NNCI @ Stanford

BRUCE CLEMENS

PROFESSOR OF MATERIALS SCIENCE &ENGINEERING

DIRECTOR OF STANFORD NANO SHARED FACILITIES (SNSF)

nano@stanford supported under NSF award ECCS-1542152

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NNCI @ STANFORD

- **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)

- **Shiva Bhaskaran**, External User Program Manager (NNCI)

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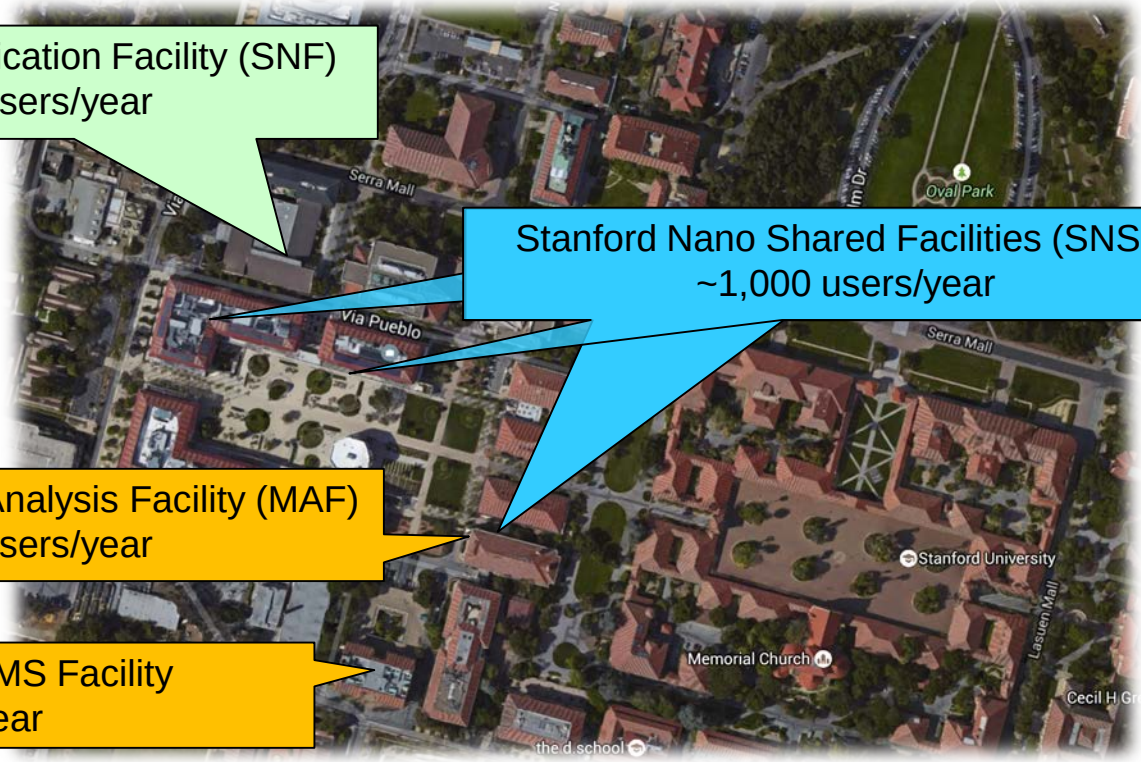
Facilities

Stanford Nanofabrication Facility (SNF)
~ 550 users/year

Stanford Nano Shared Facilities (SNSF)
~1,000 users/year

Stanford Mineral Analysis Facility (MAF)
~25 users/year

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



~30,000 ft^2

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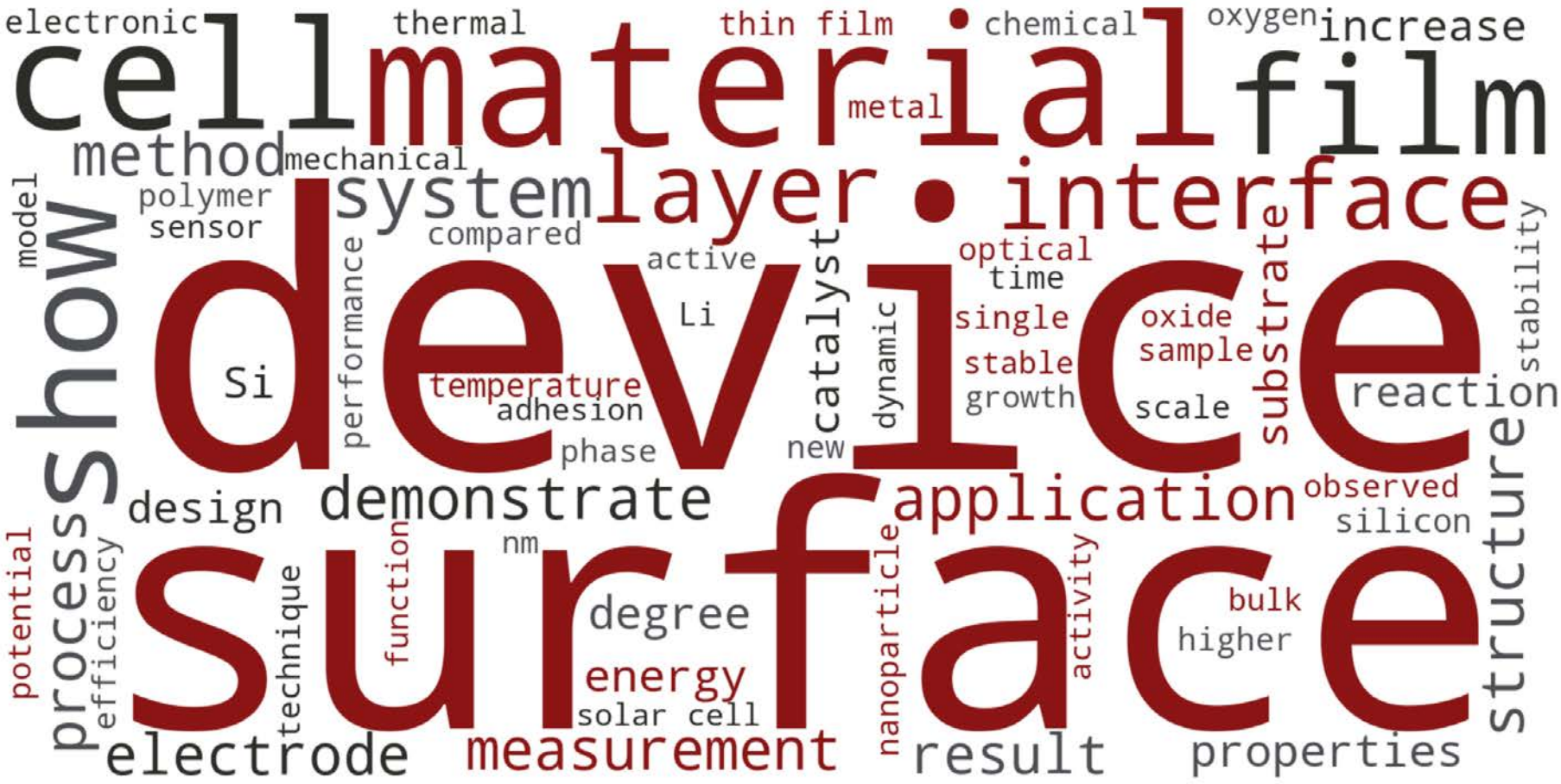
Research



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data: 2017 publication abstracts

NNCI @ Stanford: User Data

Yearly User Data Comparison			
	Year 1	**Year 2**	**Year 3 (6 months)**
Total Users	1,142	1,287	1,096
Internal Users	952	1,027	818
External Users	190 (17%)	260 (20%)	208 (25%)
External Academic	36	41	26
External Industry	154	215	179
External Government	0	4	3
External Foreign	0	0	0
Total Hours	113,089	113,193	64,578
Internal Hours	94,996	91,248	50,941
External Hours	18,093 (16%)	21,944 (19%)	13,637 (21%)
Average Monthly Users	520	572	591
Average Ext. Monthly Users	74 (14%)	92 (16%)	105 (18%)
New Users Trained	542	579	274
New External Users Trained	89 (16%)	143 (25%)	95 (35%)

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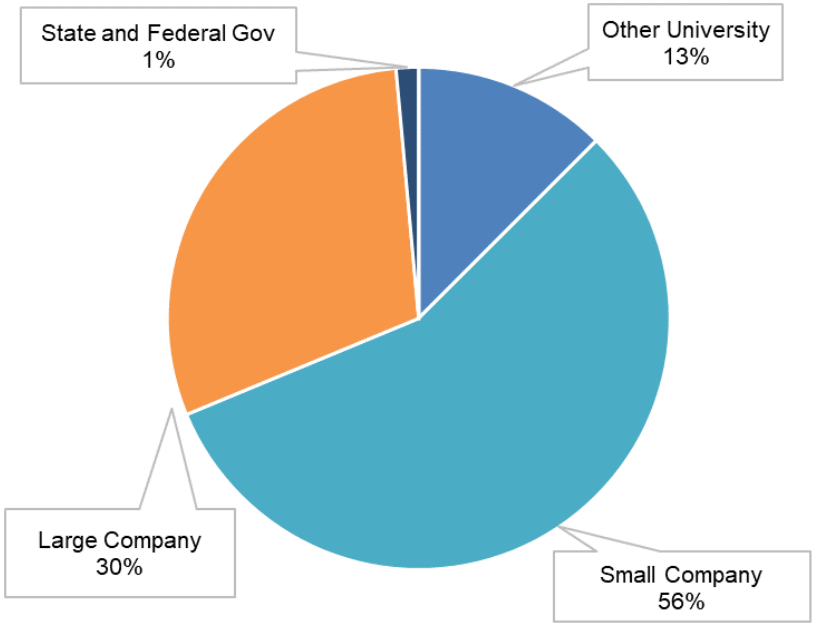
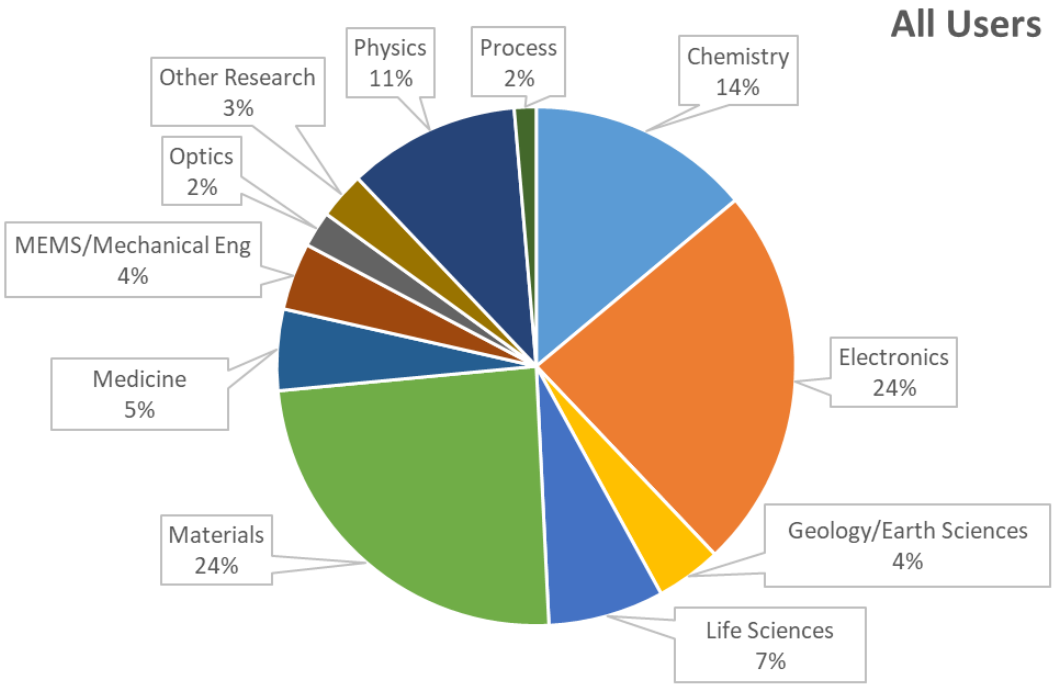
NNCI @ Stanford: User Data

External User Affiliations



All User Disciplines



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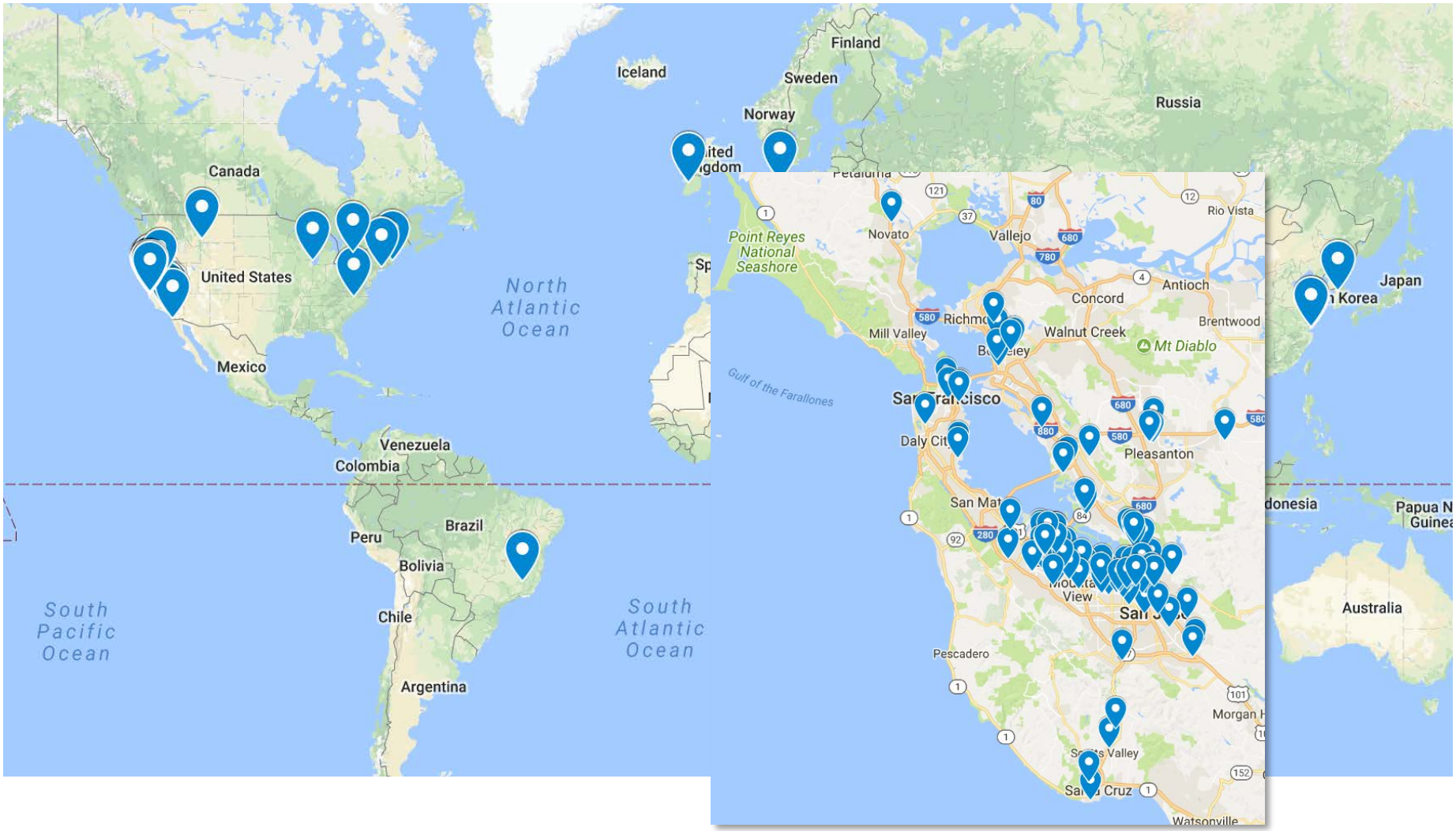
External Users during 2017/18



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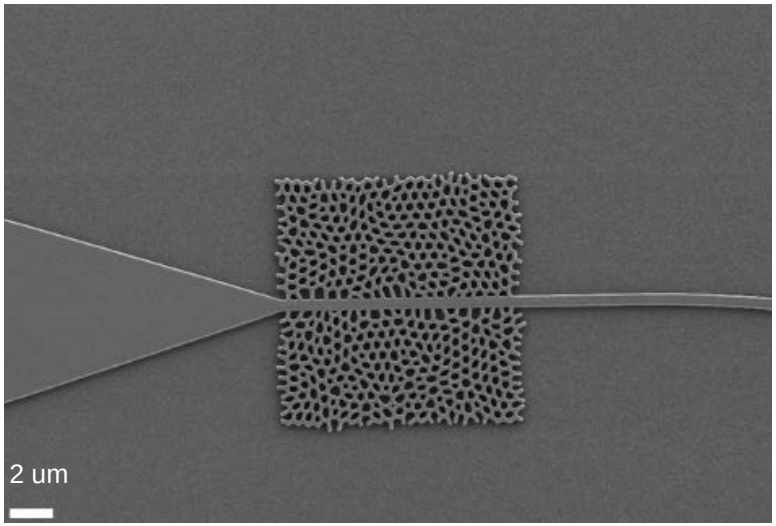
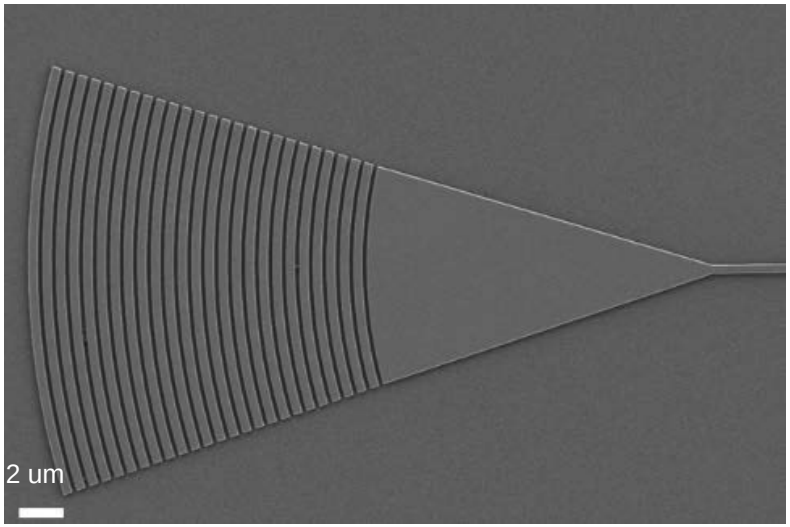
External User: San Francisco State University

- Motivation: develop submicron hyperuniform disordered photonic bandgap structure for photonic ICs
- Technique: fabrication of photonic crystal structure using EBL

Group Profile
- Prof. Weining Man (Physics & Astronomy)
- Research funded by NSF
- Why Stanford?
  - "*EBL writes in other labs were not able to handle the pattern*"
- http://www.physics.sfsu.edu



Waveguide running through Hyperuniform Disordered Structure (HUDS)



The couplers guide light through this waveguide. The HUDS pattern controls light propagation within the structure.

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Marketing Activities & User Outreach

- Website
  - Portal for facilities
- Brochure
- Direct contact (50+ faculty around Bay Area with emphasis on academic users with limited resources)
- Single Point of Entry
- Presentations and Vendor Exhibits
- ….

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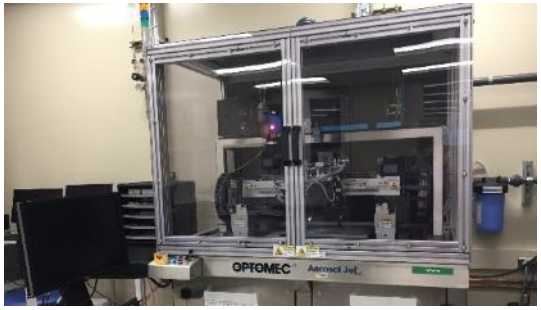
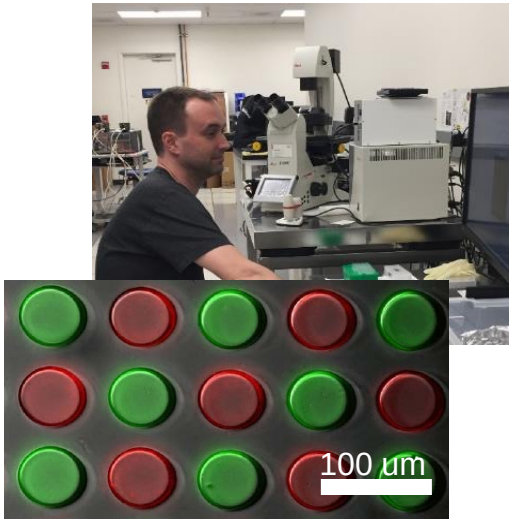
New Capabilities



The **Optomec Aerosol Jet AJ 300** is a non-contact, direct-write system with the ability to conformally print just about any ink, to feature sizes as small as 10 um.



The **Alveole PRIMO/Leica** is targeted at the bio and medical community. It allows to control the chemistry and topography of cell microenvironment and study their impacts on cell development, using a contactless and maskless quantitative photopatterning solution.

Durham Magneto Optics ML3 MicroWriter direct write system.

Nagase one-minute cleanroom: Within one minute of powering on, the volume between two laminar flow units becomes class 1, even in an ordinary office environment.

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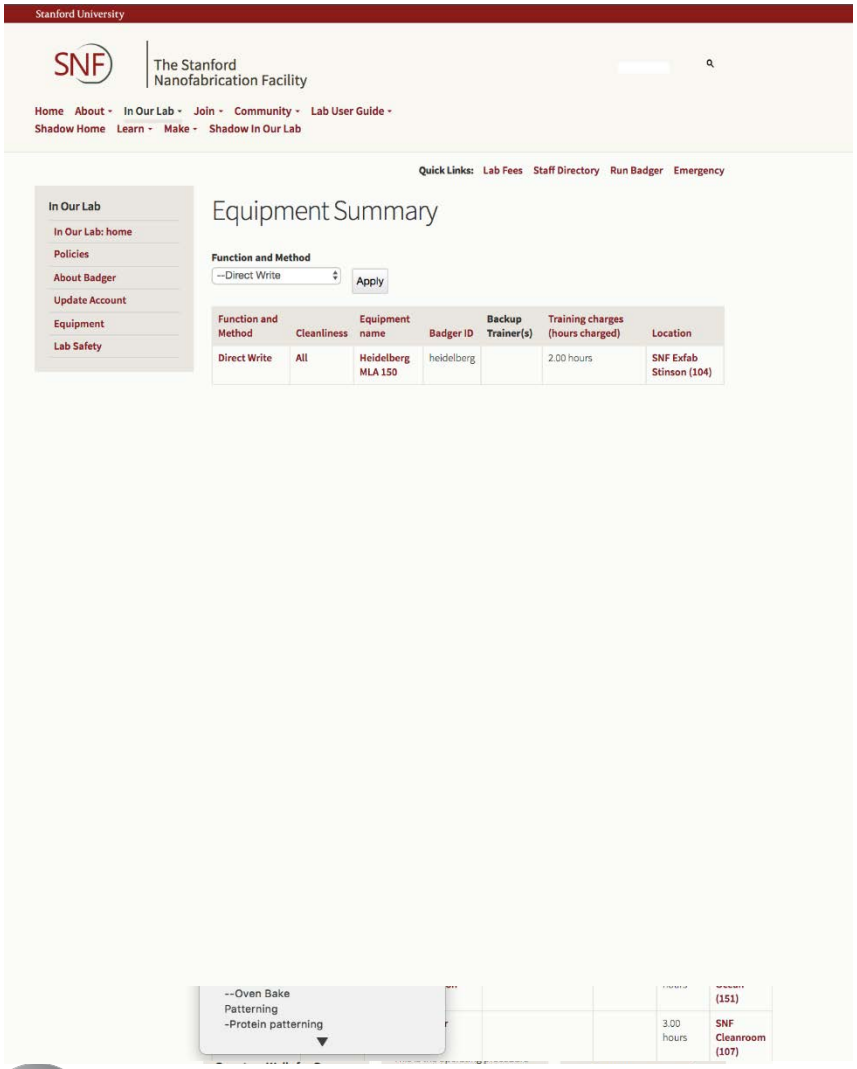
Develop and propagate a national model for **educational practices** that will help students and visitors become knowledgeable and proficient users of the facilities.

Online Learning

- User Education
  - Build online user guide researchers
    - processing & fabrication knowledge in the form of ‘nano nuggets’
    - Links to tools, recipes, processes
    - easily search and organize information



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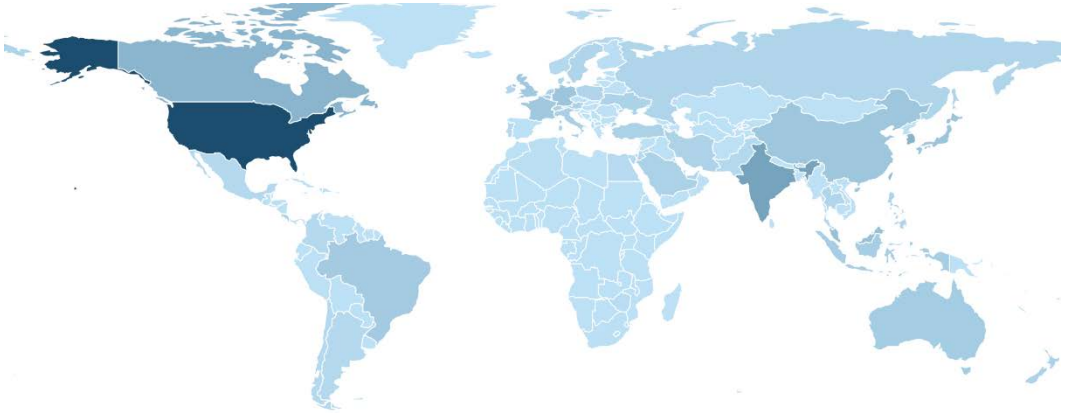
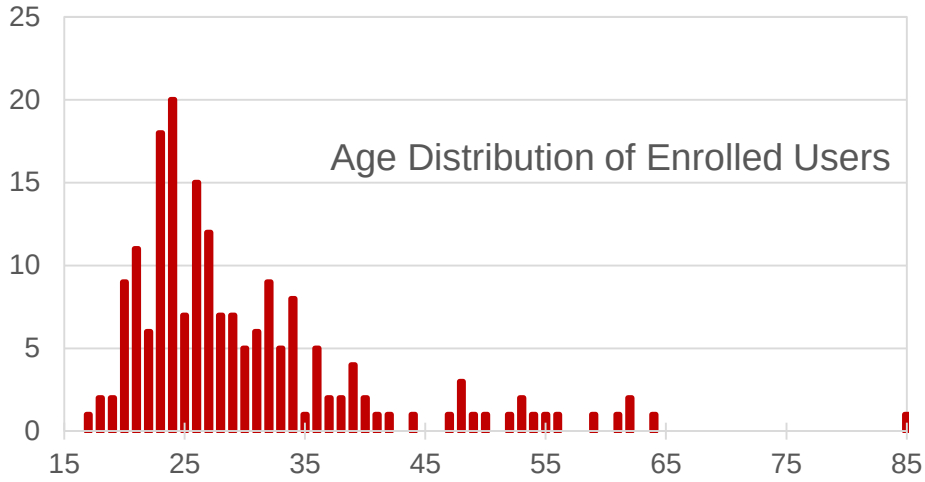
Online Learning: User Demographics

- Users in 35 countries
  - US (68%), India (7%), Germany (2%), Indonesia (2%), Columbia (2%)



- 265 enrolled users



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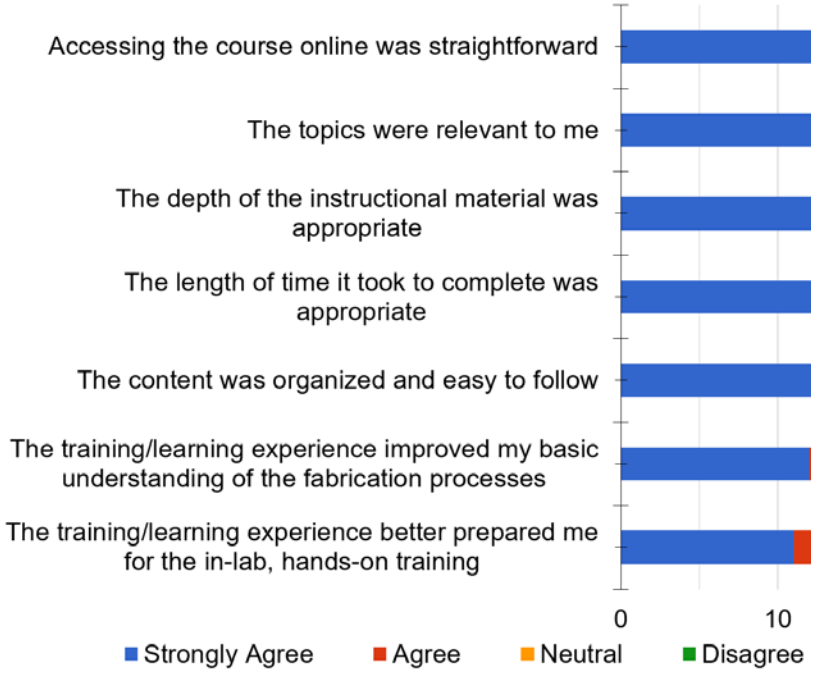
Online Learning: Evaluation & Feedback

Survey



Initial survey feedback is positive!

Knowledge Test

Q2. Which of the following samples are you least likely to analyze with XPS?

- Insulating polymer
- III-V solar cell
- Mammalian cells
- Soil sample

Q3. The surface-sensitivity of XPS comes from the fact that the Al Ka x-rays penetrate only the top few nanometers of the sample.

- True
- False

Q4. The binding energy of the F 1s peak in Teflon (a fluorinated polymer) would be _____ in CaF_2.

- higher than
- lower than
- the same as

Q5. If one were to tilt a sample such that the sample face was normal to the detector, you would enhance the signal from atoms at the surface.

- True

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Impact of E&O Activities

NNCI @ Stanford 2017-2018 Education & Outreach Events		
	Participants	
Classroom	382	23%
After School	149	9%
Teacher Workshop	12	1%
Public	842	52%
Nanodays	240	15%
Total	**1,625**	

USA Science & Engineering Festival, Apr 2018

Townley Grammar computer science students, Feb 2018

Canada College visit, Nov 2017

Bay Area Science Festival, Nov 2017

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E&O Highlight: Summer Institute for Middle School Techers (SIMST)

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

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

- Progress
  - 2nd NanoSIMST: June 25-28, 2018
    - 15 Bay Area teachers (5 from Title 1 schools)
  - Successful Fall 2017 follow-up with teachers from 1st NanoSIMST, reporting on classroom implementation of developed lesson plans

Program is new to NNCI
We are happy to share materials!

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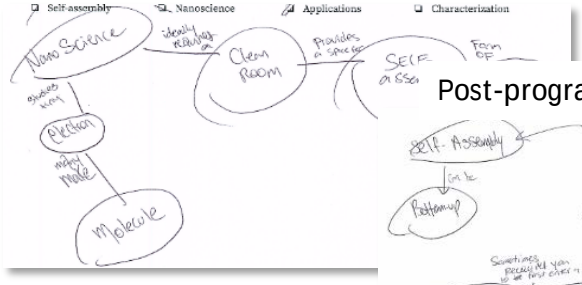
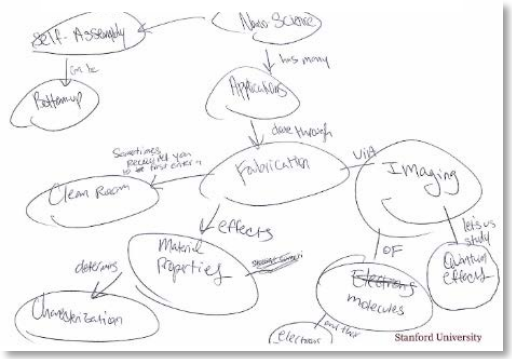
E&O Highlight: SIMST: Evaluation & Feedback

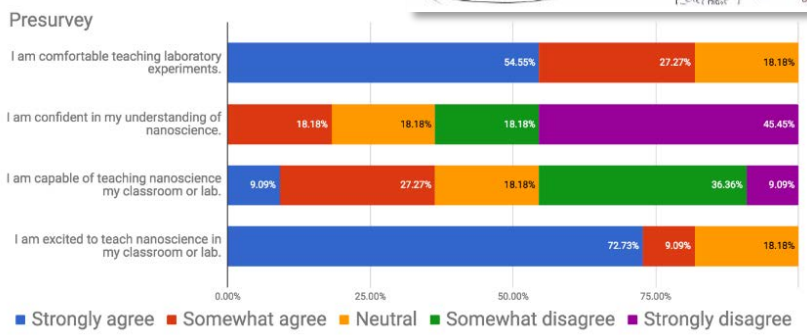
- Pre/post concept maps and survey
- Outcomes
  - **Concept maps**
    - Increased number of terms as well as appropriate connections used, showing **better and deeper understanding of nanotechnology**
  - **Survey**
    - large shift in their **confidence and excitement for teaching nanoscience**

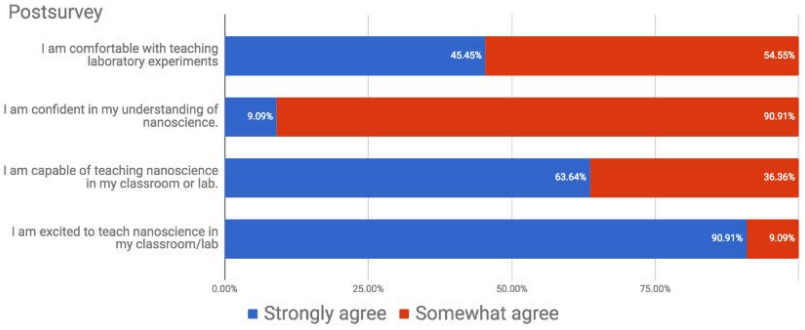
Pre-program concept map



Post-program concept map







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E&O Highlight: Partnership with Cal State University, East Bay (CSUEB)

- Fall 2015: Prof. Smith joins proposal for NNCI; CSUEB's first field trip to nanofacilities
- Fall 2016: Prof. Tandon visits with computer science class
- Spring 2017: Prof. Smith brings class to perform fabrication & characterization methods. Highlighted in Stanford Report

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JUNE 30, 2017

Local students explore science at the nanoscale in Stanford tours

Students, educators and industry professionals from outside Stanford learn about advanced tools and equipment at the Stanford Nanofabrication Facility and Stanford Nano Shared Facilities.

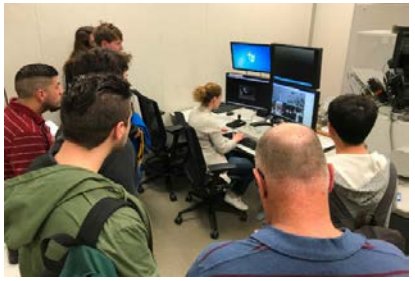
BY TAYLOR KUBOTA

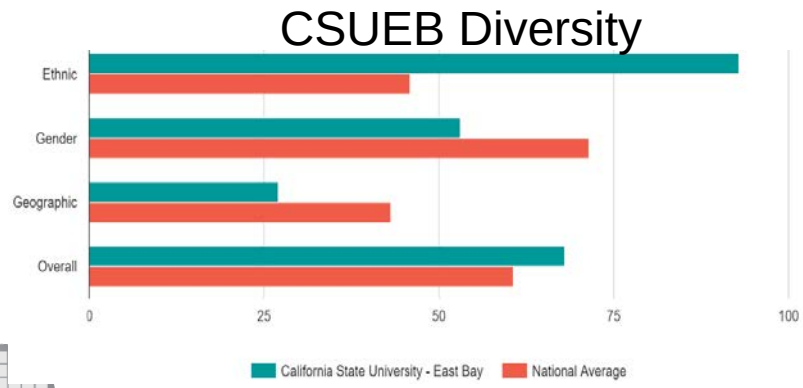
Ten people get into bunny suits, many for the first time in their lives. Under the hoods, their hair is in hair nets. Goggles cover their eyes, their gloves are tucked into their sleeves. For those with facial hair, that's netted too.

With all hair, lint and dust safely tucked out of the way, the students are ready to enter the Stanford Nanofabrication Facility. This particular group was part of a class from California State University, East Bay, co-taught by Ryan Smith, assistant professor of physics at CSU-EB, and Erik Helgren, associate professor and chair of physics at CSU-EB. The class visited as part of a collaboration between the two schools, designed to expose Cal State students to nanoscale science and engineering.

Students from California State University, East Bay, watch Uli Thumser prepare silicon photovoltaic cells during a tour of the Stanford Nanofabrication Facility. *(Image credit: Angela Hwang)*

"Many of these students have never seen a clean room. Many have an image from commercials or movies but they've never seen one firsthand," Smith said. "Having that up close experience has been very formative for some of the students. It's helped them get a deeper





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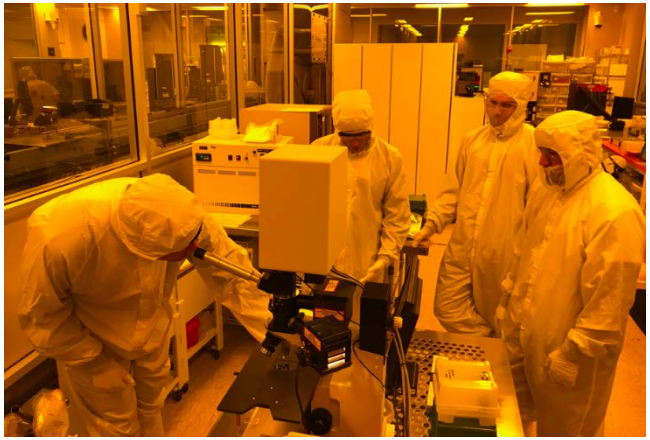
E&O Highlight: Partnership with Cal State University, East Bay (CSUEB)

- Summer 2017: CSUEB/SU submit educational journal article
- Fall 2017: Prof. Smith is onboarding as a user
- …



Introduction to Semiconductor Processing: Fabrication and Characterization of *p-n* Junction Silicon Solar Cells

Ryan P. Smith[1], Angela An-Chi Hwang[2], Tobias Beetz[2], and Erik Helgren[1]
[1]*Department of Physics, California State University - East Bay, Hayward, CA 94542, USA*
[2]*Stanford Nano Shared Facilities, Stanford, CA 94305, USA*

Abstract: We describe an upper-division undergraduate physics laboratory experiment that integrates the fabrication and characterization of a *p-n* junction in silicon. Under standard illumination, this *p-n* junction exhibits the photovoltaic effect as well as the typical diode rectification behavior when measured in the dark. This experiment introduces students to the physics of solar photovoltaics from the perspective of participating in the fabrication
measureme
lab can be a

In press at
AAPT PHYSICS EDUCATION
American Journal of Physics

NNCI Cooperative Network Activities

- Network-Wide
  - NanoDays
    - Presentations; Tours; School Visits; Mascot Race
  - Working Group Leads
    - Technical Education (Hwang)
    - Atomic Layer Deposition (Rincon – co-lead)
  - Working Group Participation
    - Optical Lithography (Tang)
    - Electron Beam Lithography (Tiberio)
    - Imaging & Analysis (Beetz)
  - NNCI Annual Conference

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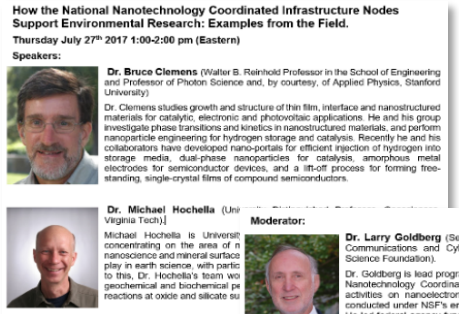
NNCI Cooperative Network Activities

- Multi-Site
  - 2018 NNCI Direct-write workshop at Stanford (July 2018)
  - USA Science & Engineering Festival, Washington, DC
  - NNCI Exhibit at TechConnect World
  - Poster presentation at NSF Grantees meeting
- On Behalf of the Network
  - Webinar: How the NNCI Nodes Support Environmental Research: Examples from the Field


How the National Nanotechnology Coordinated Infrastructure Nodes Support Environmental Research: Examples from the Field.

Thursday July 27th 2017 1:00-2:00 pm (Eastern)

Speakers:

Dr. Bruce Clemens (Walter B. Reinhold Professor in the School of Engineering and Professor of Photon Science and, by courtesy, of Applied Physics, Stanford University)

Dr. Clemens studies growth and structure of thin film, interface and nanostructured materials for catalytic, electronic and photovoltaic applications. He and his group investigate phase transitions and kinetics in nanostructured materials, and perform nanoparticle engineering for hydrogen storage and catalysis. Recently he and his collaborators have developed nano-portals for efficient injection of hydrogen into storage media, dual-phase nanoparticles for catalysis, amorphous metal electrodes for semiconductor devices, and a lift-off process for forming free-standing, single-crystal films of compound semiconductors.

Dr. Michael Hochella (Uni… Virginia Tech).]

Michael Hochella is Universit… concentrating on the area of n… nanoscience and mineral surface… play in earth science, with partic… to this, Dr. Hochella's team wo… geochemical and biochemical pa… reactions at oxide and silicate su…

Moderator:

Dr. Larry Goldberg (Senior Engineering Advisor in the Division of Electrical, Communications and Cyber Systems, Directorate for Engineering, National Science Foundation).

Dr. Goldberg is lead program officer and guided the competition for the National Nanotechnology Coordinated Infrastructure (NNCI). He has coordinated joint activities on nanoelectronics with the Semiconductor Research Corporation, conducted under NSF's emphasis area on Nanoscale Science and Engineering. He led federal agency funding for the 2012 National Academies study on Optics and Photonics: Essential Technologies for Our Nation. He serves as NSF member of the interagency Wireless Spectrum Research and Development Senior Steering Group, and represents the Engineering Directorate on the NSF program Enhancing Access to the Radio Spectrum (EARS). He also coordinates the Major Research Instrumentation (MRI) program for the Engineering Directorate.

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2018 NNCI Etch Workshop/ Symposium

- October 10-11, 2018 at Stanford University
  - Day 1 open to NNCI members only
  - Day 2 open to all
- Travel assistance up to $500 for 1 person from each NNCI site!
- NNCI Workshop organizing Committee
  - Vince Genova, Cornell, genova@cnf.cornell.edu
  - Ling Xie, Harvard, lxie@cns.fas.harvard.edu
  - Usha Raghuram, Stanford, usha@stanford.edu

Day 1 Agenda: Location – Paul G. Allen Building; Room 101X

NNCI Site Updates

- 8-8:30am: Breakfast
- 8:30-8:40am: Welcome
- 8:40-9:00am: Stanford
- 9:00-9:20am: Harvard
- 9:20-9:40am: Cornell
- 9:40-10:00am: Penn
- 10:00-10:10am: Break/Vendor Exhibit
- 10:10-10:30: Washington
- 10:30-10:50am: Georgia Tech
- 10:50-11:10am: Minnesota
- 11:10-11:30am: Texas
- 11:30-11:50am: North Carolina
- 11:50-12:10pm: Nebraska
- 12:10-1:30pm: Lunch/ Vendor Exhibit
- 1:30-2:15pm: V.Genova-Cornell-"Pulsed ICP etching of Si with HBr"
- 2:15-2:35pm: ASU
- 2:35-2:55pm: Louisville
- 2:55-3:15pm: Chicago
- 3:15-3:30pm: Break/Vendor Exhibit
- 3:30-3:50pm: Montana St.
- 3:50-4:10pm: Virginia Tech.
- 4:10-5:00pm: Open discussion
- 5:00-6:00pm: SNF tour for NNCI members
- 6:00pm: Dinner

Day 2 Agenda: Location – Paul G. Allen Building; Room 101X

Contributed Talks From Faculty Researchers, NNCI Researchers and Vendor Experts:

- 8:00-8:30am: Breakfast
- 8:30-8:40am: Director introduction
- 8:40-9:10am: Joydeep Guha-Applied Materials-"Semiconductor Scaling in the Era of Data Explosion"
- 9:10-9:40am: Haig Atikian-Harvard-"Directional Diamond Etching"
- 9:40-10:10am: David Lishan-Plasmatherm-"Plasma Dicing and F.A.S.T. CVD"
- 10:10-10:30am: Break/Vendor Exhibit
- 10:30-11:00: Keren Kanarik-Lam Research-"Atomic Layer Etching-Rethinking the Art of the Etch"
- 11:00-11:30: Ling Xie-Harvard-"Crystallographic Orientation Dependent RIE"
- 11:30-12:00: Peter Wood -Samco-"ICP Etching of Compound Semiconductor Devices"
- Noon-1:30pm: Lunch and Vendor Exhibits
- 1:30-2:00pm: Steve Vargo-SPTS- "Deep oxide etching"
- 2:00-2:30pm: Jim McVittie-Stanford-"Plasma Damage"
- 2:30-3:00pm: Demetrius Chrysostomou-Oxford Instruments-"Atomic Layer Etching"
- 3:00-3:30pm: Tony McKie-Memsstar-"Vapor Phase Etching of Sacrificial Materials-Maximizing Their Performance"
- 3:30-4:00pm: Break
- 4:00-4:30pm: wrap up, Q & A
- 4:30-5:30pm SNF &SNSF tours

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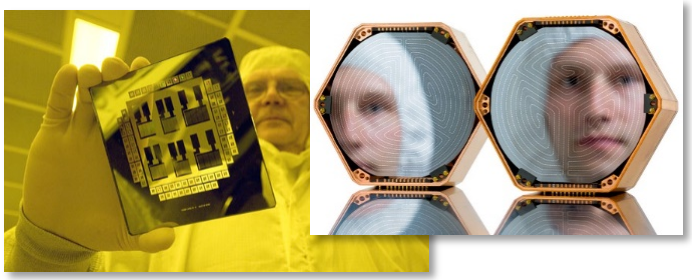
Thank you!

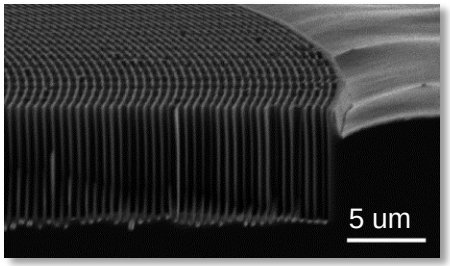
***nano@stanford* provides access to world-leading facilities and expertise in nanoscale science and engineering for internal users and for external users from academic, industrial, and government labs.**

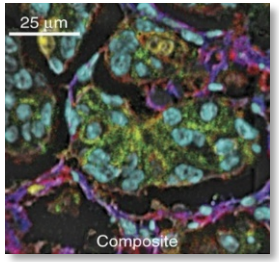


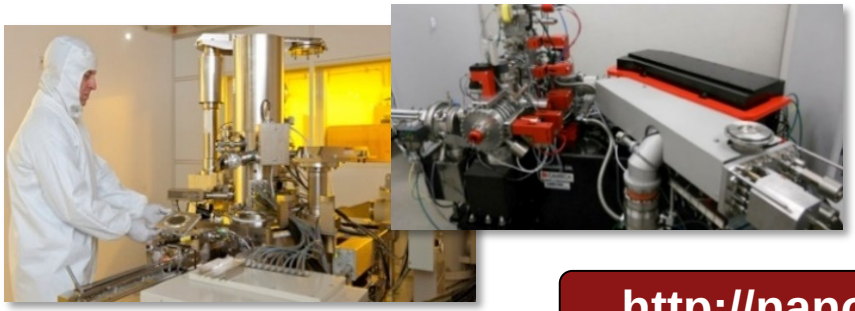
~1,350 annual users take advantage of a comprehensive array of advanced nanofabrication and nanocharacterization tools available within the Stanford Nano Shared Facilities (SNSF), the Stanford Nanofabrication Facility (SNF), the Mineral Analysis Facility (MAF), and the TCP-IMS Facility.

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

nano@stanford is supported by the National Science Foundation under award ECCS-1542152.

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Stanford University