MICHAEL J. SAILOR PHD, BIOGRAPHICAL

Michael J. Sailor is Distinguished Professor at the University of California, San Diego, Director of the UC San Diego Materials Research Science and Engineering Center (an NSF MRSEC), and Director of the UC San Diego Institute for Materials Discovery & Design. He holds Affiliate Appointments in the UCSD Bioengineering Department, the Nanoengineering Department, and the Materials Science and Engineering program. He was trained at Harvey Mudd College (BS Chemistry), Northwestern University (PhD Chemistry), Stanford (Post-doctoral), and Caltech (Post-doctoral). Other appointments include: Invited Professor, CNRS Institut Charles Gerhardt in Montpellier, France (2012); Visiting Professor, High Level Talent Program, Key Laboratory of Organosilicon Chemistry and Material Technology, Hangzhou Normal University, China (2018-2020); and Visiting Professor, Zhejiang University, China (2019-2020). He has supervised more than 160 undergraduate, graduate, and post-doctoral students, he is the author of more than 260 peer-reviewed research publications, one book, and 39 issued patents. He has an H-Index (Google Scholar) of 101. He has founded or co-founded four companies, including Lisata Therapeutics (NASDAQ: LSTA). He also serves on the scientific advisory board of TruTags, inc, which developed a GMP process to manufacture medical grade porous silicon suitable for oral, injectable, or inhalation administration. He is an elected Fellow of the American Association for the Advancement of Science, the U.S. National Academy of Inventors, and the Royal Society of Chemistry.

Research Interests

Professor Sailor's research focuses on silicon-based nanomaterials, with emphasis on drug delivery, imaging, and sensing applications. He is an expert in the chemistry, electrochemistry, and optical properties of nanomaterials, in particular porous silicon-based systems.

Research Accomplishments

Sailor's laboratory has been studying nanomaterials, with emphasis on silicon-based *in vitro* and *in vivo* systems for more than 30 years. A long-standing focus has been on solving the challenge of sequestering and delivering therapeutics (proteins, nucleic acids and small molecules) in their active form and at a rate that is appropriate to maximize the desired therapeutic response. Three key advances from his lab of relevance here are: (1) his lab's discovery of porous Si nanoparticles in 1992, the particles they have shown can more effectively deliver protein, nucleic acid and small molecule therapeutics to diseased tissues *in vivo*; (2) his lab's discovery of the drug loading and delivery capabilities of these porous nanoparticles; in particular, their ability to sequester proteins and nucleic acids and effectively deliver them to a variety of murine, rabbit, rat, and nonhuman primate disease models; and (3) his lab's discovery that specific fusogenic lipid coatings allow the porous Si nanoparticles to be delivered to specific tissues intracellularly and with avoidance of endosomal uptake for effective RNAi delivery in live animals. This latter advance was of key importance, as it was the first example of delivery of a nucleic acid therapeutic (in that case, siRNA) to completely rescue mice from a lethal lung infection (S. Aureus bacteria in that case). They showed that three aspects of the system--high payload loading, capability to enter cells and avoid endosomal uptake, lysosomal degradation, and efflux, and low systemic toxicity provided a best-in-class performance to enable this nanosystem.

Program Management Accomplishments

Sailor has administered and completed research projects funded by NIH, DARPA, NSF, NASA, AFOSR, FHI-360, and various corporate sponsors, serving as the PI in a large number of joint project grants including an NSF MRSEC (which he currently directs), an NIH U54 Center and the DARPA IVN:Tx program. He also shares research reagents (nanoparticles) and findings (research protocols) with other investigators nationally and internationally. He has been actively involved in training postdoctoral fellows and graduate students. In addition to his regular teaching duties at UC San Diego, he has run the UC San Diego Summer School for Silicon Nanotechnology, an international 8-week hands-on training program, since 2010.

25 SELECTED LEADING PUBLICATIONS-ANNOTATED

of >250 peer-reviewed publications; h-index (Google Scholar): 100; total citations >40,000

1. Heinrich, J.L., Curtis, C.L., Credo, G.M., Kavanagh, K.L., and Sailor, M.J., "Luminescent colloidal Si suspensions from porous Si." *Science* **1992**, *255*, 66-8. *First report of micro- and nanoparticles prepared from porous Si. The ultrasound method described here remains the leading means to prepare particles of electrochemically etched porous Si. Cited 347 times.*
2. Lauerhaas, J.M., Credo, G.M., Heinrich, J.L., and Sailor, M.J., "Reversible Luminescence Quenching of Porous Si by Solvents." *J. Am. Chem. Soc.* **1992**, *114*, 1911-2. *First report of photoluminescence quenching of porous Si by molecular adsorbates. Cited 269 times.*
3. Green, W.H., Le, K.P., Grey, J., Au, T.T., and Sailor, M.J., "White Phosphors from a Silicate-Carboxylate Sol-Gel Precursor that Lack Metal Activator Ions." *Science* **1997**, *276,* 1826-8. *Reported the discovery of a non-aqueous sol-gel reaction that generates intrinsically luminescent Si oxide material. Cited 436 times.*
4. Lin, V.S.-Y., Motesharei, K., Dancil, K.S., Sailor, M.J., and Ghadiri, M.R., "A Porous Silicon-Based Optical Interferometric Biosensor." *Science* **1997**, *278*, 840-3. *First porous silicon biosensor paper. Showed the interference spectrum from a porous Si film can be used as a label-free biosensor. Cited 1854 times.*
5. Sohn, H., Létant, S., Sailor, M.J., and Trogler, W.C., "Detection of fluorophosphonate chemical warfare agents by catalytic hydrolysis with a porous silicon interferometer." *J. Am. Chem. Soc.* **2000**, *122*, 5399-400. *Showed that catalytic reactions can be coupled to the optical response from porous Si to amplify detection of chemicals. First detection of a chemical warfare agent with porous Si. Cited 390 times.*
6. Colicos, M.A., Collins, B.E., Sailor, M.J., and Goda, Y., "Remodeling of Synaptic Actin Induced by Photoconductive Stimulation" *Cell* **2001**, *107*, 605-16. *First example of photoelectrochemical stimulation of live cells using a photoconductive substrate (silicon) as a cellular host. Cited 346 times.*
7. Cunin, F., Schmedake, T.A., Link, J.R., Li, Y.Y., Koh, J., Bhatia, S.N., and Sailor, M.J., "Biomolecular screening with encoded porous silicon photonic crystals." *Nature Mater.* **2002**, *1*, 39-41. *First demonstration of the use of optical signatures etched into porous Si particles to act as encoding elements. Now referred to as "Spectral Barcodes." Technology licensed to TruTag, inc., marketed under the TruTag trademark (www.trutags.com) Technology also licensed to Minus9, inc. (www.minus9labs.com), marketed under the MINT trademark. Cited 538 times.*
8. Sohn, H.; Sailor, M. J.; Magde, D.; Trogler, W. C. "Detection of Nitroaromatic Explosives Based on Photoluminescent Polymers Containing Metalloles." *J. Am. Chem. Soc.* **2003**, *125*, 3821-3830. *Photoluminescent silicon-based polymers respond selectively to nitroaromatic molecules. Technology spawned the company RedXDefense. Cited 769 times.*
9. Li, Y.Y., Cunin, F., Link, J.R., Gao, T., Betts, R.E., Reiver, S.H., Chin, V., Bhatia, S.N., and Sailor, M.J., "Polymer Replicas of Photonic Porous Silicon For Sensing and Drug Delivery Applications." *Science* **2003**, *299*, 2045-2047. *First demonstration of the use of porous Si as a template to generate nanostructured polymers. Comprises one of the core*

technologies of Spinnaker Biosciences, inc. Cited 543 times.

10. Link, J.R. and Sailor, M.J., "Smart Dust: Self-assembling, self-orienting photonic crystals of porous Si." *Proc. Nat. Acad. Sci.* **2003**, *100*, 10607-10. *"Smart dust" paper illustrating the interplay of electrochemistry, chemistry, and optics to generate functional nanostructures. Cited 157 times.*
11. Dorvee, J. R.; Derfus, A. M.; Bhatia, S. N.; Sailor, M. J. "Manipulation of liquid droplets using amphiphilic, magnetic 1-D photonic crystal chaperones." *Nature Mater.* **2004**, *3*, 896-899. DOI: doi:10.1038/nmat1253. *First paper incorporating magnetic nanoparticles and into a porous Si photonic nanostructure. Cited 290 times.*
12. Pacholski, C., Sartor, M., Sailor, M.J., Cunin, F., and Miskelly, G.M., "Biosensing using porous silicon double-layer interferometers: reflective interferometric Fourier transform spectroscopy." *J. Am. Chem. Soc.* **2005**, *127*, 11636-45. *Introduced the RIFTS (Reflectance Interference Fourier Transform Spectroscopy) technique as a nondestructive means of characterizing porous multilayers. Cited 439 times.*
13. Park, J.-H.; Maltzahn, G. A. v.; Zhang, L.; Schwartz, M. P.; Bhatia, S. N.; Ruoslahti, E.; Sailor, M. J., "Magnetic Iron Oxide Nanoworms for Tumor Targeting and Imaging." *Adv. Mater.* **2008**, *20*, 1630-1635. *Described the first synthesis of worm-shaped iron oxide (magnetite) nanoparticles now known as "nanoworms". This comparative study showed that nanoworms display superior tumor targeting (both in vitro and in vivo) relative to more well-known spherical iron oxide nanoparticles. Selected "Best work published in Advanced Materials in 2008" by the Editors. Cited 604 times.*
14. Park, J.-H.; Gu, L.; Maltzahn, G. v.; Ruoslahti, E.; Bhatia, S. N.; Sailor, M. J., "Biodegradable luminescent porous silicon nanoparticles for in vivo applications," *Nature Mater.* **2009**, *8*, 331-336. *First in-vivo use of intrinsically luminescent Si nanoparticles. Shows that 150 nm-scale porous Si nanoparticles overcome many of the disadvantages of smaller (< 6 nm) inorganic nanocrystals (CdSe, for example). This work is important for its low in vivo toxicity and its demonstration of in vivo imaging with an intrinsically luminescent Si nanocrystal. In 2012, it was selected by the editors of Nature Materials as one of the "landmark articles" published in the journal over the past ten years. Cited 2082 times.*
15. Orosco, M. M.; Pacholski, C.; Sailor, M. J., "Real-time monitoring of enzyme activity in a mesoporous silicon double layer." *Nature Nanotech.* **2009**, *4*, 255-258. *Demonstrated immobilization of nanogram quantities of enzyme in a 5 nL volume, and showed that the optical response can be used to quantify enzyme kinetics. The importance of this work is it demonstrated a multifunctional nanostructure used to simultaneously separate and detect products of a biological reaction. Cited 232 times.*
16. Alvarez, S. D.; Li, C.-P.; Chiang, C. E.; Schuller, I. K.; Sailor, M. J., "A Label-Free Porous Alumina Interferometric Immunosensor." *ACS Nano* **2009,** *3*, 3301-3307. *First example of porous alumina used as a label-free optical biosensor. Cited 182 times.*
17. Andrew, J. S.; Anglin, E. J.; Wu, E. C.; Chen, M. Y.; Cheng, L.; Freeman, W. R.; Sailor, M. J., "Sustained Release of a Monoclonal Antibody from Electrochemically Prepared Mesoporous Silicon Oxide." *Adv. Funct. Mater.* **2010**, *20*, 4168–4174. *First demonstration of loading and controlled release of the antibody bevacizumab (Avastin) from a porous SiO_2 carrier. Bevacizumab is a common injectable therapeutic for cancer and for age*

related macular degeneration. Because of their large size and susceptibility to denaturation, antibodies have been difficult to formulate in most other controlled release drug delivery materials. Comprises one of the core technologies of Spinnaker Biosciences, inc. Cited 94 times.

18. Gu, L.; Ruff, L. E.; Qin, Z.; Corr, M.; Hedrick, S. M.; Sailor, M. J., "Multivalent Porous Silicon Nanoparticles Enhance the Immune Activation Potency of Agonistic CD40 Antibody." *Adv. Mater.* **2012**, *24*, 3981-3987. *First demonstration of immune system activation by porous Si nanoparticles. Showed the ability of porous Si nanoparticles to act as multivalent hosts to enhance the binding to, and activation of, immune b-cells. Cited 97 times.*

19. Gu, L.; Hall, D. J.; Qin, Z.; Anglin, E.; Joo, J.; Mooney, D. J.; Howell, S. B.; Sailor, M. J., "In vivo time-gated fluorescence imaging with biodegradable luminescent porous silicon nanoparticles." *Nat. Commun*. **2013**, *4*, 2326. *First example of time-gated imaging of porous Si nanoparticles in-vivo. Demonstrated elimination of interfering light emission from organic chromophores and tissue autofluorescence*. *Cited 349 times.*

20. Li, X.; Gu, M.; Hu, S.; Kennard, R.; Yan, P.; Chen, X.; Wang, C.; Sailor, M. J.; Zhang, J.-G.; Liu, J. "Mesoporous silicon sponge as an anti-pulverization structure for high-performance lithium-ion battery anodes." *Nat. Commun.* **2014**, *5*, 4105. DOI: 10.1038/ncomms5105. *Discovery that mesoporous silicon significantly improves Li-ion battery performance. While it was predicted that silicon could display 10 times the energy storage capacity of graphite as the anode in a Li-ion battery, development of a silicon-based Li-ion battery was hindered by low cycle life, caused by the massive volume changes (300%) the material undergoes with each charge/discharge cycle as lithium enters and exits the fragile silicon lattice. In collaboration with Jason Zhang at the Pacific Northwest National Laboratory, we developed a mesoporous form of silicon that resulted in volume expansion during lithiation of only 30%, which resulted in a capacity of ~750 mAh/g based on total electrode weight, and > 80% capacity retention over 1000 cycles. All of these metrics were significant improvements over the state of the art for silicon at that time. Cited 666 times.*

21. Kim, D.; Zuidema, J. M.; Kang, J.; Pan, Y.; Wu, L.; Warther, D.; Arkles, B.; Sailor, M. J., "Facile Surface Modification of Hydroxylated Silicon Nanostructures Using Heterocyclic Silanes." *J. Am. Chem. Soc.* **2016,** *138*, 15106-15109. *Introduced a new means to quickly and efficiently modify nanoparticle surfaces using heterocyclic silane reagents. Cited 77 times.*

22. Hussain, S.; Joo, J.; Kang, J.; Kim, B.; Braun, G. B.; She, Z.-G.; Kim, D.; Mann, A. P.; Mölder, T.; Teesalu, T.; Carnazza, S.; Guglielmino, S.; Sailor, M. J.; Ruoslahti, E., "Antibiotic-loaded nanoparticles targeted to the site of infection enhance antibacterial efficacy." *Nat. Biomed. Eng.* **2018,** *2*, 95–103. *First time a peptide-targeted nanoparticle delivery system was shown to improve efficacy of a first-line antibiotic in treating a drug resistant strain of Staph. aureus. Demonstrated in mouse lung and skin infection models. Showed the advantage of selective tissue targeting (by peptides) and the use of nanoporous delivery vehicle to improve performance of a conventional antibiotic Cited 278 times.*

23. Kim, B.; Pang, H.-B.; Kang, J.; Park, J.-H.; Ruoslahti, E.; Sailor, M. J., "Immunogene therapy with fusogenic nanoparticles modulates macrophage response to Staphylococcus

aureus." *Nat. Commun.* **2018,** *9*, 1969. *Using a nanotherapeutic to deliver siRNA that targets cells in the immune system, this paper represents the first time an siRNA therapeutic was fully effective against a lethal bacterial infection of any kind. Demonstrated on a Staph. aureus pneumonia model in mice. Cited 145 times.*

24. Zuidema, J. M.; Kumeria, T.; Kim, D.; Kang, J.; Wang, J.; Hollett, G.; Zhang, X.; Roberts, D. S.; Chan, N.; Dowling, C.; Blanco-Suarez, E.; Allen, N. J.; Tuszynski, M. H.; Sailor, M. J., "Oriented Nanofibrous Polymer Scaffolds Containing Protein-Loaded Porous Silicon Generated by Spray Nebulization." *Adv. Mater.* **2018,** *30*, 1706785. *Important because it demonstrated the ability to formulate sensitive protein therapeutics into common drug delivery polymers without substantial degradation of activity. Cited 41 times.*

25. Vijayakumar, S.; Alberstein, R. G.; Zhang, Z.; Lu, Y.-S.; Chan, A.; Wahl, C. E.; Ha, J. S.; Hunka, D. E.; Boss, G. R.; Sailor, M. J.; Tezcan, F. A. Designed 2D protein crystals as dynamic molecular gatekeepers for a solid-state device. *Nat. Commun.* **2024**, *15*, 6326. DOI: 10.1038/s41467-024-50567-8. *Proteins feature prominently in a number of important technologies, such as blood sugar monitors, rapid antigen assays for disease diagnosis, and DNA sequencing devices. A major challenge with all of these is the need to preserve the function of the protein, even though it is operating in a non-natural environment. This work demonstrates an engineered protein that operates in an open air environment, as a gatekeeper for admission of molecules into a solid state sensor device.*