NNCI @ Stanford

TOBI BEETZ

ASSOCIATE DIRECTOR

STANFORD NANO SHARED FACILITIES (SNSF)

nano@stanford supported under NSF award ECCS-1542152

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NNCI @ STANFORD

- **PI:**
- **Bruce Clemens**, Professor of Materials Science & Engineering, Director of Stanford Nano Shared Facilities (SNSF)

- **Co-PIs:**
- **Curt Frank**, W.M. Keck, Sr. Professor in Chemical Engineering
- **Kate Maher**, Assistant Professor of Geological and Environmental Sciences
- **Debbie Senesky**, Assistant Professor of Aeronautics and Astronautics

- **Key Participants:**
- **Tobi Beetz**, Associate Director of Stanford Nano Shared Facilities (SNSF)
- **Mary Tang**, Associate Director of Stanford Nanofabrication Facility (SNF)
- **Nick Melosh**, Associate Professor of Materials Science & Engineering, Deputy Director of Stanford Nanofabrication Facility (SNF)
- **Angela Hwang**, Education & Outreach Program Manager (NNCI)

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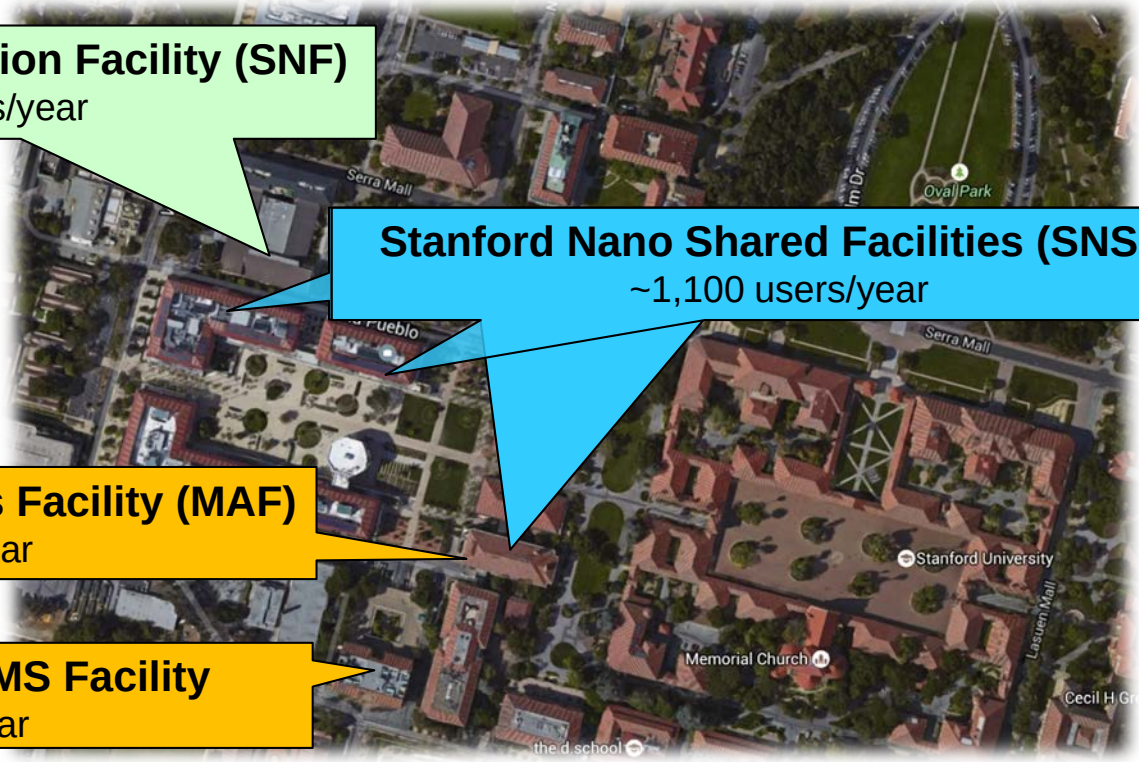
Stanford Nanofabrication Facility (SNF)
~ 550 users/year

Stanford Nano Shared Facilities (SNSF)
~1,100 users/year

Microchemical Analysis Facility (MAF)
~30 users/year

Stanford ICP-MS/TIMS Facility
~20 users/year



~30,000 ft^2

~1,400 users/year

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Over 40 expert staff members

Over 190 faculty members

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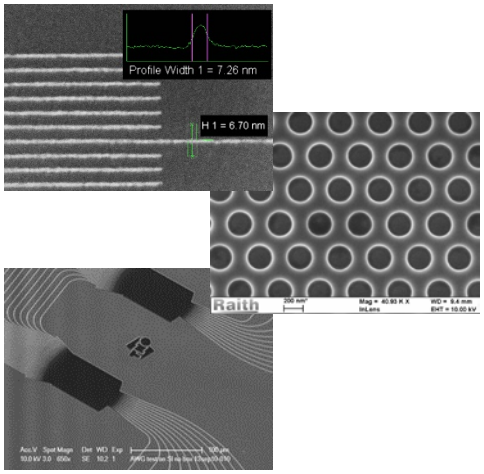
Stanford: Facilities and Tools

- Investments into direct-write litho
  - Optical:
    - 2016: Heidelberg MLA 150
    - 2018: Durham Magneto Optics ML3
    - 2019: Heidelberg MLA 150
  - EBL:
    - 2019: Raith Voyager
      - 50 keV system to complement 100keV and SEM-based EBL
      - 50 MHz pattern generator
      - Sub 8 nm writing performance guaranteed
      - Advanced writing modes for perfectly round-shaped circles
      - Stitching error-free writing mode for extended structures



New staff
06/19: from HRL Laboratories)

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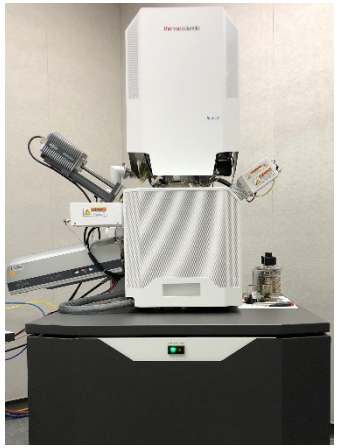
Stanford: Facilities and Tools

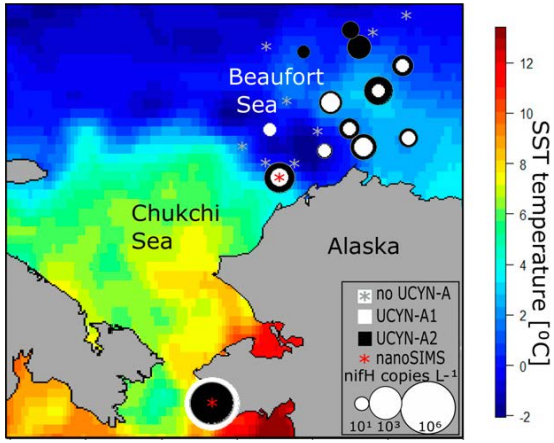
- In-situ characterization
  - Thermo Fisher Apreo SEM
    - In-situ stages
      - Nanoindentation
      - Tensile/Compression
      - Sectioning for 3D reconstruction (planned)
      - …

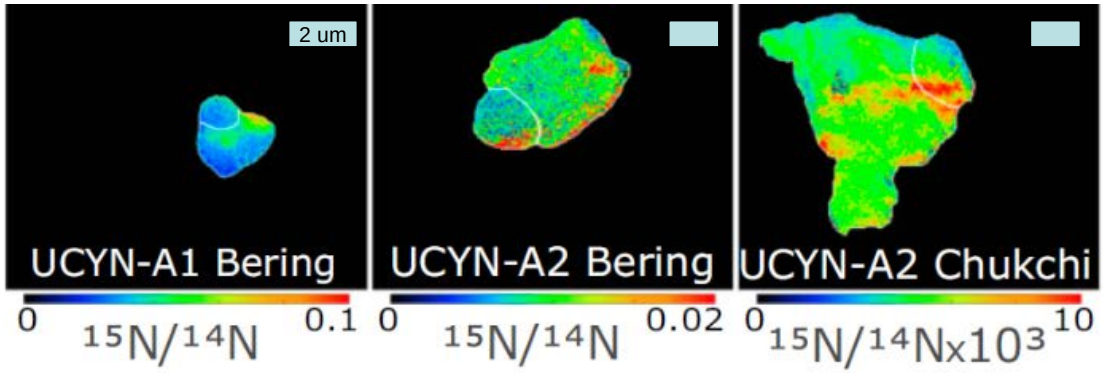


  - Malvern Panalytical Empyrean XRD
    - In-situ stages
      - Gas-tight
      - Anton Paar High-temperature (1,200 C)
      - Anton Paar Reaction Chamber (up to 900 C and 1 mbar to 10 bar)
      - Cooling (LN2)
      - …

Cyanobacteria fix nitrogen in the Arctic Ocean

- Biological dinitrogen (N2) fixation (BNF) is an important source of nitrogen in marine systems. Marine BNF is mainly attributed to cyanobacteria.
- NanoSIMS measurements show that a certain type of cyanobacteria are present and are fixing N2 in the Western Arctic and Bering Seas.





UNIVERSITY OF CALIFORNIA SANTA CRUZ
WILLIAM & MARY CHARTERED 1693
Memorial University of Newfoundland
Stanford University
Bigelow Laboratory for Ocean Sciences

NanoSIMS acquired through NSF-MRI: ECCS-0922648 (2009)

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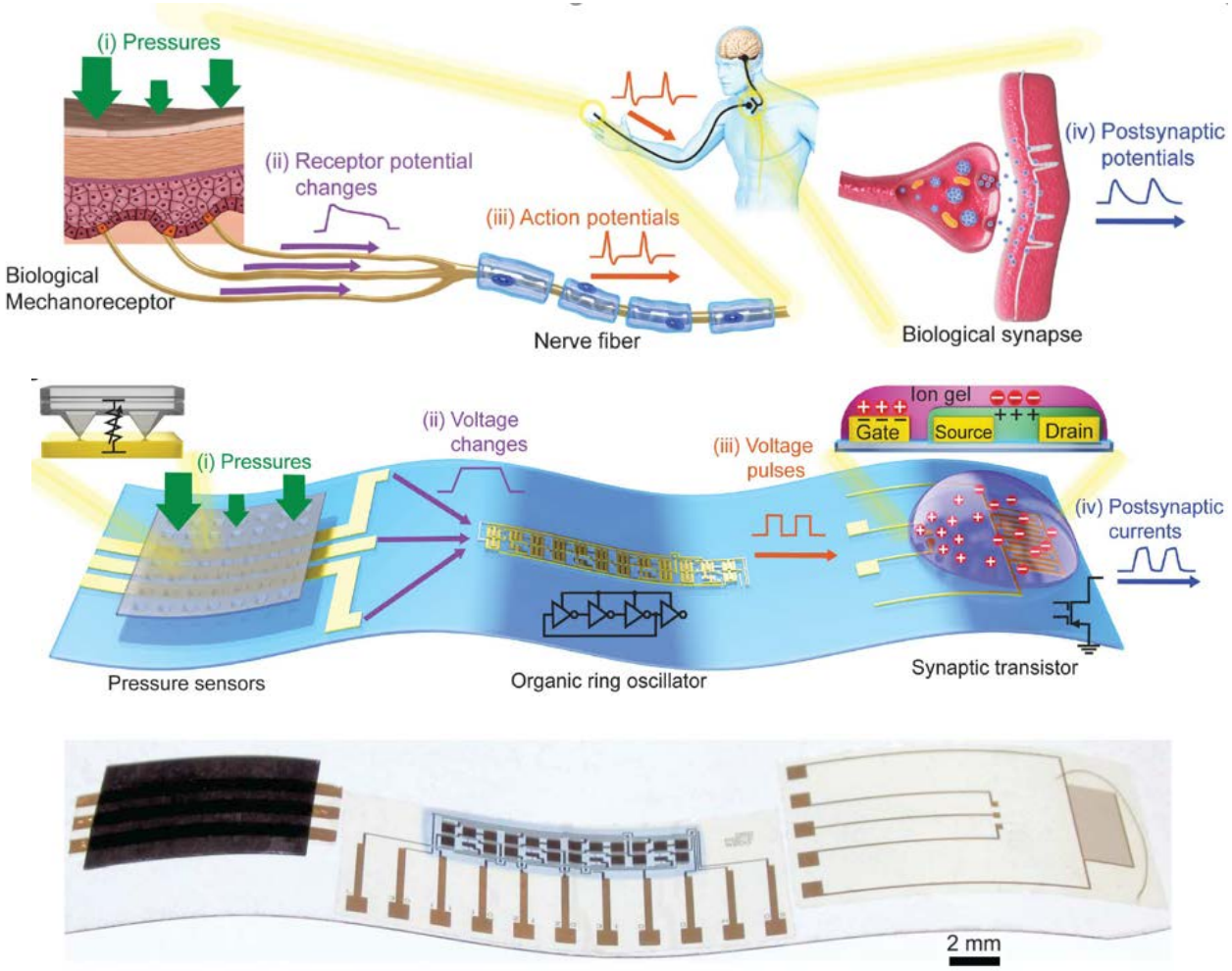
Harding et al., *PNAS* ***115*** *(2018)*

Bioinspired flexible organic artificial nerves



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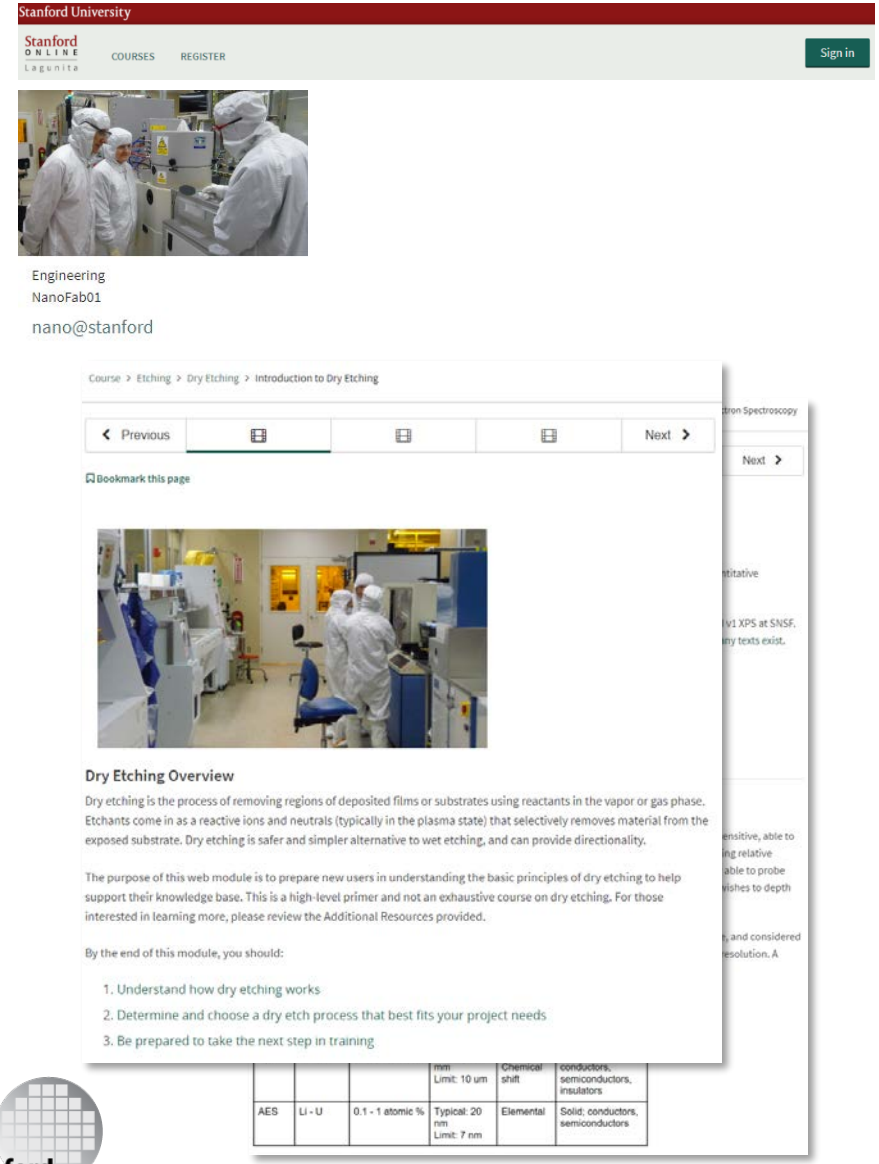
Z. Bao Group, *Science* ***360*** *(2018)*

Education and Outreach

Develop and propagate a national model for **educational practices** that will help students and visitors become knowledgeable and proficient users of the facilities.

E&O: Online Learning

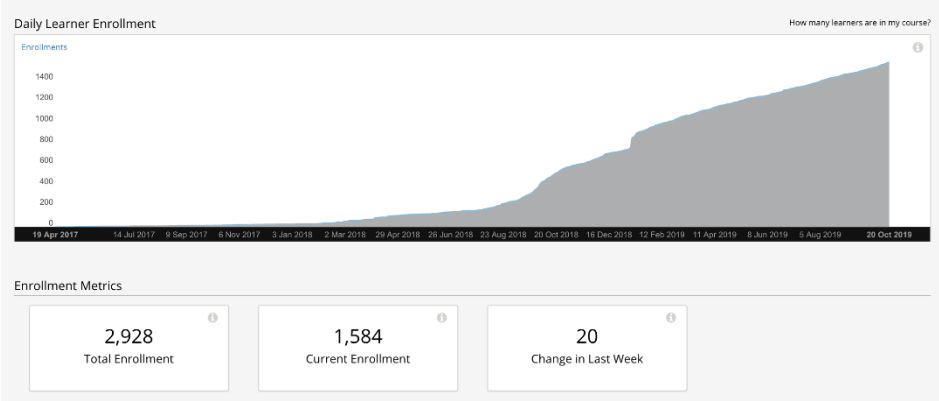
- User Education
  - Create online educational materials
  - hosted on an edX-based platform
  - Start with fundamental knowledge on general fabrication and characterization techniques
  - Modules available/in-development:
    - Lithography, direct-write, nanoscribe, microfluidics, deposition …
    - Optical microscopy, TEM, SEM, XPS, XRD, …

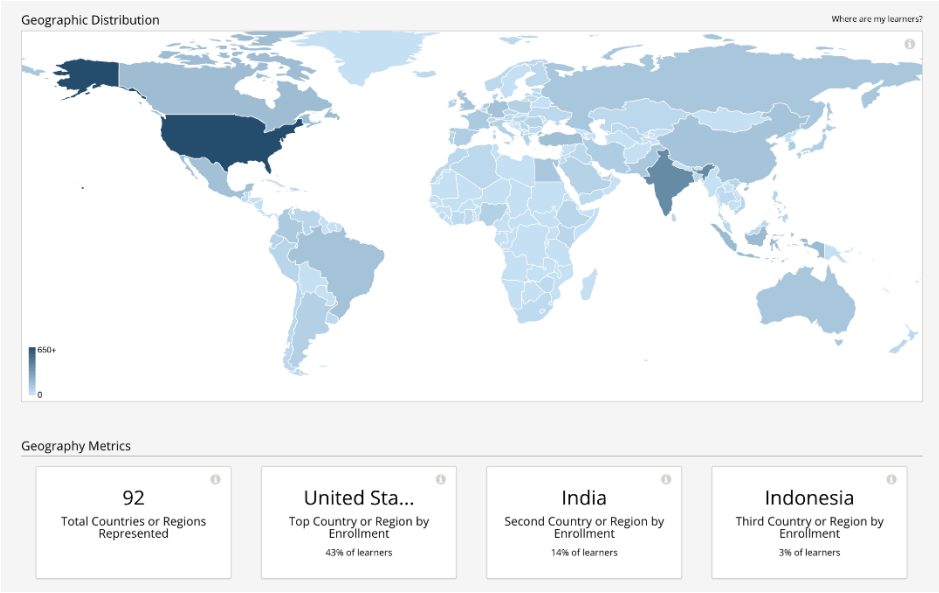


E&O: Education and Outreach

- Assessment
  - Tests within modules
  - Feedback sections
  - Enrollment
- Key Takeaways
  - Training expedited for users and staff
  - Staff spend less time on repetitive work
  - Reach beyond the network
- What's next?
  - Hoping that NNCI is coming together for content creation and adoption! >> renewal?

NNCI approved





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E&O: Summer Institute for Middle School Techers

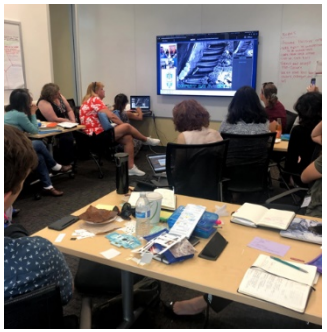
- Motivation
  - Middle school is when students lose their natural interest in science
  - Fewer programs exist for middle school teachers
  - Teachers provide broader and deeper impact for student

- Goal
  - Inspire middle school students by training their teachers
  - Provide teachers with the support to be comfortable teaching nanoscience

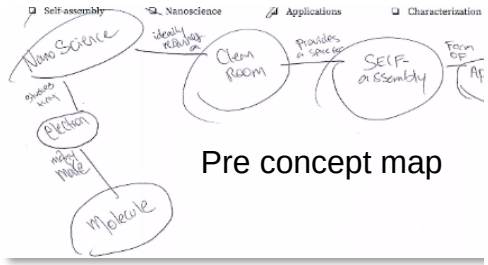
https://www.youtube.com/watch?v=7CXsReFAw-8

E&O: Summer Institute for Middle School Techers

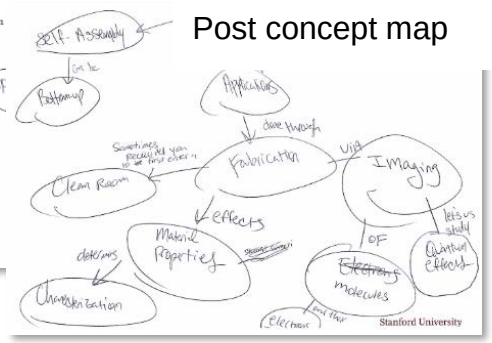
- Progress
  - 3rd nanoSIMST June 2019 (4-day program)
    - 15 Bay Area teachers (5 from Title 1 schools)



  - Assessment for teacher understanding as well as confidence and excitement for teaching

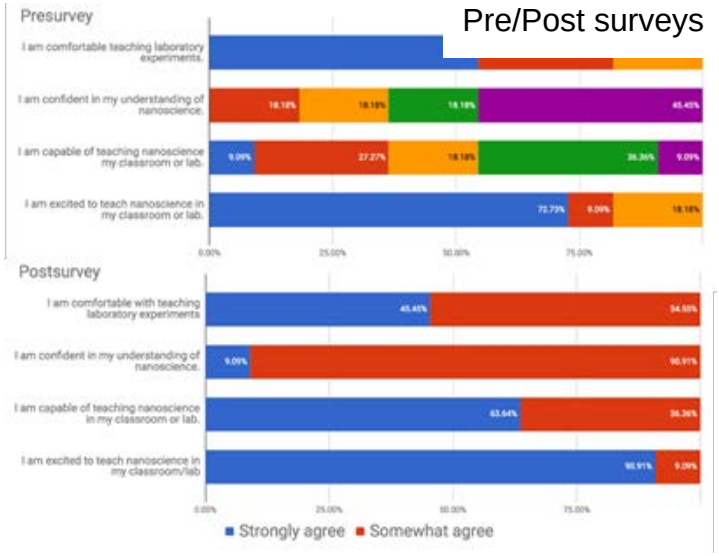


Pre concept map



Post concept map

Pre/Post surveys



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E&O: Summer Institute for Middle School Techers

- nanoSIMST beyond Stanford
  - Georgia Tech
    - SENIC nanoSIMST in Summer 2019
    - Supported by Stanford (Angela)
    - Expansion to include RAIN
    - 4-day program
    - 15 teachers from across Georgia
  - UCSD:
    - Participated remotely in Stanford nanoSIMST (remote SEM access)
    - Observed nanoSIMST at Stanford in Summer 2019
    - Planning program for 2020

YouTube
7CXsReFAw-8

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E&O: Community College Internships

- Recently established program with local community colleges
- Goal: gain hands-on experience and while providing facility support
- Implementation: Students gain college credit for Workforce Development and are paid hourly to help the lab

College of San Mateo

Foothill College

"incredible opportunity to gain real world experience"

"learn more about the equipment"

"run small projects … to get started in research"

"staff provide a fun and engaging learning environment"

"would definitely recommend it to other students"

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Impact

per year

1,100 students performing research
200 external users trained

1,400 users/year
2,500 public participants

150 active external organizations
270 industry users

Est. 800 publications

$7.4M User Fees
$2.6M Industry Usage Fees

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Impact Statements from Industry

Quantum Biosystems

"…Stanford SNSF offers a whole range of instruments and facilities … "
"… helps us to efficiently use our limited funds by avoiding investments in heavy weight instruments with high capital and maintenance costs."

"No in-house capability to do extensive material characterizations"

PHONAK life is on

BW10 Inc.

"The JEOL system is state of the art and ~ 10 X faster than any other systems available."

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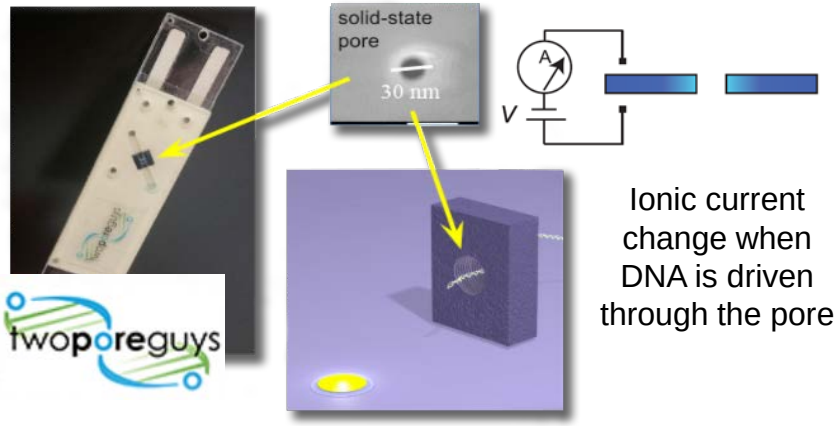
Impact on Economic Growth

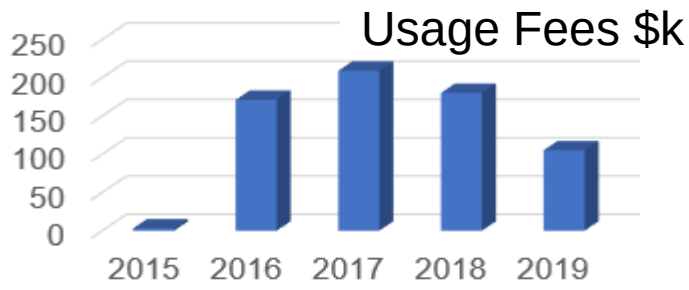
- Facilities seed economic growth

- Example: TwoPoreGuys
  - solid state nanopore technology for molecular diagnostics, genome mapping and DNA sequencing



Ionic current change when DNA is driven through the pore

2011: Founded
2011: 2 employees
2013: $150k SBIR
2015: joined nano@stanford
2016: ~40 employees
2016: $475k SBIR
2016: $5.2M Angel Round
2017: $24.5M Series A
2017: ~60 employees
2018: $2.8M Gates Foundation
2019: renamed to Ontera
2019: >100 employees



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Stanford: Impact

NSF NNCI funding is essential in keeping Stanford facilities open to external for-profit users.

Unrelated business income (UBI) considerations normally limits that participation and we ***would need to turn away more than ½ of our external for-profit users***.

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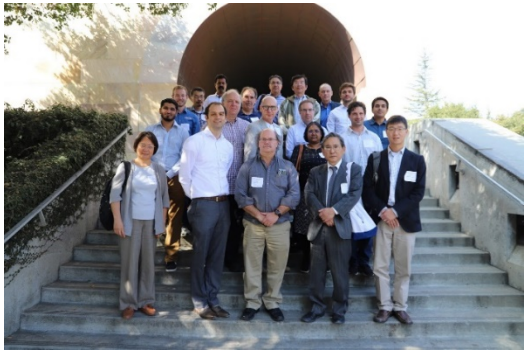
Stanford: Network Collaboration

- Workshops
  - 2018 NNCI Etch Symposium (Stanford)
    - Organized by Cornell, Harvard & Stanford
    - 2-day workshop
    - > 100 attendees from acad., gov. & industry
    - **13 NNCI sites**
  - 2019 NNCI ALD/MOCVD/MBE Symposium (Harvard)
    - Organized by Harvard & Stanford
    - 2-day workshop
    - ~ 60 attendees from acad., gov. & industry
    - **8 NNCI sites**
  - 2019 NNCI Direct-Write (Stanford)
    - Organized by Stanford & Industry
    - 2-day workshop
      - Optical Lithography Working Group Meeting
    - ~ 100 attendees from acad., gov. & industry
    - **11 NNCI sites**



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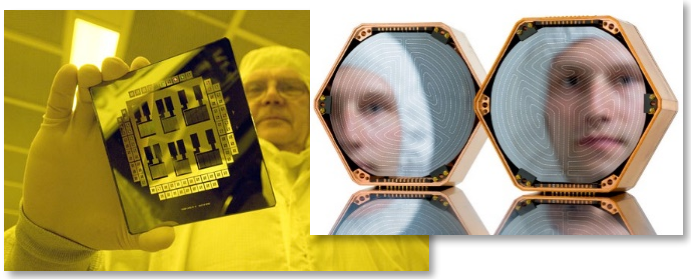
Thank you!

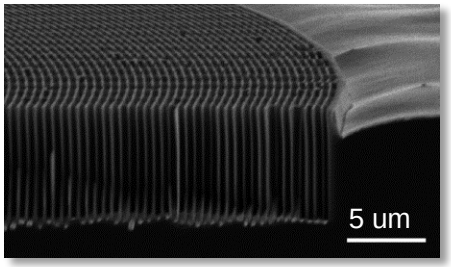
***nano@stanford* provides access to world-leading facilities and expertise in nanoscale science and engineering for internal users and for external users from academic, industrial, and government labs.**

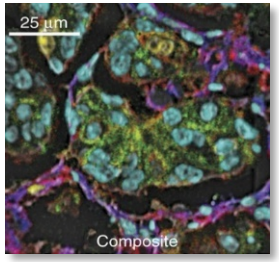


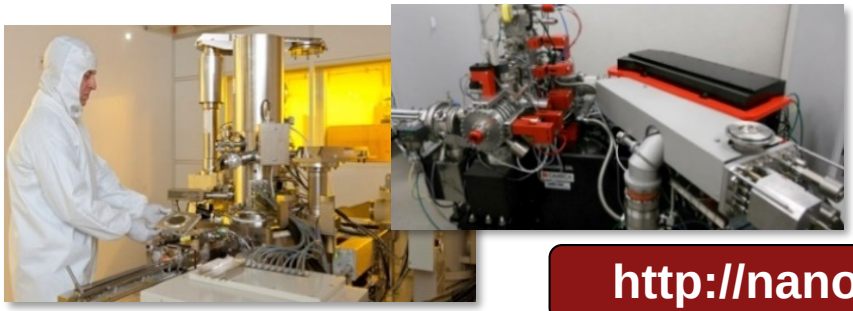
~1,400 annual users take advantage of a comprehensive array of advanced nanofabrication and nanocharacterization tools available within the Stanford Nano Shared Facilities (SNSF), the Stanford Nanofabrication Facility (SNF), the Mineral Analysis Facility (MAF), and the TCP-IMS Facility.

Facilities feature:

- ~16,000 sqft fully equipped cleanroom facilities, including resources that are not routinely available, such as an MOCVD and advanced e-beam lithography
- ~15,000 sqft of characterization facilities, including SEM, TEM, FIB, XRD, SPM, XPS and unique tools such as a NanoSIMS, and a scanning SQUID microscope.







Broad research portfolio spanning traditional nano areas as well as life science, medicine, and earth and environmental science. Broad education and outreach programs.

http://nanolabs.stanford.edu

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Stanford University

Panel Discussion: Resource Allocation and New Equipment

- New Equipment
  - Cutting-edge vs bread & butter instrumentation: How do we decide?

TEM 1

- $7M
- $400k service contract
- 25 users/yr
- 10 faculty groups
- Lots of downtime
- Long sessions > high cost
- High impact papers
- Outdated after 10 years

TEM 2

- $1.5M
- $120k service contract
- 60 users/yr
- 25 faculty groups
- Mostly up
- Short sessions > low cost
- Supplemental characterization
- Workhorse for 15-20 years

  - Vendor demo sites: How do we leverage our diverse user base to get vendors to install/loan/donate equipment?
    - Example: ASML, EBL, USC, …