alignment

-Scaling up production

Suggestion

Try BNNT instead of CNT

(J. Azamat 2015) Molecular dynamics simulation of ion separation and water transport through boron nitride nanotubes

(T.A. Hilder 2009) Salt rejection and water transport through boron nitride nanotubes

(J. Azamat 2014) Separation of a heavy metal from water through a membrane containing boron nitride nanotubes: molecular dynamics simulations

(CY Won 2009) A chloride ion-selective boron nitride nanotube

(ME Suk 2008) Fast reverse osmosis using boron nitride and carbon nanotubes

(A. Siria 2013) Giant osmotic energy conversion measured in a single transmembrane boron nitride nanotube

End

Thank you for listening!

Paper trends on “control”

Field: Publication Years	Record Count	% of 4852709	Bar Chart
2015	336191	6.928 %	
2016	319736	6.589 %	
2014	310859	6.406 %	
2013	297715	6.135 %	
2012	278131	5.731 %	
2011	252987	5.213 %	
2009	237574	4.896 %	
2010	237523	4.895 %	
2008	220593	4.546 %	
2007	203496	4.193 %	

Field: Publication Years | Record Count | % of 4852709 | Bar Chart

Notes

Synthesis- Normality (N), product of molarity and "n-factor." N-factor is the number of H+ ions replaced by 1 mole of acid in a reaction

Notes to myself ahead (ignore)

Questions 1

What is the purpose of speed?

I think it’s worthwhile studying this property of CNT if only because of it’s of its importance. Not only that, but a marked increase from 3min to 1min in one paper could be an indicator that more progress can be made. Down to the seconds.

Is there any literature on smaller CNTs absorbing faster? (small mass as bigger CNTS)

Yes! The higher the pore density, the faster CNTs transport the water. However the pores have to be a certain size to let only water pass. The optimal pore size seems to be 7nm

Questions 2

Does water travel inside the CNT through the end or through openings in the wall? How does it work for MWCNTs?

-Water is trapped inside the CNT and not outside (see figure).

Why is water trapped inside? How does this get rid of salts? Shouldn't the salts be trapped inside?

- The water is the only thing that can travel through these CNTs. The salts get stuck on one end and the water is able to pass. Water goes inside the tube because of pressure and theory attribute Hydrogen Bonds as playing a hand too.

Questions 3

How do MWCNTs absorb MB? Is it different than CNTs absorb MB?

How are CNTs and MWCNTs grown? Is it possible to add defects into them?

-Vertically aligned CNTs are grown through CVD. I definitely think more defects are possible and wonder if a hole in the CNT

Questions 4

Doesn’t equilibrium have something to say about this? Or the laws of entropy? Why is the system spontaneously getting more ordered?

- There’s a pressure applied to the system and the membrane (CNT) is semi-permeable so it follows different dynamics. Work is added through pressure and energy is lost through friction. Thermodynamics and thus the world are safe.

How does changing the surface or creating holes improve the process if the magic is happening inside?

- I don’t think it does, the paper I’m reporting on says the improvement is from better crystalline structure and smaller pore size. That begs the question, how does what they did effect that?

Questions 5

What makes them better than other filtration methods?

- They are a low energy solution for water treatment

Why use MWCNTs over SWCNTs?

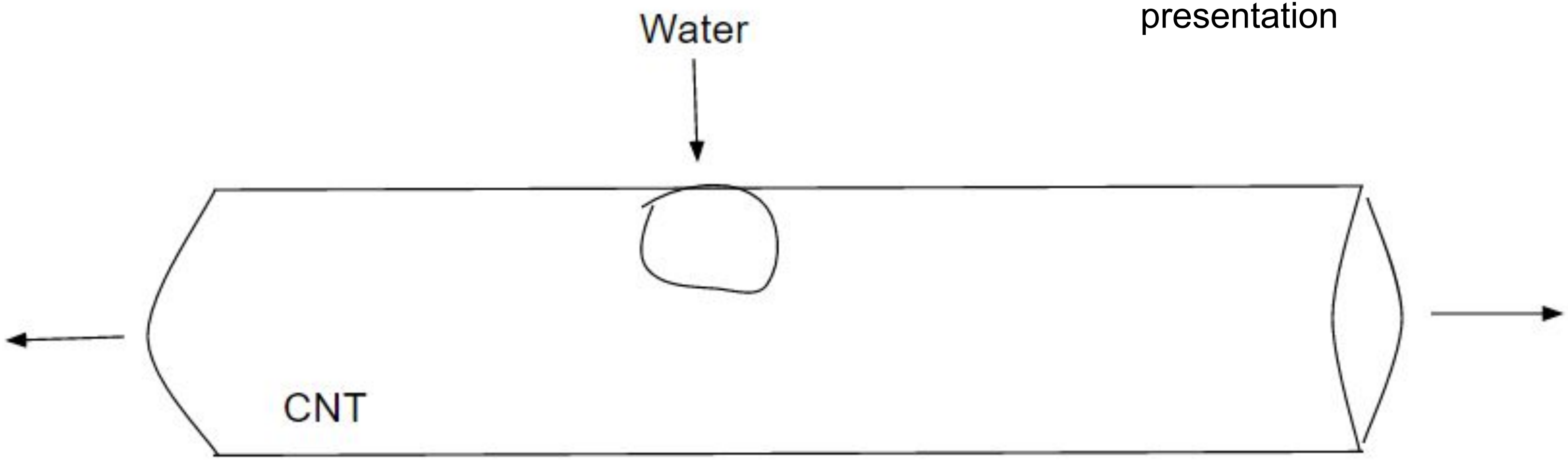
- MWCNTs are cheaper than SWCNTs or DWCNTs

Questions 6

CNT are cytotoxic, how do these filters prevent against killing us?

Suggestions

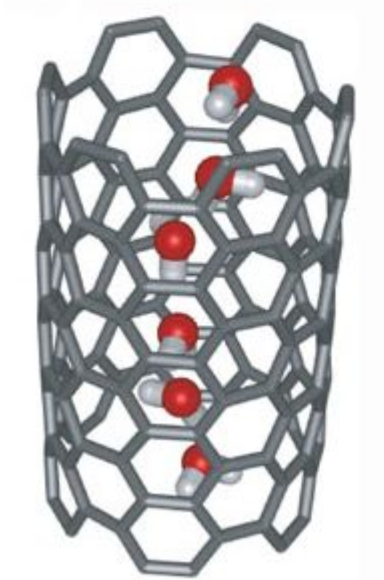
Hole vacancies make CNTs brittle. Don’t include in presentation



Water in chain in CNT

http://www.nature.com/nature/journal/v414/n6860/pdf/414188a0.pdf

Despite being nonpolar, initially empty CNTs will be filled with water.



G. Hummer, et al. Nature 414, 188-190 (2001)

Notes

CNT Desalination: It’s like a nanoscale hyperloop

Read

CNT screening of ionic impurities

F. Fornasiero, H.G. Park, J.K. Holt, M. Stadermann, C.P. Grigoropoulos, A. Noy, and O. Bakajin, Ion exclusion by sub-2-nm carbon nanotube pores, PNAS. 105 (2008), pp. 17250–17255.