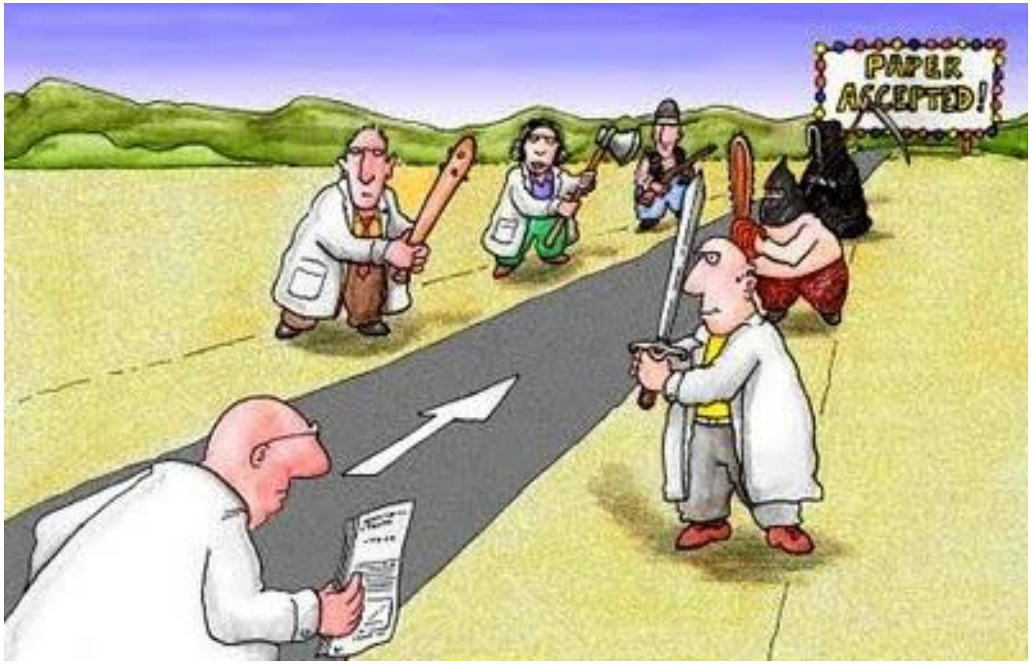
Practical Tips for Writing Effective Papers

Menachem Elimelech
Department of Chemical and Environmental Engineering
Yale University
New Haven, Connecticut

Presented first at: NSF CAREER Workshop, Association of Environmental Engineering & Science Professors (AEESP) Conference, June 14, 2015, Yale University, New Haven, CT.

Updated: April 2017.

Yale



© fran@francartoons.com

http://oncirculation.com/2013/05/22/write-that-journal-article-in-7-days/

Highly Recommended to Read

ADVANCED MATERIALS

Whitesides' Group: Writing a Paper**

By *George M. Whitesides**

Adv. Mater. **2004**, *16*, No. 15, August 4

DOI: 10.1002/adma.200400767

G.M. Whitesides, Harvard University, is one the world most cited chemists and author of over 1,000 journal publications

Tips from Whiteside….**Outline**!

A paper is an organized description of hypotheses, data and conclusions, intended to instruct the reader. Papers are a central part of research. If your research does not generate papers, it might just as well not have been done. "Interesting and unpublished" is equivalent to "non-existent".

A paper is not just an archival device for storing a completed research program; it is also a structure for *planning* your research in progress. If you clearly understand the purpose and form of a paper, it can be immensely useful to you in *organizing* and conducting your research. A good outline for the paper is also a good plan for the research program. You should write and rewrite these plans/outlines throughout the course of the research.

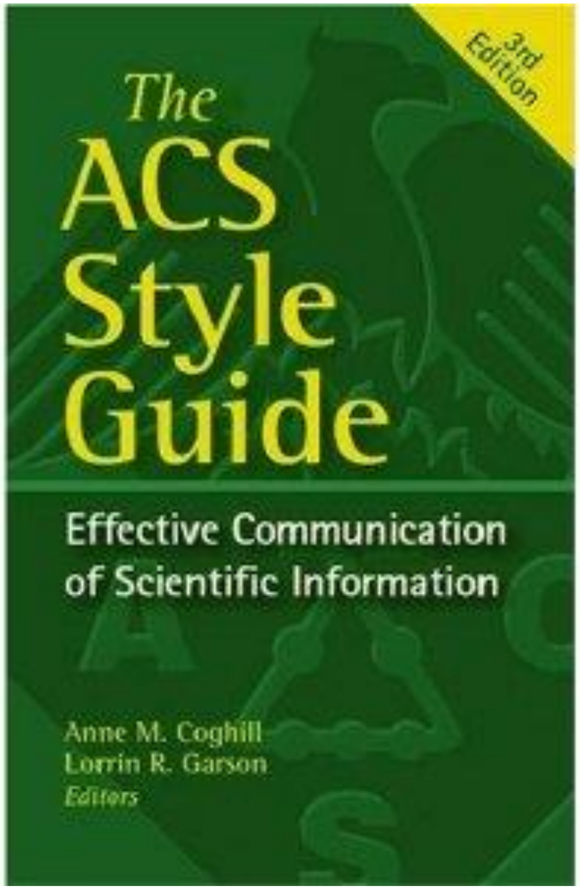
I emphasize the central place of an outline in writing papers, preparing seminars, and planning research. I especially believe that for you, and for me, it is most *efficient* to write papers from outlines. An *outline* is a written plan of the organization of a paper, *including* the data on which it rests. You should, in fact, think of an outline as a carefully organized and presented set of data, with attendant objectives, hypotheses, and conclusions, rather than an outline of text.

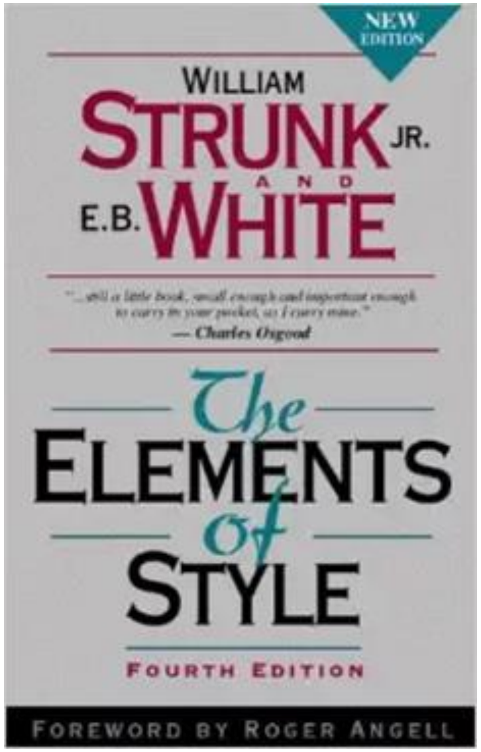
All writing that I do—papers, reports, proposals (and, of course, slides for seminars)—I do from outlines. I urge you to learn how to use them as well.

Yale

Recommended Book for Effective Writing

Series: American Chemical Society Publication Series
ISBN-13: 9780841239999. 2006





The Elements of Style, Fourth Edition,1999
by William Strunk Jr. and E. B. White

Yale

More Recommended Readings

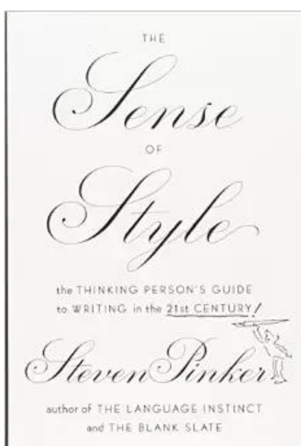
- The Chronicle of Higher Education: Why Academics Stink at Writing

  http://chronicle.com/article/Why-Academics-Writing-Stinks/148989/

- Bad Writing Contest

  http://denisdutton.com/bad_writing.htm/

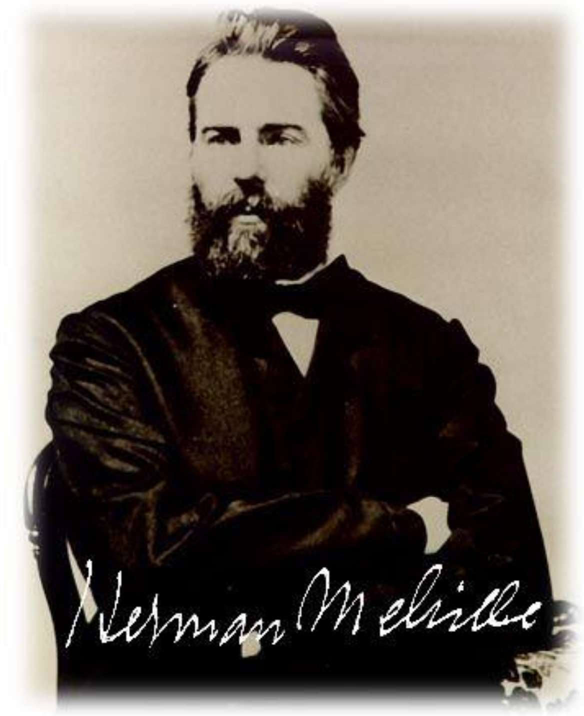
- The Sense of Style: The Thinking Person's Guide to Writing in the 21st Century, by Steven Pinker, 2014

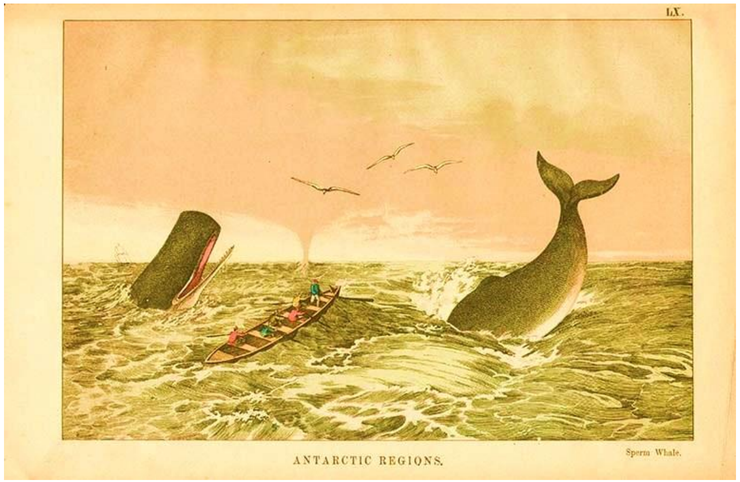


Yale

General Steps

- "*To produce a mighty book, you must choose a mighty theme*" (Herman Melville).
  - Topic is important — new, hot topics are easier to publish, but strive for rigor and relevance (R^2)
- *No great and enduring volume can ever be written on the flea*... (Herman Melville).
  - Good writing takes tremendous efforts





Yale

General Steps

- Decide about a suitable journal and rough title of the paper
- Likely journals in our environmental engineering/scienvce field are *ES&T, ES&T Letters,* and other specialized journals; can aim higher – *Science, Nature, PNAS*....
- Criteria for journal: Right audience; high impact factor (not an obscure journal, like JW Gibbs)

- Start drafting the outline of the paper as you continue to collect data; it will help you to better plan the experiments

Outline as a Planning Tool

- Think about what data you plan to collect and how to present the data most effectively (insightful figures, detailed tables, etc.)
- Sketch the future figures (can be done even by hand) with the expected data; this will help you to design the experiments
- Get ideas about figures and style from good published papers that you read (of well respected and impactful authors that you appreciate)

General: Paper Structure for Drafting the Outline

- Papers usually have the following sections:
  - Abstract
  - Introduction
  - Theory or Modeling (for papers with modeling, if model is new)
  - Materials and Methods
  - Results and Discussion (some split to “Results” and “Discussion” as separate sections)
  - Conclusion (ES&T doesn’t have this section)
- Plan on ~4-8 figures and a few tables (if any) presenting important data
- Most journals have online **Supporting Information** for other data (usually less important or “boring” data)

Yale

Outline — General

- Decide about the journal and adopt its style for sections, subsections, etc.
- Most journals allow sections and subsections. Some (like Elsevier journals) allow sub-subsections (e.g., 2.xx, 2.1.xx, 2.1.1.xx)
- Think about a logical way to present the data so you can tell the “story” of your research in a way that is easy to follow and understand
- It is like a flowchart for a computer code — ideas should flow logically and in the right order
- *Creative* research, but *effective* writing — *Story* NOT a *mystery*

The Outline

- Have the headings (titles) of sections and subsections (and sub-subsections) in order
- Indicate what figures, tables, and equations will be included in each of the sections or subsections
- Provide final form of figures (if you have data) and sketch of what you hope will be the data while you are still collecting data or planning experiments
- Provide equations and *detailed* figure and table captions

Outline: Start with Title Page

Ultrafiltration Membranes Incorporating Amphiphilic Comb Copolymer Additives Prevent Irreversible Adhesion of Bacteria

In preparation for

Environmental Science & Technology

2009….

ATAR ADOUT[a], SEOKTAE KANG[a], AYSE ASATEKIN[b], ANNE M. MAYES[c], MENACHEM ELIMELECH[a*]

[a] *Department of Chemical Engineering, Environmental Engineering Program, Yale University, New Haven, CT 06520-8286.*
[b] *Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139.*
[c] *Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139.*

* Corresponding author: Menachem Elimelech, Email: menachem.elimelech@yale.edu, Phone: (203) 432-2789.

Yale

Outline: Rest of the Paper

Abstract

Introduction

Materials and Methods

Ultrafiltration Membrane

Membrane Characterization

Model Bacteria

Static Bacterial Adhesion and Reversibility Tests

Direct Microscopic Observation of Bacterial Deposition and Reversibility

FIGURE S1

Interaction Force Measurements

Results and Discussion

Bacterial Properties

FIGURE 1

Bacterial Adhesion and Reversibility

FIGURE 2

Bacterial Deposition Rate and Reversibility in Crossflow Filtration

FIGURE 3

Why Bacterial Adhesion to the PAN-g-PEO Membrane is Negligible?

FIGURE 4

FIGURE S2

FIGURE 5

Acknowledgement

Literature Cited

Yale

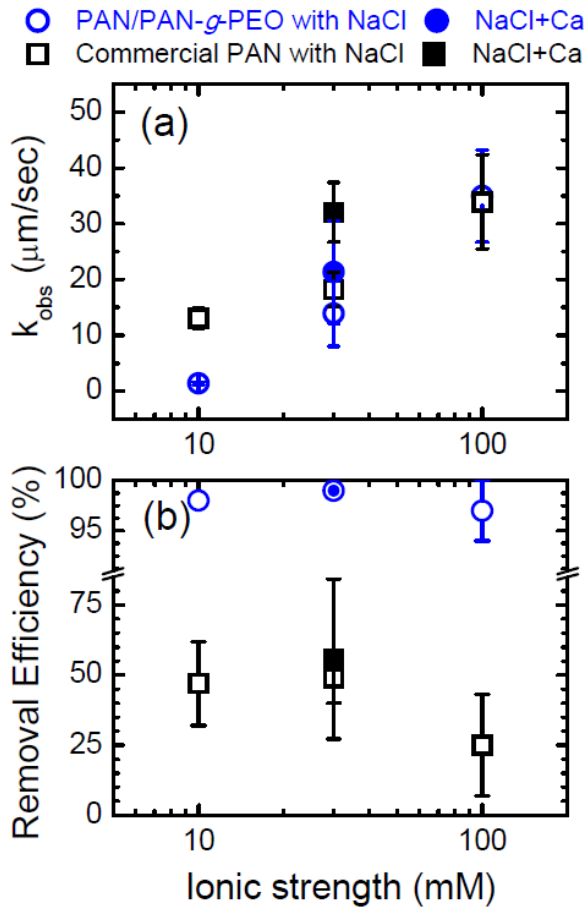


Figure 3: (a) Observed cell deposition rate of *E. coli* during 30 min of crossflow filtration. Deposition experiments were done at a crossflow velocity of 10 cm/s, permeation velocity of 30 μm/s, and cell concentration of ~1.3×10^5 cells/mL at a constant pressure of 150 kPa. (b) Percent removal of *E. coli* cells from the membrane after 10 minutes of rinsing with the same solution at 150 cm/s cross flow velocity and with no permeate flow at 150 kPa.

Yale

Outline: Include the Last Paragraph of the Introduction

ABSTRACT

INTRODUCTION

In this study, we fabricate an omniphobic membrane for MD by coating a hydrophilic glass fiber membrane with silica nanoparticles, followed by subsequent surface fluorination and polymer coating. The fabricated omniphobic membrane is then compared to a hydrophobic commercial PTFE membrane for their anti-wetting property against liquids of a wide range of surface tensions. Direct contact membrane distillation (DCMD) experiments are also conducted using both the omniphobic and PTFE membranes to compare their anti-wetting performance in the presence of a commonly used surfactant, sodium dodecyl sulfate (SDS).

MATERIALS AND METHODS

Modification of Glass Fiber Membrane.

Membrane Characterization.

Membrane Performance Testing.

RESULTS AND DISCUSSION

Morphology and Wetting Properties of the Omniphobic Membrane.

FIGURE 1

FIGURE 2

Membrane Performance in DCMD.

FIGURE 3

Implications.

ASSOCIATED CONTENT

ACKNOWLEDGEMENTS

REFERENCES

Yale

Supplementary Information

Ultrafiltration Membranes Incorporating Amphiphilic Comb Copolymer Additives Prevent Irreversible Adhesion of Bacteria

ATAR ADOUT[a], SEOKTAE KANG[a], AYSE ASATEKIN[b], ANNE M. MAYES[c], MENACHEM ELIMELECH[a*]

[a] *Department of Chemical Engineering, Environmental Engineering Program, Yale University, New Haven, CT 06520-8286.*
[b] *Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139.*
[c] *Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139.*

Yale

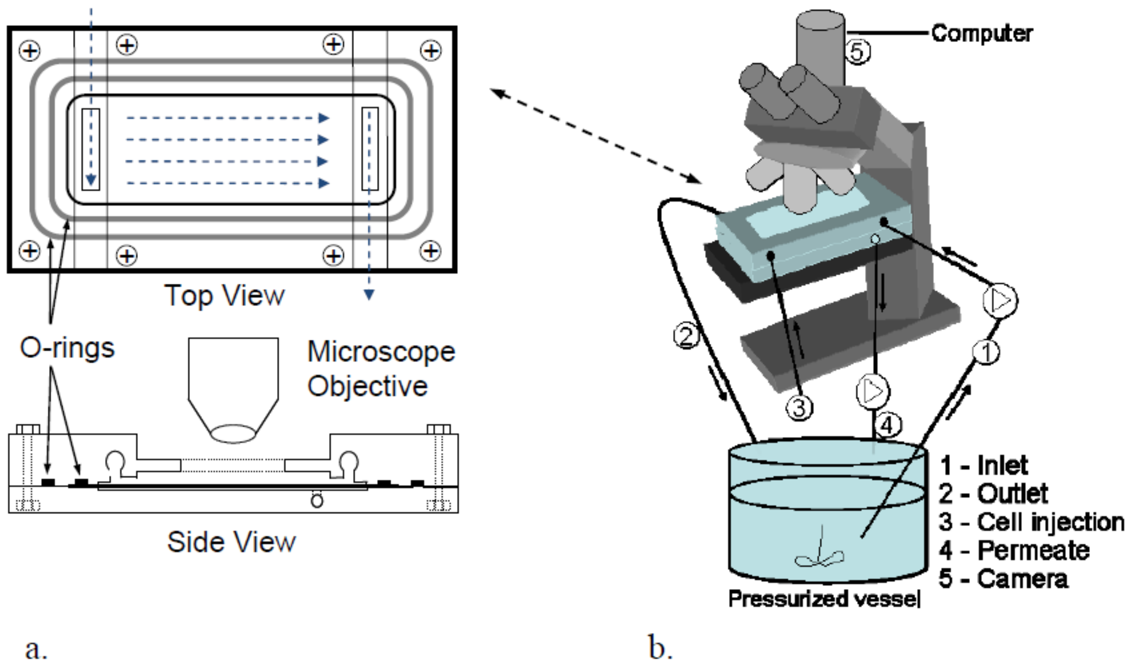


Figure S1: Schematic diagrams of (a) flow cell and (b) close loop direct microscopic observation crossflow membrane filtration system.

Title

- Attractive titles, but not too “commercial”, “PR” style
- Should reflect the contents of the paper
- Concise but still informative
- Avoid jargon, symbols, commercial names
- Avoid papers with titles followed by “Part 1: xxx” (with future papers having “Part 2: yy” etc.)

Example of "Good" Titles

Correlation Equation for Predicting Single-Collector Efficiency in Physicochemical Filtration in Saturated Porous Media

NATHALIE TUFENKJI AND MENACHEM ELIMELECH*
Department of Chemical Engineering, Environmental Engineering Program, P.O. Box 208286, Yale University, New Haven, Connecticut 06520-8286

Aggregation Kinetics of Multiwalled Carbon Nanotubes in Aquatic Systems: Measurements and Environmental Implications

NAVID B. SALEH, LISA D. PFEFFERLE, AND MENACHEM ELIMELECH*
Department of Chemical Engineering, Yale University, New Haven, Connecticut 06520-8286

Antibacterial Effects of Carbon Nanotubes: Size Does Matter!

Seoktae Kang, Moshe Herzberg,[†] Debora F. Rodrigues, and Menachem Elimelech*
Department of Chemical Engineering, Yale University, P.O. Box 208286, New Haven, Connecticut 06520-8286

Received March 26, 2008. Revised Manuscript Received May 6, 2008

Example of “Good” Titles

Energy & Environmental Science

ROYAL SOCIETY OF CHEMISTRY

REVIEW

View Article Online
View Journal | View Issue

CrossMark
click for updates

Cite this: *Energy Environ. Sci.*, 2016, **9**, 31

Pressure-retarded osmosis for power generation from salinity gradients: is it viable?

Anthony P. Straub, Akshay Deshmukh and Menachem Elimelech*

Environmental Science & Technology LETTERS

Review

pubs.acs.org/journal/estlcu

The Critical Need for Increased Selectivity, Not Increased Water Permeability, for Desalination Membranes

Jay R. Werber,[†] Akshay Deshmukh,[†] and Menachem Elimelech*[,†,‡]

[†]Department of Chemical and Environmental Engineering, Yale University, New Haven, Connecticut 06520-8286, United States
[‡]Nanosystems Engineering Research Center for Nanotechnology-Enabled Water Treatment (NEWT), Yale University, New Haven, Connecticut 06520-8286, United States

Yale

Example of Not So Good Titles (Yes…my papers ☹)

Journal of Colloid and Interface Science **229,** 554–567 (2000)
doi:10.1006/jcis.2000.7062, available online at http://www.idealibrary.com on IDEAL®

Coupled Influence of Colloidal and Hydrodynamic Interactions on the RSA Dynamic Blocking Function for Particle Deposition onto Packed Spherical Collectors

Chun-Han Ko, Subir Bhattacharjee, and Menachem Elimelech[1]

Department of Chemical Engineering, P.O. Box 208286, Yale University, New Haven, Connecticut 06520-8286

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Journal of Membrane Science 296 (2007) 42–50

journal of MEMBRANE SCIENCE

www.elsevier.com/locate/memsci

Protein antifouling mechanisms of PAN UF membranes incorporating PAN-*g*-PEO additive

Seoktae Kang[a], Ayse Asatekin[b], Anne M. Mayes[c], Menachem Elimelech[a,*]

Example of Not So Good Titles

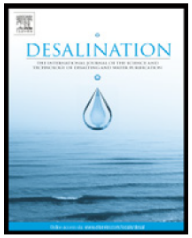
Desalination 350 (2014) 61–68

ELSEVIER

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal



Using indigenous microalga species to reduce HCO_3^-, NH_3N, NO_3N, total P, Ca^{2+}, SO_4^{2-}, and Cl^- from a high conductivity concentrate

CrossMark

Yale

Abstract

- Concise, yet informative (some journals have word count limit)
- Length – about 0.5 to 0.75 page (single space)
- Unless it is a new area of research, no need for general/overview opening sentences
- Not too general and vague
- Some specific/quantitative details (but not too much)
- Avoid acronyms, equations, references
- Avoid heavy jargon
- Think about some busy researchers who read only the abstract…..

Abstract (Paper)

A new equation for predicting the single-collector contact efficiency (η_0) in physicochemical particle filtration in saturated porous media is presented. The correlation equation is developed assuming that the overall single-collector efficiency can be calculated as the sum of the contributions of the individual transport mechanisms—Brownian diffusion, interception, and gravitational sedimentation. To obtain the correlation equation, the dimensionless parameters governing particle deposition are regressed against the theoretical value of the single-collector efficiency over a broad range of parameter values. Rigorous numerical solution of the convective—diffusion equation with hydrodynamic interactions and universal van der Waals attractive forces fully incorporated provided the theoretical single-collector efficiencies. The resulting equation overcomes the limitations of current approaches and shows remarkable agreement with exact theoretical predictions of the single-collector efficiency over a wide range of conditions commonly encountered in natural and engineered aquatic systems. Furthermore, experimental data are in much closer agreement with predictions based on the new correlation equation compared to other available expressions.

Correlation Equation for Predicting Single-Collector Efficiency in Physicochemical Filtration in Saturated Porous Media

NATHALIE TUFENKJI AND MENACHEM ELIMELECH*

Department of Chemical Engineering, Environmental Engineering Program, P.O. Box 208286, Yale University, New Haven, Connecticut 06520-8286

Environ. Sci. Technol. **2004**, *38*, 529−536

Yale

Abstract (Paper

nature energy

ARTICLES

PUBLISHED: 27 JUNE 2016 | ARTICLE NUMBER: 16090 | DOI: 10.1038/NENERGY.2016.90

Harvesting low-grade heat energy using thermo-osmotic vapour transport through nanoporous membranes

Anthony P. Straub[1], Ngai Yin Yip[2], Shihong Lin[3], Jongho Lee[1] and Menachem Elimelech[1*]

Low-grade heat from sources below 100 °C offers a vast quantity of energy. The ability to extract this energy, however, is limited with existing technologies as they are not well-suited to harvest energy from sources with variable heat output or with a small temperature difference between the source and the environment. Here, we present a process for extracting energy from low-grade heat sources utilizing hydrophobic, nanoporous membranes that trap air within their pores when submerged in a liquid. By driving a thermo-osmotic vapour flux across the membrane from a hot reservoir to a pressurized cold reservoir, heat energy can be converted to mechanical work. We demonstrate operation of air-trapping membranes under hydraulic pressures up to 13 bar, show that power densities as high as $3.53 \pm 0.29\ \mathrm{W\ m^{-2}}$ are achievable with a 60 °C heat source and a 20 °C heat sink, and estimate the efficiency of a full-scale system. The results demonstrate a promising process to harvest energy from low-temperature differences (<40 °C) and fluctuating heat sources.

Yale

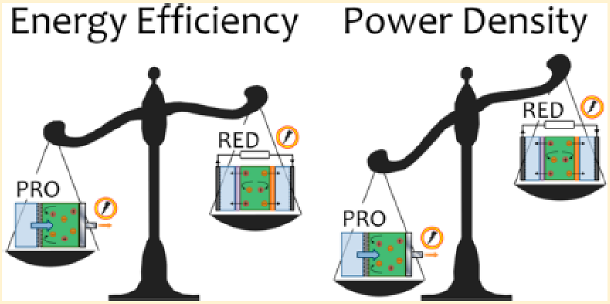
Abstract (Paper): Use Effective TOC Art (Graphic Abstract)

Comparison of Energy Efficiency and Power Density in Pressure Retarded Osmosis and Reverse Electrodialysis

Ngai Yin Yip and Menachem Elimelech*

Department of Chemical and Environmental Engineering, Yale University, New Haven, Connecticut 06520-8286, United States

Supporting Information



ABSTRACT: Pressure retarded osmosis (PRO) and reverse electrodialysis (RED) are emerging membrane-based technologies that can convert chemical energy in salinity gradients to useful work. The two processes have intrinsically different working principles: controlled mixing in PRO is achieved by water permeation across salt-rejecting membranes, whereas RED is driven by ion flux across charged membranes. This study compares the energy efficiency and power density performance of PRO and RED with simulated technologically available membranes for natural, anthropogenic, and engineered salinity gradients (seawater−river water, desalination brine−wastewater, and synthetic hypersaline solutions, respectively). The analysis shows that PRO can achieve both greater efficiencies (54−56%) and higher power densities (2.4−38 W/m^2) than RED (18−38% and 0.77−1.2 W/m^2). The superior efficiency is attributed to the ability of PRO membranes to more effectively utilize the salinity difference to drive water permeation and better suppress the detrimental leakage of salts. On the other hand, the low conductivity of currently available ion exchange membranes impedes RED ion flux and, thus, constrains the power density. Both technologies exhibit a trade-off between efficiency and power density: employing more permeable but less selective membranes can enhance the power density, but undesired entropy production due to uncontrolled mixing increases and some efficiency is sacrificed. When the concentration difference is increased (i.e., natural → anthropogenic → engineered salinity gradients), PRO osmotic pressure difference rises proportionally but not so for RED Nernst potential, which has logarithmic dependence on the solution concentration. Because of this inherently different characteristic, RED is unable to take advantage of larger salinity gradients, whereas PRO power density is considerably enhanced. Additionally, high solution concentrations suppress the Donnan exclusion effect of the charged RED membranes, severely reducing the permselectivity and diminishing the energy conversion efficiency. This study indicates that PRO is more suitable to extract energy from a range of salinity gradients, while significant advancements in ion exchange membranes are likely necessary for RED to be competitive with PRO.

Abstract (Letter, Feature/Perspective Article) –Shorter than Paper

Antibacterial Effects of Carbon Nanotubes: Size Does Matter!

Seoktae Kang, Moshe Herzberg,[†] Debora F. Rodrigues, and Menachem Elimelech*

Department of Chemical Engineering, Yale University, P.O. Box 208286, New Haven, Connecticut 06520-8286

Received March 26, 2008. Revised Manuscript Received May 6, 2008

We provide the first evidence that the size (diameter) of carbon nanotubes (CNTs) is a key factor governing their antibacterial effects and that the likely main CNT-cytotoxicity mechanism is cell membrane damage by direct contact with CNTs. Experiments with well-characterized single-walled carbon nanotubes (SWNTs) and multiwalled carbon nanotubes (MWNTs) demonstrate that SWNTs are much more toxic to bacteria than MWNTs. Gene expression data show that in the presence of both MWNTs and SWNTs, *Escherichia coli* expresses high levels of stress-related gene products, with the quantity and magnitude of expression being much higher in the presence of SWNTs.

The unique and tunable properties of carbon-based nanomaterials enable new technologies for identifying and addressing environmental challenges. This review critically assesses the contributions of carbon-based nanomaterials to a broad range of environmental applications: sorbents, high-flux membranes, depth filters, antimicrobial agents, environmental sensors, renewable energy technologies, and pollution prevention strategies. In linking technological advance back to the physical, chemical, and electronic properties of carbonaceous nanomaterials, this article also outlines future opportunities for nanomaterial application in environmental systems.

Critical Review

Environmental Applications of Carbon-Based Nanomaterials

MEAGAN S. MAUTER AND MENACHEM ELIMELECH*

Abstract (Letter, Feature/Perspective Article) –Shorter than Paper

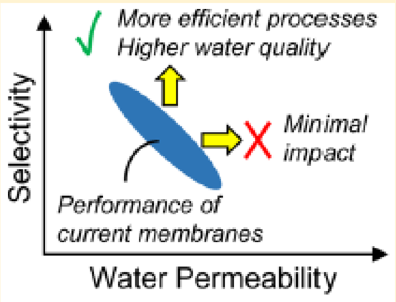
The Critical Need for Increased Selectivity, Not Increased Water Permeability, for Desalination Membranes

Jay R. Werber,[†] Akshay Deshmukh,[†] and Menachem Elimelech*[,†,‡]

[†]Department of Chemical and Environmental Engineering, Yale University, New Haven, Connecticut 06520-8286, United States
[‡]Nanosystems Engineering Research Center for Nanotechnology-Enabled Water Treatment (NEWT), Yale University, New Haven, Connecticut 06520-8286, United States

Supporting Information

ABSTRACT: Desalination membranes are essential for the treatment of unconventional water sources, such as seawater and wastewater, to alleviate water scarcity. Promising research efforts on novel membrane materials may yield significant performance gains over state-of-the-art thin-film composite (TFC) membranes, which are constrained by the permeability−selectivity trade-off. However, little guidance currently exists on the practical impact of such performance gains, namely enhanced water permeability or enhanced water−solute selectivity. In this critical review, we first discuss the performance of current TFC membranes. We then highlight and provide context for recent module-scale modeling studies that have found limited impact of increased water permeability on the efficiency of desalination processes. Next we cover several important examples of water treatment processes in which inadequate membrane selectivity hinders process efficacy. We conclude with a brief discussion of how the need for enhanced selectivity may influence the design strategies of future membranes.



Yale

Introduction

- At least 3-4 paragraphs (short paragraphs, each ~ 1/3 page or less, but no less than 3 sentences)
- First paragraph – overview about the general, broad importance
- Second paragraph (optional) – more overview about the specific focus of your paper
- Middle paragraphs – critical review of past work
- One before last – why your work is new and how it will add to the body of knowledge
- Last paragraph – state the objectives and scope of the paper, with possibly a general finding and/or importance

Last Paragraph of Introduction

- State the objective(s) and scope of the paper — Don’t repeat the abstract!
- Avoid specific details on the experiments and detailed results
- After stating the objective, highlight in general terms what you have done and the general/broad findings

General Tips for Writing the Main Body of Paper

- Use short paragraphs (typically ~ 3-6 sentences)
- Minimize the use of long sentences
- Simple is better!
- Elegant and eloquent, but not Shakespearean
- Avoid redundancy
- Can use “we”, “our”; NOT “I”, “my”
- When you are not sure about style (e.g., equations), look at previously published papers in that journal

Yale

Conclusion Section

- “Conclusion” or “Concluding Remarks” — not “Conclusions”
- Do not repeat the abstract
- Summarize the key findings
- Indicate the broader impact
- Avoid references and equations
- ES&T and some other journals do not have a Conclusion section
- For ES&T can use “Implications”

Figures

- Thoughtful presentation of data
- Avoid simple figures with only one data set
- Use multiple graphs if possible
- Large fonts and symbols
- Clear and easy to read legends
- Units for y and x axes; e.g. “Residence Time (min)”
- Capitalize first letter of each word in title (US style)
- Moderately thick lines
- Provide very detailed figure captions with all necessary experimental conditions
- Use colors when needed (dark colors): black, blue, red, green, etc.

Examples of Good Figures

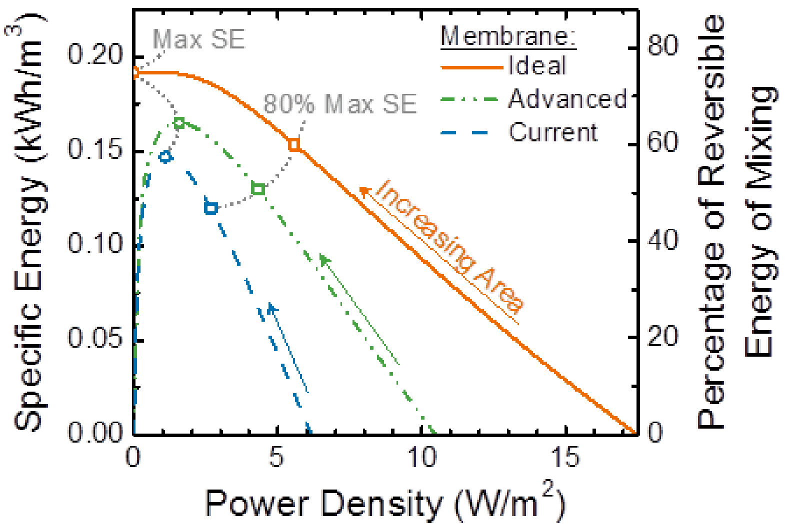


Figure 5. Specific energy vs power density for three different types of counter-current modules: an ideal module with no reverse salt flux or concentration polarization (solid red line), a module using advanced membranes (dashed and dotted green line), and a module using currently available commercial membranes (dashed blue line). The ideal membrane has a water permeability coefficient, A, of 3 L m^{-2} h^{-1} bar^{-1} and $B = 0$. For the advanced membrane, $A = 3$ L m^{-2} h^{-1} bar^{-1}, $B = 0.36$ L m^{-2} h^{-1} (determined from the permeability-selectivity trade-off, eq 5), and S = 100 μm. The commercial membrane properties are representative of a thin-film composite membrane from Hydration Technology Innovations ($A = 2.49$ L m^{-2} h^{-1} bar^{-1}, $B = 0.39$ L m^{-2} h^{-1}, and $S = 564$ μm). In both cases with concentration polarization, a mass transfer coefficient of $k = 138.6$ L m^{-2} h^{-1} is used. The feed solution is river water (0.015 M NaCl) and the draw solution is seawater (0.6 M NaCl). Curves are obtained by increasing the membrane area with fixed operating conditions of $\phi = 0.5$ and $\Delta P = 14.5$ bar. For each membrane, the maximum specific energy (hollow circle) and 80% of the maximum specific energy (hollow square) are indicated. The coupon-scale power density for each membrane occurs at the horizontal axis (power density) intercept.

Examples of Good Figures

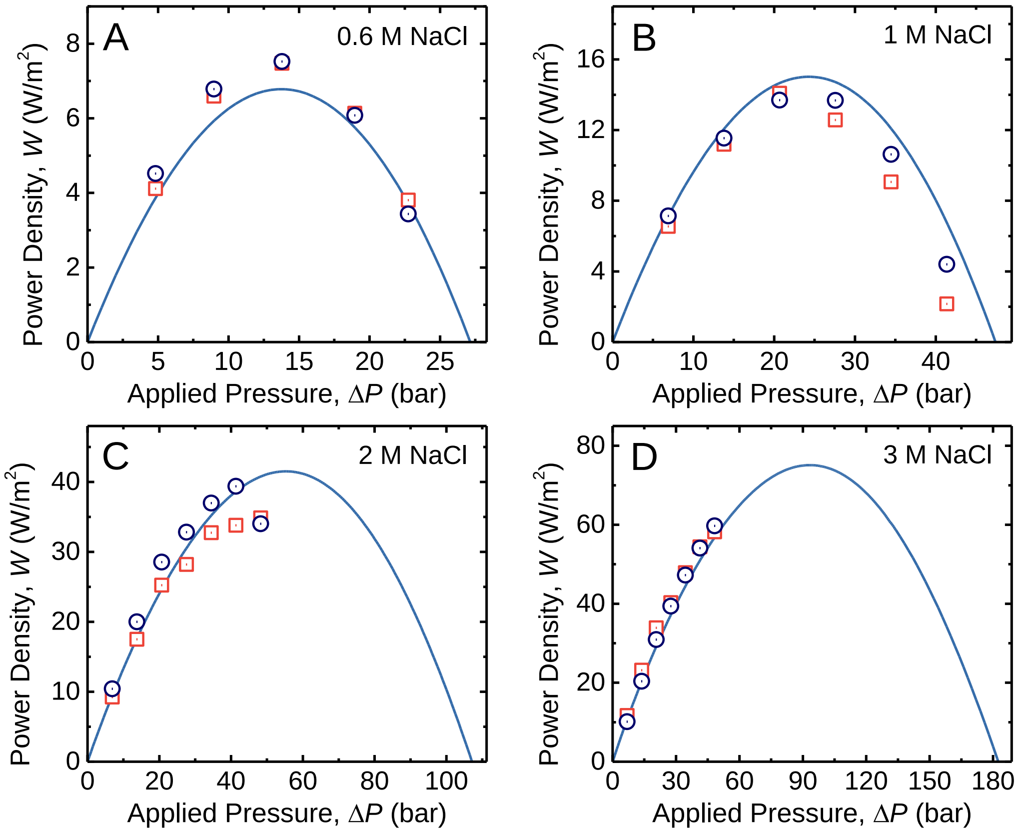
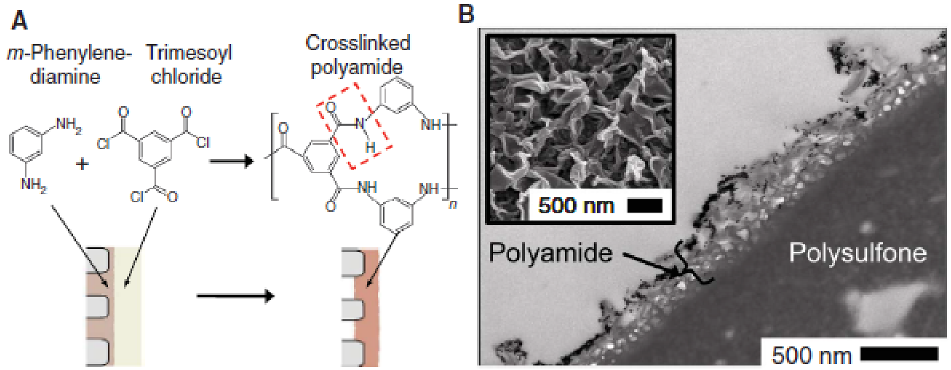


Figure 3. Experimental and modeled projected power densities as a function of applied hydraulic pressure difference, ΔP. Draw (NaCl) solution concentrations of (A) 0.6, (B) 1, (C) 2, and (D) 3 M were used with osmotic pressures of 28.3, 49.4, 111.2, and 188.8 bar, respectively (calculated using OLI software). Modeled power densities (light blue lines) were determined using parameters from an RO and FO characterization. Experimental power densities were determined in duplicate using eq 1 (blue circles and red squares). All experiments were performed with feed (DI water) and draw solutions at 25 ± 0.5 °C.

Examples of Good Figures



C

Surface property	TFC membrane
Contact angle	50 – 60°
Surface charge	Negative
-COO⁻/nm²	20 – 30
RMS roughness	100 – 200 nm

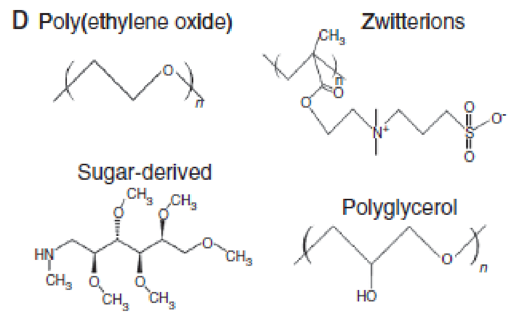
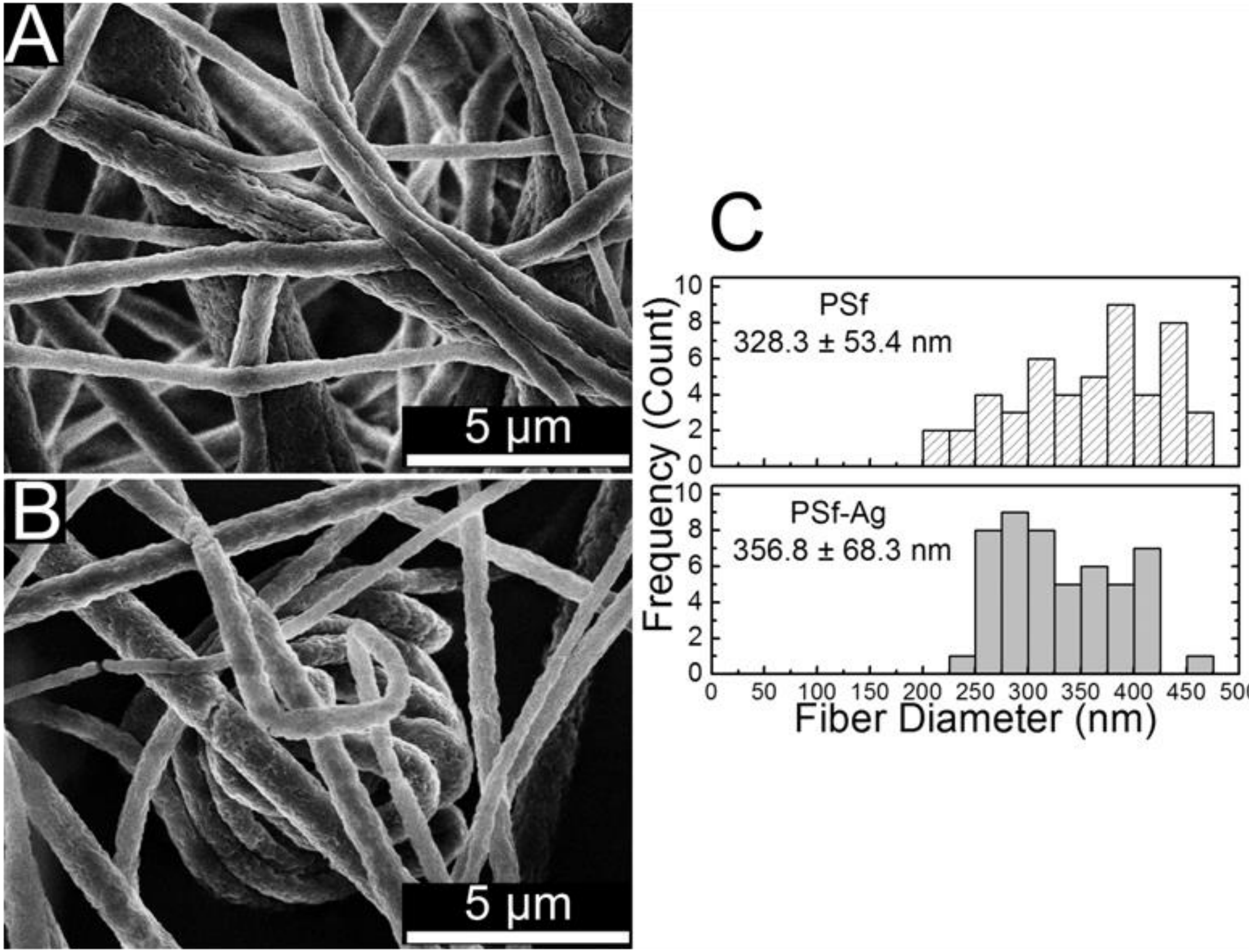


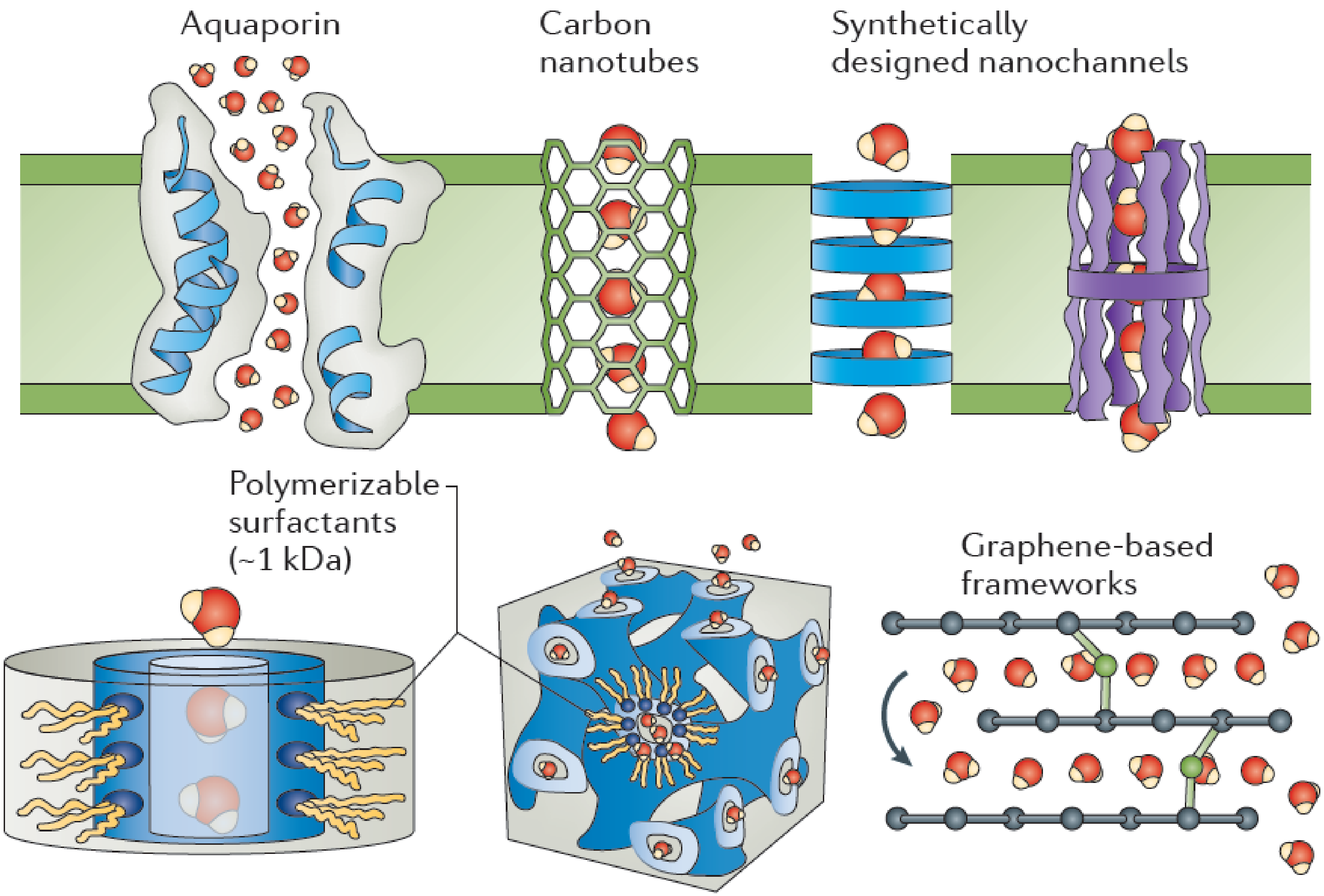
Fig. 3. (**A**) A schematic of the interfacial polymerization used to form thin-film composite (TFC) membranes. The monomers *m*-phenylenediamine and trimesoyl chloride react to form a highly cross-linked polyamide layer, which allows for the selective transport of water over salt. Ultrathin films are fabricated by dissolving the *m*-phenylenediamine in water and trimesoyl chloride in a water-immiscible organic solvent, such as hexane. A porous support is soaked in the aqueous solution and then contacted with the organic solution. The resulting polyamide formation is confined to the region near the interface of the two solutions. One drawback of the polyamide chemistry is the amide linkage (highlighted in dashed box), which is susceptible to attack by chlorine and other oxidizing agents. (**B**) Micrographs displaying the structure of the TFC membranes (*48*). A transmission electron micrograph of the membrane cross-section shows the extremely thin polyamide layer on top of a porous polysulfone support. The dark regions on top of the polyamide layer are gold nanoparticles used to obtain sufficient contrast between the polyamide and polysulfone layers during imaging. (Inset) A scanning electron micrograph of the polyamide top surface showing the rough ridge and valley structure typical of these films. (**C**) Surface properties of TFC membranes (*49*, *50*). Fouling-resistant membranes would be smooth and possess surface chemical properties postulated by (*30*); TFC membranes do not meet all of these constraints, consistent with their high fouling propensity. (**D**) Chemistries that have demonstrated the ability to resist protein or organic macromolecule adhesion: poly(ethylene oxide) (*31*), zwitterions such as poly(sulfobetaine) (*33*), sugar-derived molecules (*30*), and polyglycerol (*34*).

5 AUGUST 2011 VOL 333 **SCIENCE** www.sciencemag.org

Examples of Good Figures



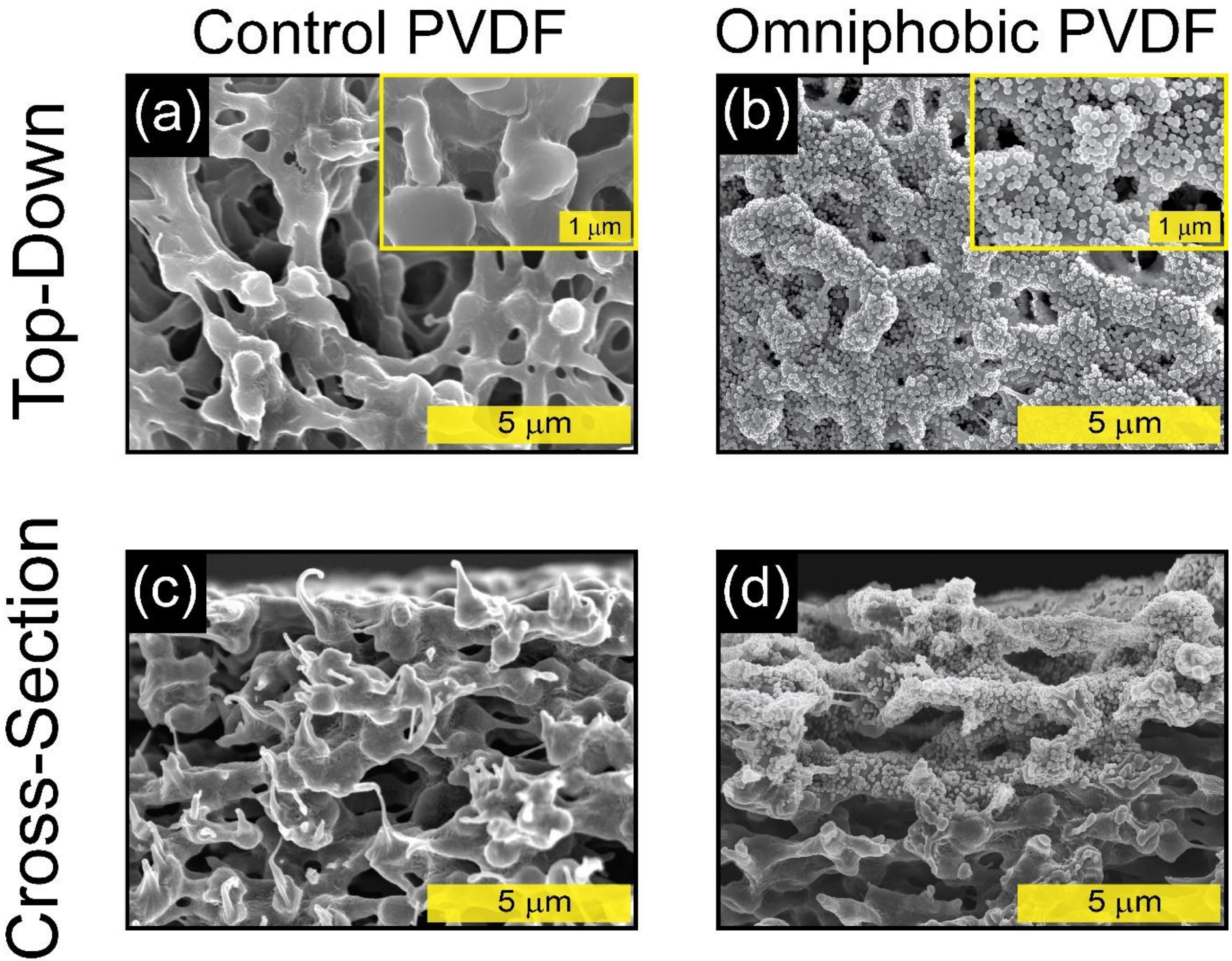
Examples of Good Figures



Werber, et al., *Nature Reviews Materials*, 1 (2016) 1-15.

Yale

Examples of Good Figures



Yale

Examples of Good Figures

NATURE ENERGY DOI: 10.1038/NENERGY.2016.90 ARTICLES

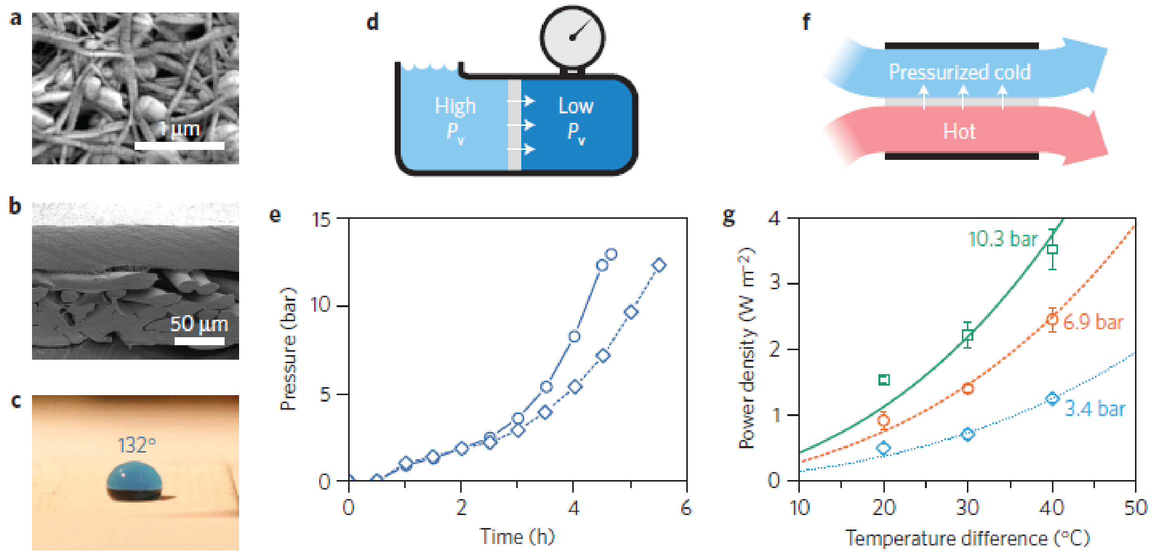
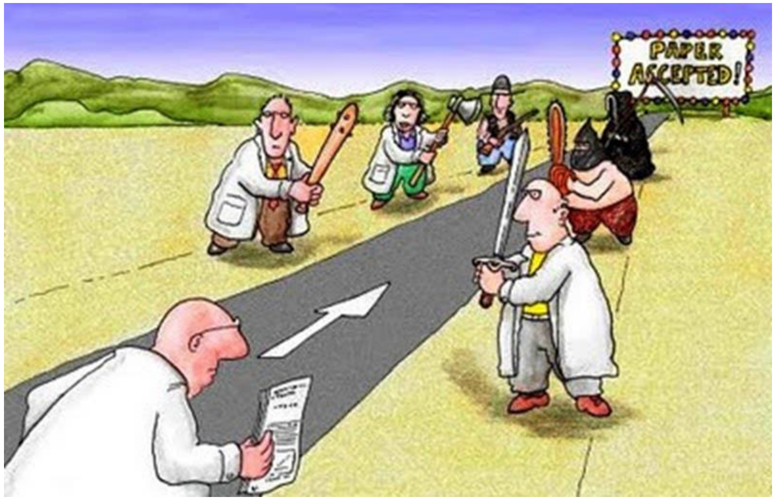


Figure 2 | Demonstration of power generation using a vapour-gap membrane. a, SEM micrograph of polytetrafluoroethylene (PTFE) membrane top surface. **b**, Cross-section image of the PTFE hydrophobic layer and polyester supporting mesh. **c**, Average sessile contact angle of a water droplet on the membrane surface. **d**, Schematic of pressure generation set-up where a membrane is placed between a low partial vapour pressure 5 M NaCl salt solution (low P_v) in a sealed reservoir and deionized water with a higher partial vapour pressure (high P_v) in an open reservoir. The partial vapour pressure difference across the membrane is theoretically equivalent to a 1.9 °C temperature difference with a cold temperature of 20 °C. **e**, Hydraulic pressure generated in the sealed reservoir over time. Duplicate runs using separate membrane coupons are shown, with temperature maintained at 20 ± 1 °C. **f**, Schematic of the temperature-driven flux experiment used to measure the power output of the system. Crossflow was maintained on both sides of the membrane. **g**, Experimental power density obtainable in the system as a function of the temperature difference between the bulk streams with operating pressures of 3.4 bar (blue diamonds), 6.9 bar (red circles) and 10.3 bar (green squares). The cold source temperature is fixed at 20 °C. Error bars indicate the standard deviation for three experimental runs with different membrane coupons. Lines show the expected performance determined from models accounting for temperature polarization and conductive heat transfer (Supplementary Note 4).

Recap

- Good writing takes tremendous efforts
- Always start with an outline!
- Creative research, but effective writing — a story not a mystery
- Strive for rigor and relevance (R^2)



Yale