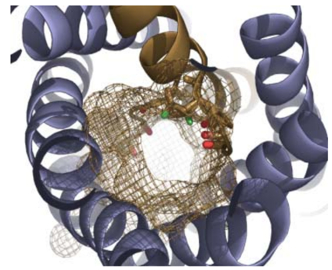
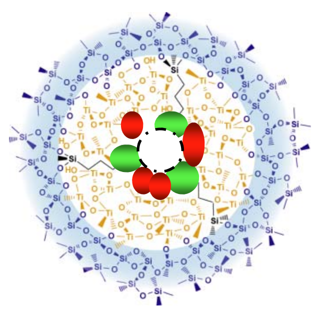
Desalination Research at Sandia National Laboratories

Patrick V. Brady (pvbrady@sandia.gov)

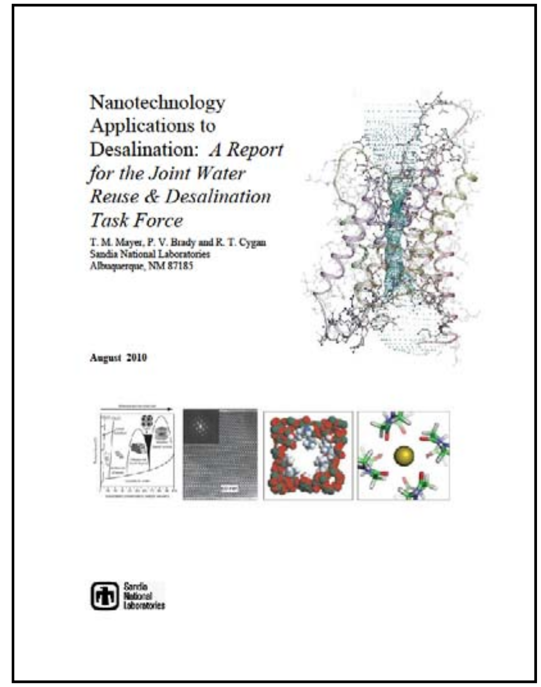
1. Energy-Water Nexus: Silica Control

2. Biomimetic Membranes





3. Nanotechnology Applications to Desalination



Nanotechnology Applications to Desalination: *A Report for the Joint Water Reuse & Desalination Task Force*

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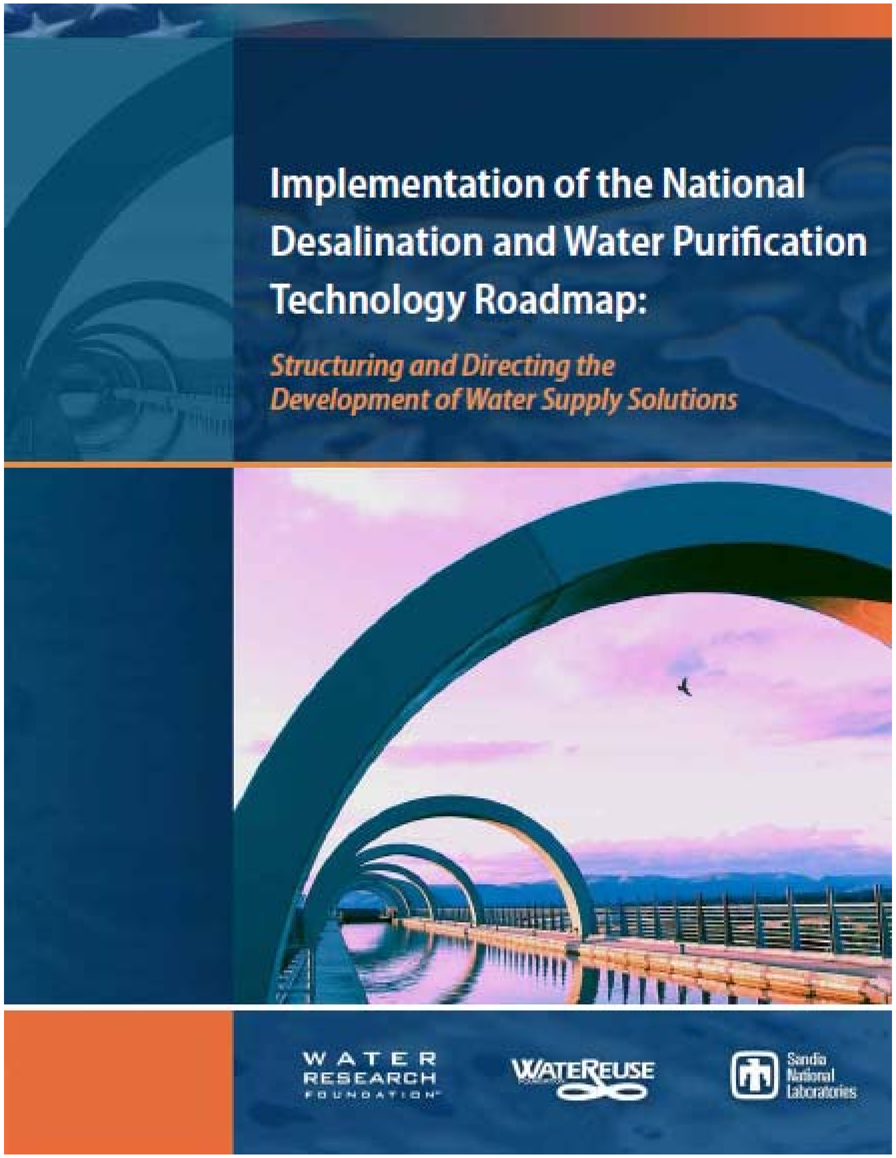
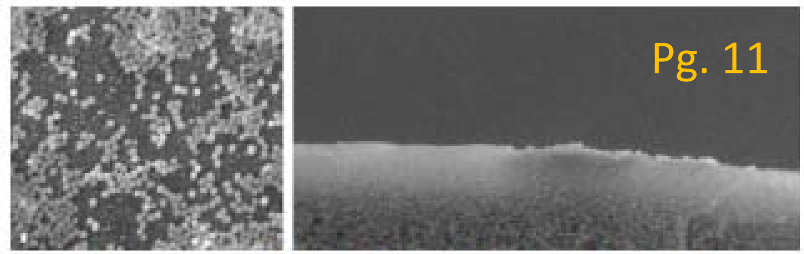


Research Project: Particulate and Other Inorganic Fouling—Foulant Characterization and Indices Development, Mechanisms, Modeling, and Real-Time Sensing

- Problem/Need. Most membrane manufacturers require a silt density index (SDI) < 5 in the feedwater, but an SDI < 3 is preferred. However, SDI is a poor predictor of inorganic fouling. Fouling by most inorganic salts is fairly well understood, but inorganic fouling by silica is problematic—it is not as well understood, or easily controlled.
- Objective. Reduce or eliminate fouling so that existing membrane systems can be operated at a higher throughput.
- Approach. Improve fouling indices. Develop improved control techniques for silica and inorganic colloidal materials. Develop real-time sensing tools.

Pg. 10



Surface and cross-section views of silica colloid fouling on an NF membrane. Developing an enhanced understanding of silica fouling is necessary to facilitate higher system throughput. (http://water.usgs.gov/wrri/04grants/Progress%20Completion%20Reports/2004OR47B.pdf)

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Research Project: Nano-Coagulation of Silica

- Problem/Need. Silica removal is a critical challenge to inland desalination as it limits water recovery and concentrate disposal options.
- Objective. Dramatically increase recoveries and lower costs of silica removal.
- Approach. Develop novel nano-materials (metal oxides and metals sorbed on nano-oxides) that can rapidly and effectively remove silica from solution by establishing the ability of designer nano-materials to abstract silica from solution. Optimize (e.g., feed rate, sequencing) and pilot test at an inland desalination site.

http://www.sandia.gov/water/docs/DesalImplementRoadmap1-26-2010_c_web.pdf

The Problem

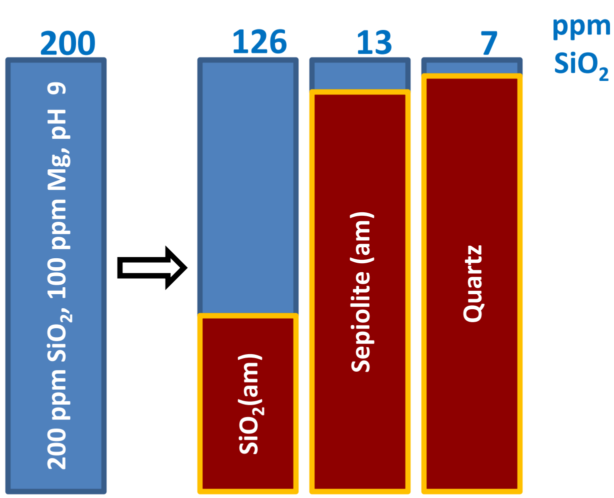
"Without testing it is impossible to know the exact silica solubility in production waters. Tables of silica solubility as a function of temperature or pH exist only for pure water. In the presence of other anions, cations, or dissolved solids the silica solubility is unpredictable" (from Pedenaud et al., SPE Production and Operations, Feb. 2006.)

The Waters

	Los Alamos tapwater	El Paso Desal conc.	Cooling Tower	Wairakei geothermal	Ohnuma geothermal	SAGD
SiO_2^{aq}	**88**	**148**	**123**	**560**	**521**	**239**
Na^+	14	2674	152	1190	384	1050
Ca^{2+}	13	589	163	2	13	8
Mg^{2+}	4	153	27	18	0.6	1
Cl^-	4	4699	105	2100	540	1435
SO_4^{2-}	3	1039	139	32	199	*
HCO_3^-	90	412	374	13	*	316
T	25°C	24°C		90-100°C	97°C	
pH	7.8-8.2	8.0	8.9	7.9	7.3	

LANL – Wohlberg, C., V. P. Worland, et al. (1999). The management of silica in Los Alamos National Laboratory tap water. Los Alamos, NM, Los Alamos National Laboratory. I. **El Paso** - Tarquin, T. (2009). High tech methods to reduce concentrate volumes prior to disposal. *Draft Final Report to Texas Water Development Board*, University of Texas at El Paso. **Cooling Tower** – 1/14/2010 analyses from SNL/CINT cooling tower water. **Wairakei** - Rothbaum, H. P., B. H. Anderton, et al. (1979). "Effect of silica polymerisation and pH on geothermal scaling." *Geothermics* 8: 1-20. **Ohnuma** - Kato, K., A. Ueda, et al. (2003). "Silica recovery from Sumikawa and Ohnuma geothermal brines (Japan) by addition of CaO and cationic precipitants in a newly developed seed circulation device." *Geothermics* 32: 239-273. **SAGD** – average of 5 de-oiled produced waters, Portelance, S. N. (2000). *Waste Water Treatment Options for a SAGD oil production facility; IWC-07-26.* International Water Conference, Pittsburgh, PA.

The Solids



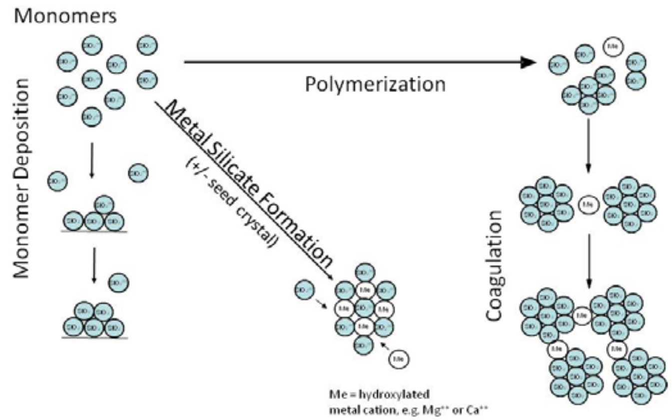
Existing Solutions

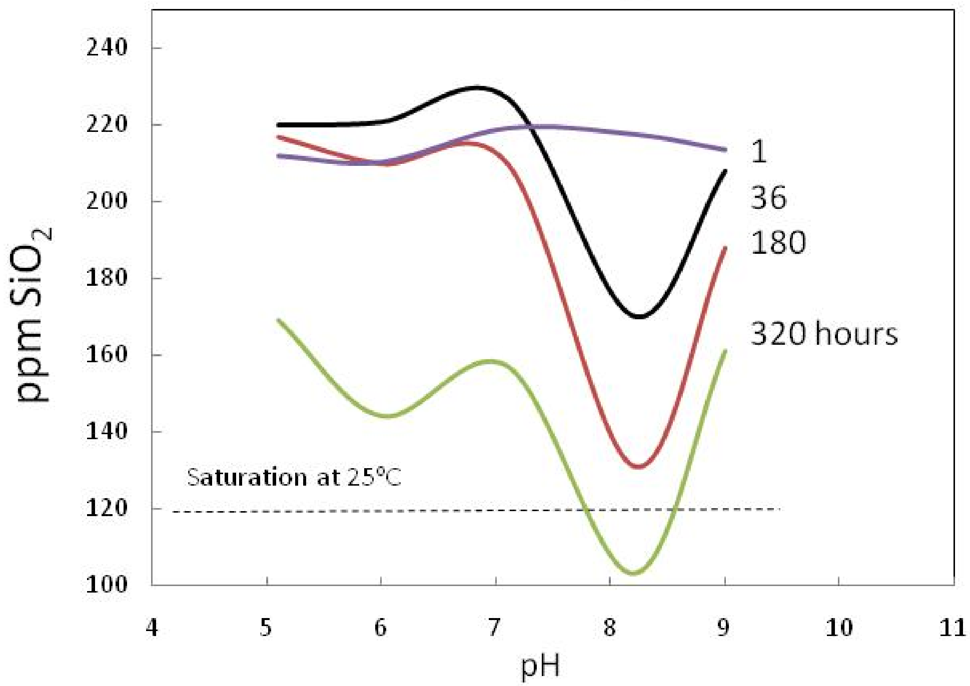
Solid forming reactions (→ Monomer Deposition, Coagulation, Metal:Silicate Formation)

	Silica Control Method	Targeted Chemical Process: Monomer Deposition	Polymerization	Coagulation	Metal:Silicate Formation
keep silica dissolved	Ion exchange			decreases	decreases
	+ Acid		decreases	decreases	decreases
	+ Anti-scalant	decreases?	decreases?	decreases	decreases
	Mixing	decreases	decreases	decreases	
	Magnets		decreases?		
make silicate solids	+ Seeds	increases			can increase
	+ Coagulant			increases	can increase
	WLS	decreases	decreases	increases	increases
	Ageing	decreases	increases	increases	

Silica Control: Pat Brady, Jim Krumhansl, and Charles Bryan

1. pH Control of Polymerization





Biomimetic Membranes: Susan Rempe, Shaorong Yang (UNM), Ying-bing Jiang (UNM), David Rogers, Kevin Leung, and Jeff Brinker.

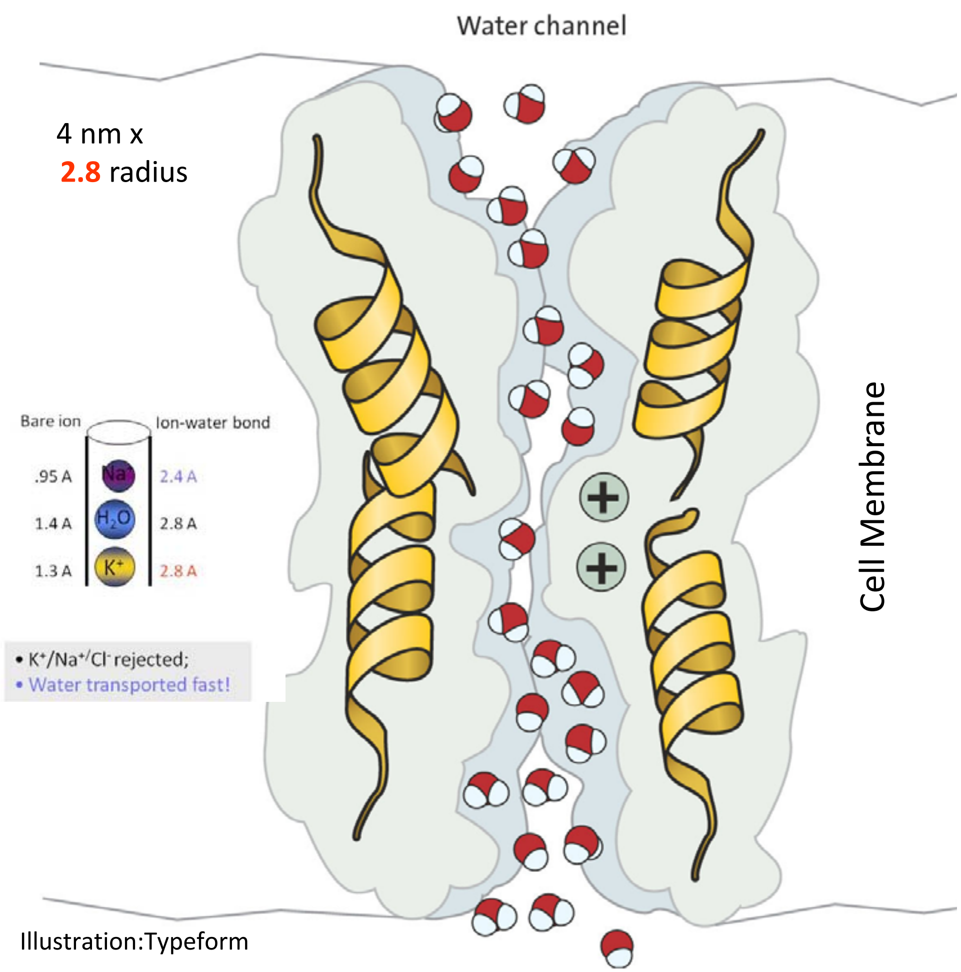
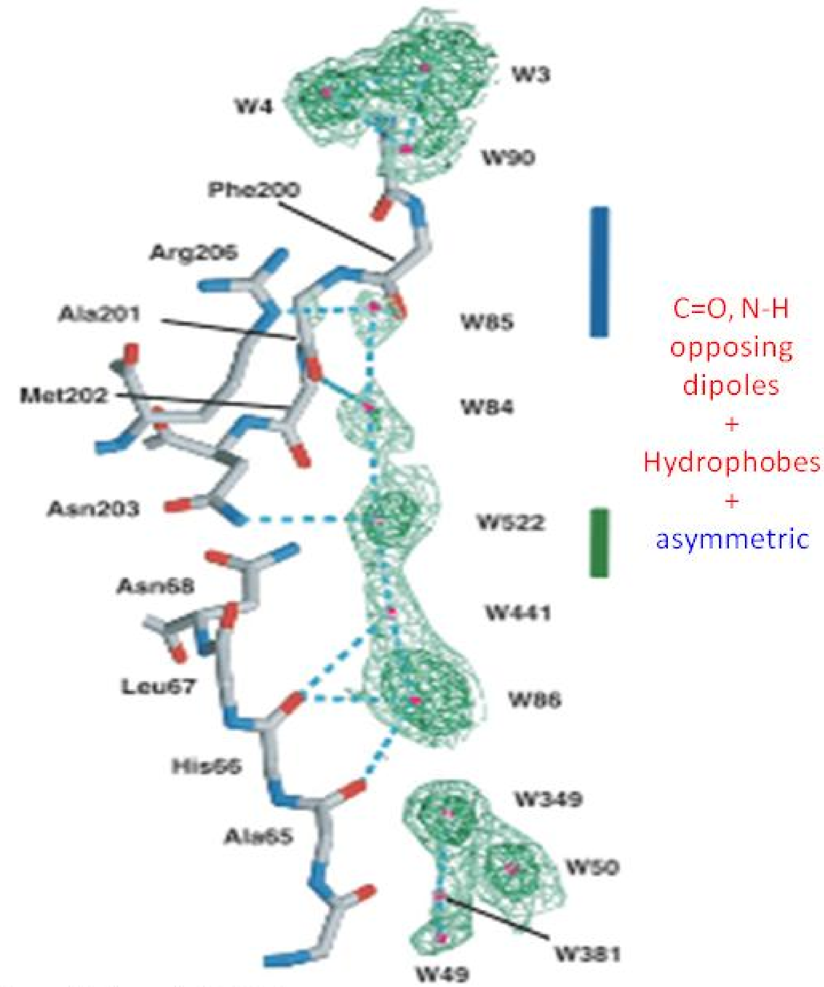


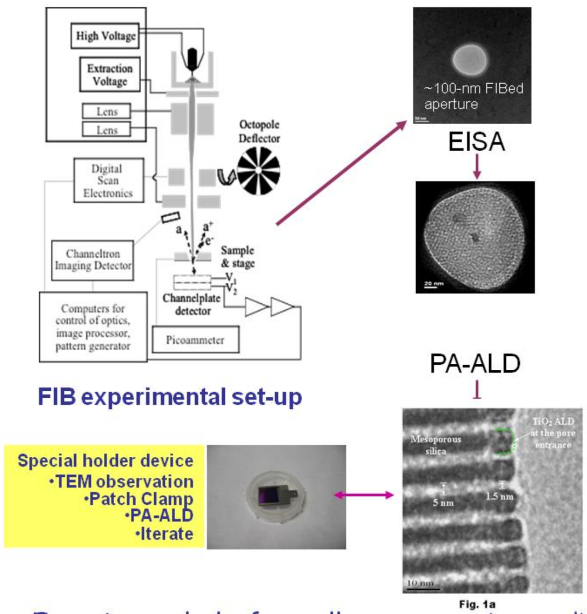
Illustration:Typeform

Aquaporin molecule
(www.nobelprize.org)

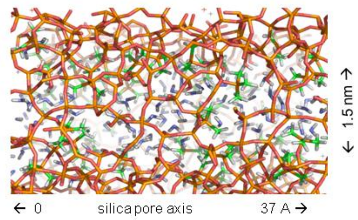


Tajkhorshid et. al. (2002).

New Platforms for Experiments & Modeling

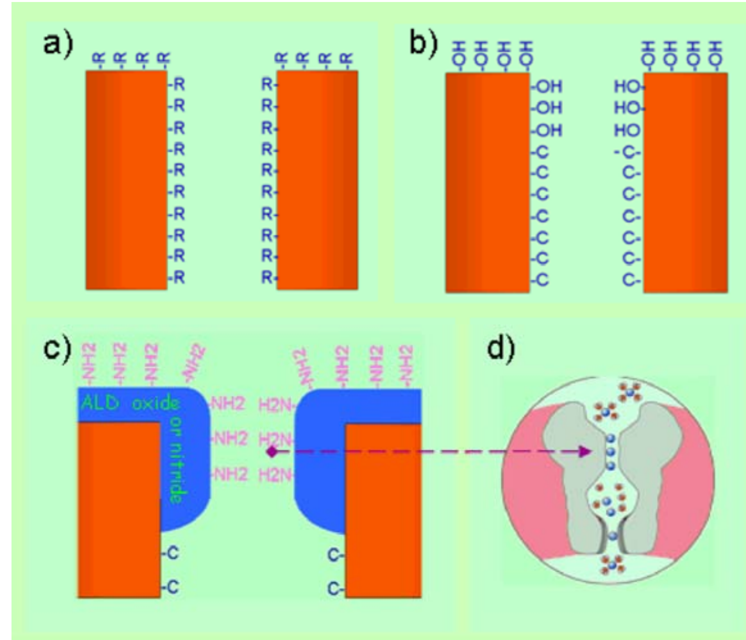


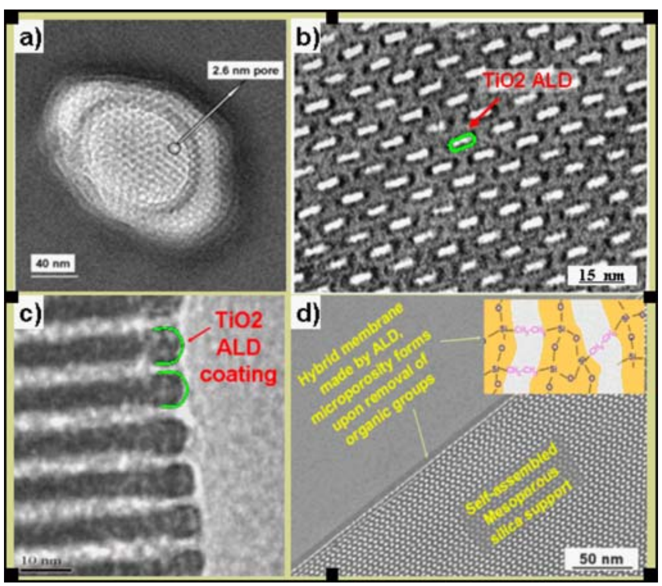
• Multiscale modeling essential to understand combined effects of pore size, structure, chemistry and charge.

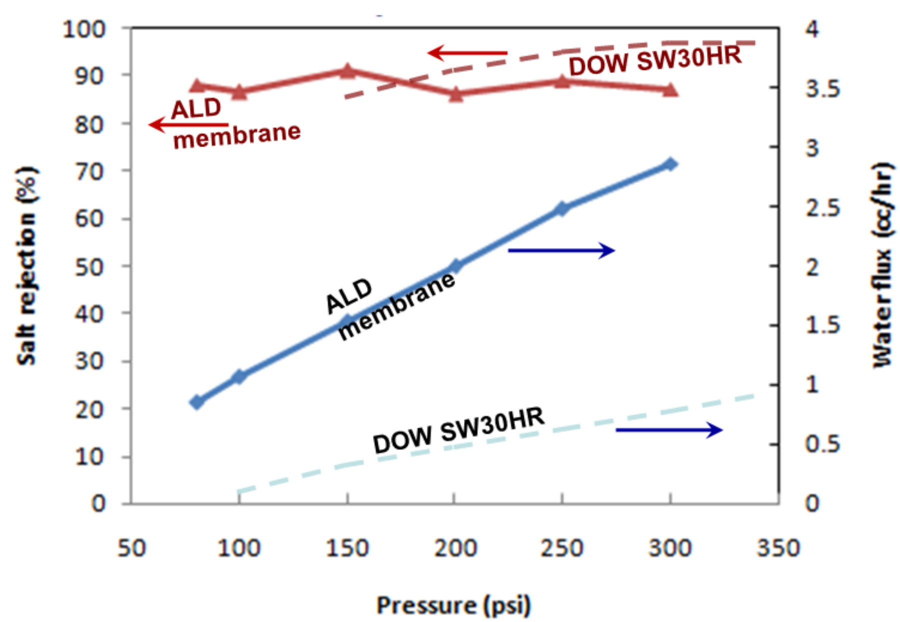


• Classical (large, long times)
• Quantum (accuracy)
  • Thermodynamics (work)
  • Dynamics (transport)

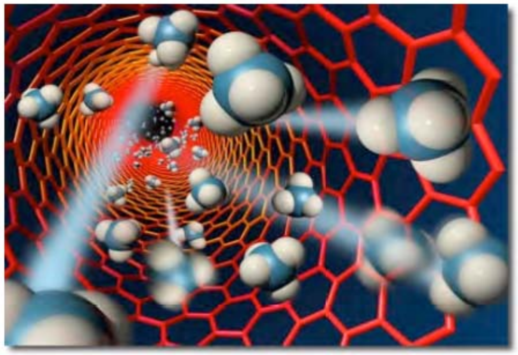
• Experimental platform allows successive modification (pore size, and surface chemistry), imaging and transport measurements on identical sample.



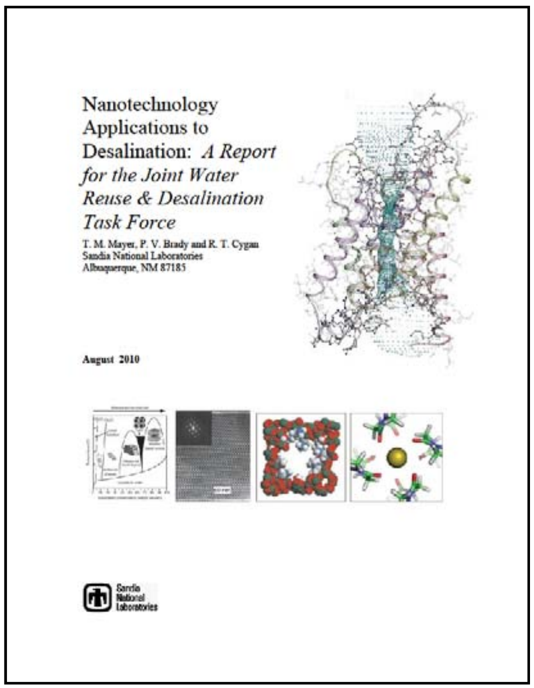




Nanotechnology Applications to Desalination: Tom Mayer, Pat Brady, Randy Cygan.



Schematic of methane moving through carbon nanotubes. Similar carbon nanotubes might be used for desalination (http://www.llnl.gov/PAO/news/news_releases/2006/images/membrane86x86s.jpg;Scott Dougherty, Lawrence Livermore National Laboratory).



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Sandia National Laboratories

- 2001 - Passive Nanostructures
- 2005 - Active Nanostructures
- 2010 - Nanosystems
- 2015 – Heterogeneous molecular nanosystems

(After Roco, 2004)