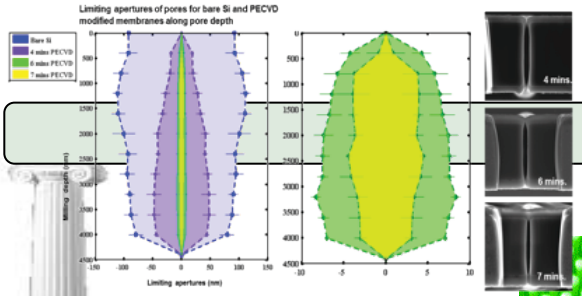
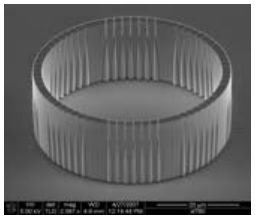
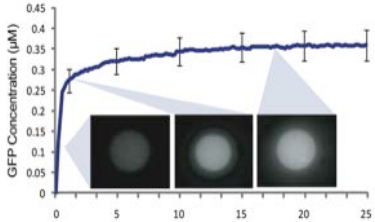
Bio2Nano *Signature Strength*

The BESAC "Grand Challenges" Report (*Directing Matter and Energy: Five Challenges for Science and the Imagination*) laid out a daunting vision by identifying *The Grand Challenge for Nanoscience: master energy and information on the nanoscale to create new technologies with capabilities rivaling those of living systems*. Living systems self-organize and self-repair; they learn and adapt; and they scavenge energy from the environment. In short, Nature has mastered creating complex behavior from collective phenomena on the nanoscale. In the Nanofabrication Research Laboratory (NRL), we are addressing this Grand Challenge by bringing the lessons of Nature to synthetic nanoscale systems in the Signature Strength we call Bio2Nano. Bio2Nano is built on the expertise of the NRL staff, a strong collaboration with the CNMS-affiliated Nanobioscience Laboratory, and strong interactions with numerous users. Bio2Nano combines exquisite control over the size, shape, composition, placement and functionalization of multiscale structures (more than 6 orders of magnitude from single digit nano to tens of millimeters) with a growing understanding of how biological cells and collections of cells use nanoscale structure, stochastic fluctuations, confinement and crowding, and higher scale coordination to produce complex functionality. The enabling capability present in the Nanofabrication Research Laboratory ranges from bottom-up engineered self-assembly of natural materials to top-down fabrication methods employing combinations of deposition, lithography and etching. In addition, we have developed basic building blocks of highly correlated molecular networks based on a viral system and have begun to combine these networks with our micro- and nanofabricated environments. Moving forward, the Bio2Nano Signature Strength will produce systems of ever increasing complexity and generate a deeper understanding of the mastery of energy and information on the nanoscale that can enable technologies with capabilities that rival those of living systems.

Tune transport



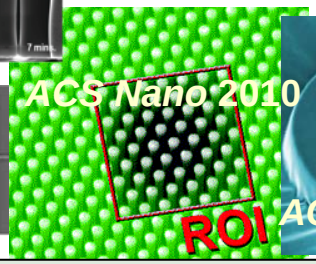




Sustained molecular network, Lab on Chip, 2011

Synthetic systems that assume cell-like behavior

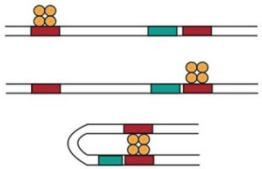
Lab on Chip, 2013

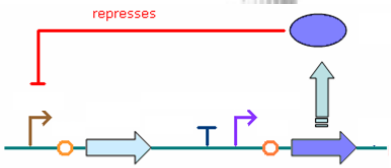


ACS Nano 2010

ACS Syn Bio in review

Nuc. Acids Res. 2012
ACS Syn Bio in revision

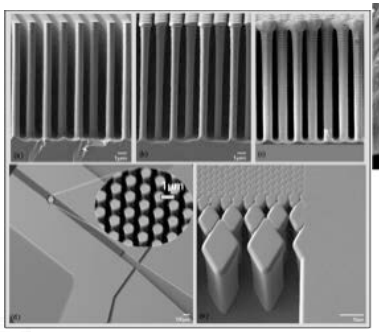


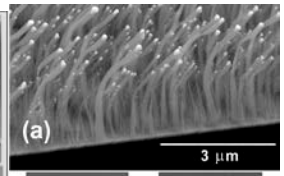


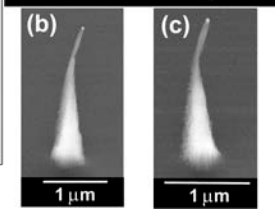
Crowded, confined systems: correlations, fluctuations rule

Highly correlated molecular networks

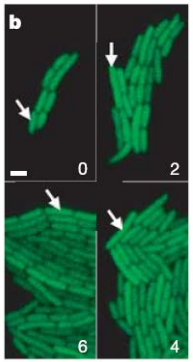
Multiscale Integration of Structures



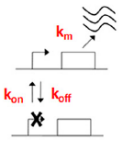


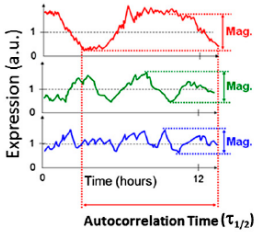


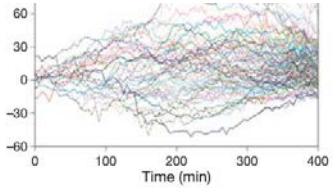
Architectures and strategies learned from biology



Episodic 'bursty' gene expression







Nature is noisy and "bursty": *Nature* 2006, *PNAS* 2012

Bio2Nano *Signature Strength* : recent publications

J.B. Boreyko, P. Mruetusatorn, S.A. Sarles, S.T. Retterer and C.P. Collier, “Evaporation-Induced Buckling and Fission of Microscale Droplet Interface Bilayers”, *J. Am. Chem. Soc.* **135**, 5545-5548 (2013).

J.B. Boreyko, P. Mruetusatorn, S.T. Retterer and C.P. Collier, “On-Demand Generation of Aqueous Two-Phase Microdroplets with Reversible Phase Transitions”, *Lab Chip* **13**, 1295-1301 (2013).

J.D. Fowlkes and C.P. Collier, “Single-Molecule Mobility in Confined and Crowded Femtolitre Chambers”, *Lab Chip* **13**, 877-885 (2013).

Teng, MW, Bolovan-Fritts, C, Dar, RD, Womack, A, Simpson, ML, Shenk, T, Weinberger, LS, “An Endogenous Accelerator for Viral Gene Expression Confers a Fitness Advantage”, *Cell*, **151**, 1569-1580 (2012).

Dar, RD, Razooky, BS, Singh, A, Trimeloni, TV, McCollum, JM, Cox, CD, Simpson, ML, Weinberger, LS, “Transcriptional burst frequency and burst size are equally modulated across the human genome”, *Proc. Natl. Acad. Sci. USA,* **109**, 17454-17459 (2012).

Siuti, P, Retterer, ST, Doktycz MJ, “Continuous protein production in nanoporous, picolitre volume containers”, *Lab Chip,* **11**, 3523-3529 (2011).

Bio2Nano *Signature Strength* : impact

"Vertically aligned carbon nanofibers and related structures: controlled synthesis and directed assembly", *Journal of Applied Physics* **97**, 041301. **cited 475 times**

"Gene network shaping of inherent noise spectra", *Nature* **439**, 608. **cited 172 times**

"Frequency domain analysis of noise in autoregulated gene circuits", *Proceedings of the National Academy of Sciences* **100**, 4551. **cited 128 times**

Total number of papers, patents: 105

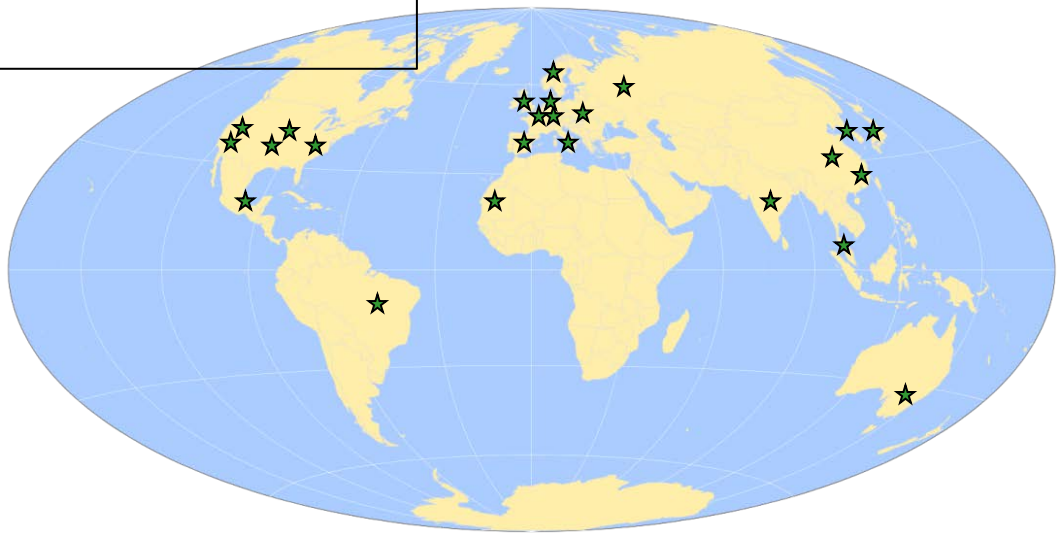
Nature, Nature Genetics, Cell: 4

PNAS, ACS Nano, Nano Letters: 10

Molecular Systems Biology, Lab on a Chip: 10

Total number of cites: 2856

Average cites/paper: 27.2



Michael L. Simpson
Distinguished R&D Staff
and Group Leader,
Nanofabrication
Research Laboratory

Theme Co-Leader
Collective Phenomena
in Nanophases

Controlled synthesis and directed assembly of nanomaterials, stochastic processes in complex systems, biomimetic nanoscience

>150 peer reviewed publications; 33 U.S. Patents; h-index 44

Google Scholar profile:
Mike Simpson

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Fellow of the IEEE

College of Fellows
of the AIMBE

Mitch J. Doktycz
Distinguished Staff Scientist,
Nanofabrication Research Laboratory

Group Leader
Biological and Nanoscale Systems

Bionanotechnology, microfluidics, imaging, scanning probe microscopy, cell mimics, biomineralization

>120 peer reviewed publications; 17 U.S. Patents; h-index 31

Google Scholar profile:
Mitch Doktycz

College of Fellows
AIMBE

Pat Collier
Research staff,
Nanofabrication
Research
Laboratory

Microfluidics
Nanofabrication
Single-molecule
Dynamics
Collective
Phenomena

54 peer reviewed publications; 6 patents; h-index 28

Google Scholar profile:
Pat Collier

High profile publications

Science (4 papers)

Nano Letters, ACS Nano, Phys. Rev. Letts. (6 papers)

Scott T. Retterer
Research Staff,
Nanofabrication
Research
Laboratory

Multi-scale fluidic environments for interfacing with biological systems; Nanostructure fabrication and assembly

>50 peer reviewed publications; h-index 16

Google Scholar profile:
Scott Retterer

High Profile Papers

Nano Letters, ACS Nano (7 papers)

Advanced Functional Materials, Lab on Chip (8 papers)

Jason D. Fowlkes
Staff Scientist,
Nanofabrication
Research Laboratory

Theme;
Collective Phenomena
in Nanophases

Beam-induced chemistry and assembly, Self and directed assembly of thin film materials, Nanobio-related reaction/diffusion systems

>80 peer reviewed publications; h-index 22

Google Scholar profile:
Jason Fowlkes

High Profile Publications

ACS Nano and
Nano Letters (5 papers)

Small, Nanoscale, Lab on Chip (4 papers)