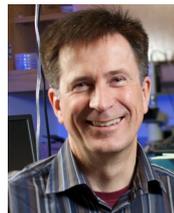




Northwest Nanotechnology Infrastructure (NNI)



University of Washington / Oregon State University
Site directors: Karl F. Böhringer / Greg Herman
October 24, 2019



Karl Böhringer, UW



Greg Herman, OSU



Maria Huffman, UW



Daniel Ratner, UW

Conference Attendees:

Northwest Nanotechnology Infrastructure (NNI)

NNI infrastructure builds on over 30 years of operating shared facilities:



- **WNF** (Washington Nanofabrication Facility)
largest publicly accessible cleanroom in WA
- **MAF** (Molecular Analysis Facility)
unique and custom-made analytical characterization



- **MaSC** (Materials Synthesis and Characterization Facility)
only publicly accessible cleanroom in OR
- **APSCCL (Ambient Pressure Surface Characterization Laboratory)**
only open lab ambient pressure XPS system on West Coast
- **ATAMI** (Advanced Technology and Manufacturing Institute)
shared 20,000 sf facility for startups on HP campus adjacent to OSU
- **OPIC (Oregon Process Innovation Center)**
process development facility, collaboration space with local industry



- Close working relationship with **PNNL (Pacific Northwest Nat'l Labs)**



NNCI NORTHWEST
NANOTECHNOLOGY
INFRASTRUCTURE



NNI: Staffing Updates

- New WNF director: Dr. Maria Huffman
 - Previously director, Lund Nano Lab, Sweden
 - Semiconductor / solar R&D veteran
- New MAF director: Dr. Lara Gamble
 - Research Professor, Bioengineering
- Jason Tauscher, WNF Program Operations Specialist
- Sarice Jones, WNF Research Engineer
- Dr. Samantha Young, MAF Senior Scientist/Engineer
- Dr. Rafik Addou, Surface Scientist and Nanoscale Analyst, OSU



➔ • *Job opening: WNF Senior Scientist/Engineer*

- Also note: Dr. Andrew Lingley, MONT Microfabrication Facility manager, UW alumnus, former WNF senior staff and WNF/MAF industrial user

NNI: Facilities and Tools

- **UW Buildings**
 - NanoES building
 - WNF renovation
- **WNF**
 - NanoScribe (NSF MRI)
 - 2 SPTS vapor phase etchers
 - Ritetrack SVG 90S coat and development track
 - Picosun ALD
 - N₂ glovebox (PZT, ALD precursors)
- **MAF**
 - Bruker D8 Discover XRD
 - Biolin Scientific Qsense QCMD
 - Bruker Hysitron TI980 Triboindenter
 - 2 Tecnai TEMs w/ cryo capability
 - FEI Apreo S LoVac SEM
- **Adjacent BioChem cryoEM Center**
 - FEI Titan Krios G3
 - FEI Arctica cryo-TEM
- **OSU Buildings**
 - Johnson Hall
 - Phased renovation of ATAMI
 - MaSC extension
- **Ambient Pressure Surface Characterization Laboratory**
 - Unique ambient-pressure x-ray photoelectron spectroscopy and scanning tunneling microscopy (AP-XPS/AP-STM)
- **ATAMI**
 - LPKF ProtoMat S103 micromill
 - LPKF MicroLine 2820P laser system

8-figure investments
in equipment
9-figure investments
in building infrastructure

NNI: WNF Facility and Tool Highlights

- 2 Picosun Atomic Layer Deposition (ALD) systems
 - Oxides: Al_2O_3 , SiO_2 , soon ZrO_2 , HfO_2
 - Nitride/metal: AlN , TiN , Pt , Ru
 - Thermal, upgrade to plasma possible
 - Installed in shared nitrogen-purged glovebox
 - Applications:
 - Low temp depositions on complex and high aspect ratio surfaces, porous structures, powders
 - In-house TSV process, plating seeds
 - Electronics, MEMS, biomedical devices
- Oxford PlasmaPro 100 Cobra
 - Cl etcher dedicated to PZT
- Glovebox with nitrogen environment
 - PZT synthesis
 - ALD precursor work



NNI: MAF Facility and Tool Highlights

- FEI Vitrobot Cryoplunge sample prep tool for cryoTEM, now installed and open for business.
- New FEI Apreo-S SEM with 500 Pa low vacuum mode.
- Instrumentation Plans
 - An *in situ* nanoindenter has been purchased by ME Prof. Lucas Meza.
 - An EBSD detector to be added to the Apreo SEM: funded by Earth and Space Sciences Dept. as part of new faculty hire for Dr. Cailey Condit.



Ellen Lavoie, MAF

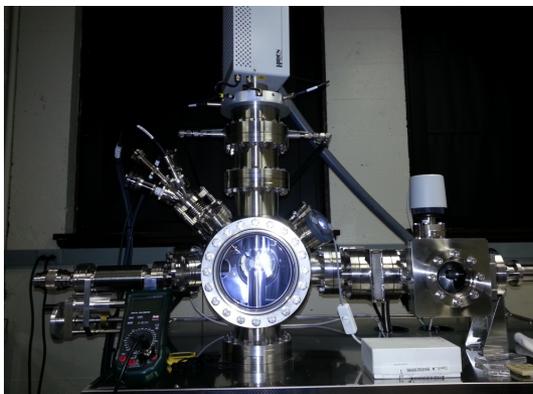


Scott Braswell,
MAF

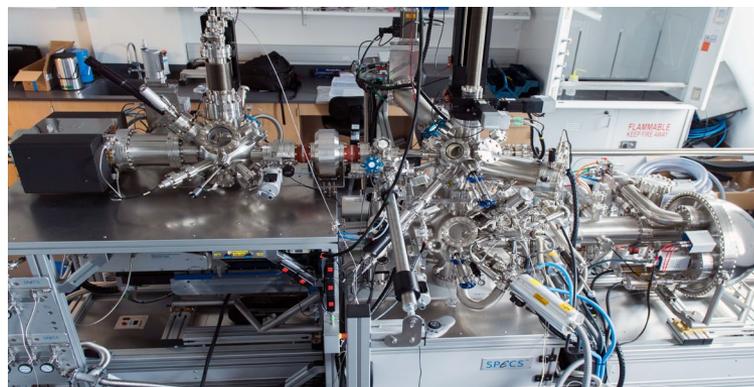
NNI: OSU Facility and Tool Highlights

- Ambient Pressure Surface Characterization Laboratory
 - Added TPD/ESD system to APSCS and started to include STM imaging from AP-XPS/AP-STM system
 - Hired Rafik Addou to manage surface characterization facilities

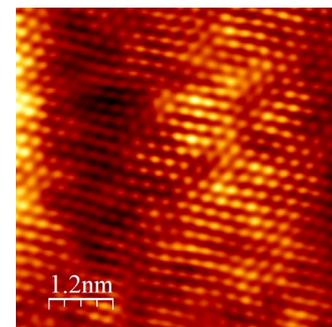
Hidden Temperature Programmed Desorption Workstation with Electron Stimulated Desorption



SPECS Ambient Pressure XPS and STM



STM image of industrial user sample



NNI: Principal Focus Areas

- **Integrated Photonics / Quantum:** large-scale integrated networks of photonic devices for cutting-edge optical communication, quantum computing, and biosensing
- **Advanced Energy Materials and Devices:** development and integration of benign materials for batteries and solar power
- **Bio-nano Interfaces and Systems:** devices and systems ranging from drug delivery to diagnostic sensors to bio-scaffolds
- **Additional evolving themes:**
 - Bio-3D-printing
 - “Augmented Humanity”

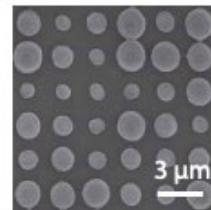
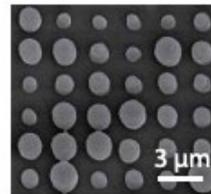
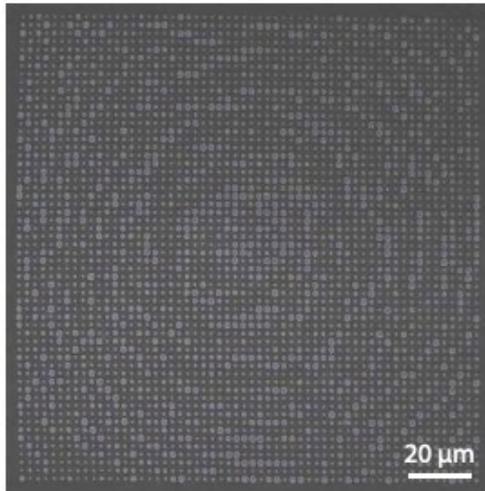
NNI Research Highlights: Photonics / Quantum Sciences

NSF'S
10 BIG IDEAS

Quantum Leap



Inverse Design of Metasurface and Computational Sensor



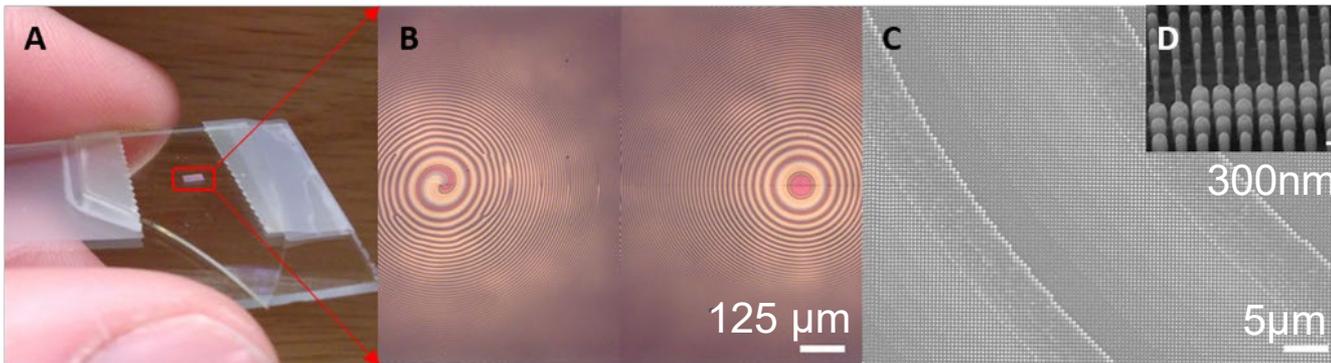
Majumdar Lab, UW

3D point spread function engineering via inverse design.

The metasurface is fabricated via Nanoscribe 3D printer (NSF-MRI).

Zhan et al., Science Advances, 2019

TUNOPTIX



By spatially multiplexing two metasurfaces, depth information can be extracted from a scene in a single shot.

NNI Research Highlights: Bio-nano Interfaces and Systems

NSF'S
10 BIG IDEAS

Growing
Convergence Research



Conversion of cellulose-containing structures into nano-cellulose via environmentally friendly oxidation process

Wollenberg Paper & Bioresource Science Lab,
School of Environmental & Forest Sciences, UW

Hop bine vessel element (undamaged cellulose structure) isolated from woody biomass through acetic acid/hydrogen peroxide maceration process.



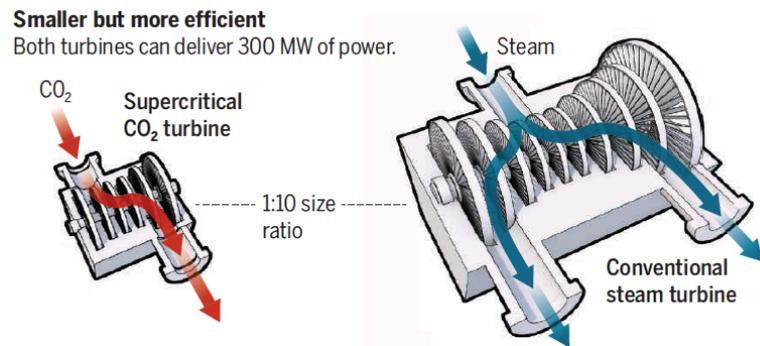
Kurt Haunreiter, Lab Manager

In preparation

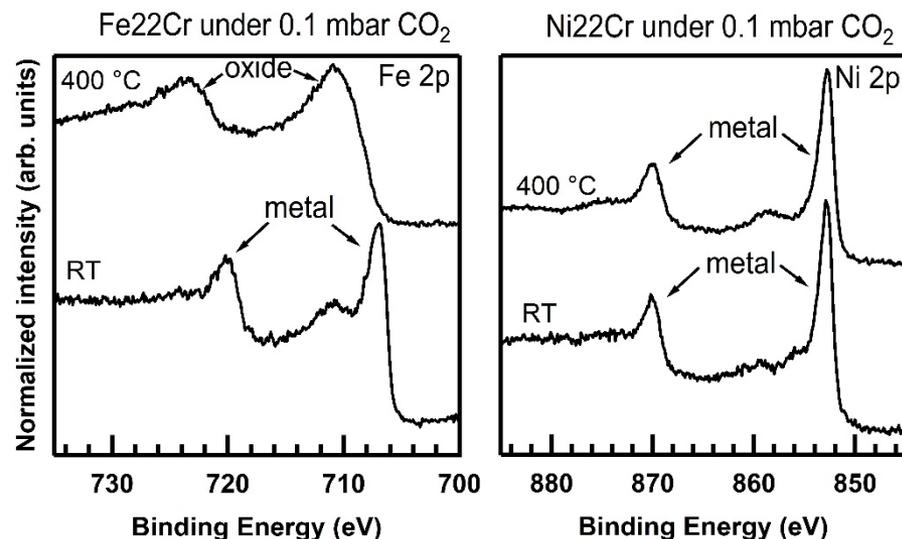


NNI Research Highlights: Advanced Energy Materials and Systems

Revealing Alloy Corrosion Mechanisms in High-Temp. CO₂



L. Irwin, Y.L. Moullec, Science 356, 805 (2017)



AP-XPS spectra of model Fe-based and Ni-based alloys containing 22 wt% Cr during exposure to CO₂ at room temperature and 400°C. The Fe-based alloy undergoes significant oxidation whereas the Ni-based alloy is completely unchanged at this temperature.

- Next-generation power plants require structural alloys resistant to corrosion in high-temperature CO₂.
- Ambient-pressure X-ray photoelectron spectroscopy provides fundamental understanding of the reactive surface species beginning at the very initial stages of oxidation and allows development of corrosion-resistant and economical alloys.

Richard P. Oleksak, National Energy Technology Laboratory.

Work performed at Oregon State University Ambient Pressure Surface Characterization Laboratory.

NNI: Education and Outreach

NSF'S
10 BIG IDEAS

NSF INCLUDES



- NNI E&O activities are reaching an annual audience of over 16,000 members of the regional K-Gray community
 - Classrooms
 - Cleanroom visits
 - Campus visits/events
 - STEM/career fairs
 - Regional National Nanotechnology Day
- Associated REU (Clean Energy Bridge to Research)
- Faculty/lab mentored research experiences
 - 27 OSU undergrad nano-related projects
- Mary Gates research symposium
- Workforce Development and First Nation Partnership
 - 37 paid student interns (13 women, 4 URM)
 - 2 Native American Student interns
 - Hosted Paschal Sherman Indian School @UW



NNI: Impact

- Site activity (6 months into Year 4)
 - user hours up 38%, user count steady
 - 22,383 internal, 14,051 external (about 2/3 small businesses)
 - about \$2M revenue (\$500k internal, \$1.5M external)
 - Industry impact survey – ongoing
- Publications (2018)
 - > 150 archival papers
 - > 30 patents
 - estimate: > 1000 conference papers
- Education & Outreach (Year 4)
 - K-to-gray activities reaching > 16,000 participants
 - workforce development > 60 undergrad researchers & assistants

NNI: Network Collaboration

Network-wide

- Participation in E&O, Workforce Development, Assessments subcommittees
- Etch Processing working group: sharing reports and best practices
 - e.g., XeF₂ wafer thinning, etching of unique materials: PZT, CdS, Ta
- In prior years, Vendor Relations working group: leveraging network purchasing power to obtain discounts and perform bulk purchases of high-cost items (e.g. e-beam resists)
- Participation in Nano Day activities

Multi-site

- User project support and staff technical interactions
 - Dense array TSV development (SDNI UCSD, SNSF Stanford, IEN GaTech, OSU)
- Workshop on Ambient Pressure XPS/STM (at OSU, with UW and PNNL participation)
- Conference exhibit booths at Transducers, SEMICON West, TechConnect
- ➔ • AccelNet proposal “Global Quantum Leap” – resubmission in preparation

On Behalf of the Network

- Equipment sharing/coordination with
 - MRSEC Molecular Engineering Materials Center – MEM-C
 - UW/PNNL DOE Center for the Science of Synthesis Across Scales – CSSAS
 - Northwest Quantum Nexus – NQN – a UW/PNNL/Microsoft collaboration

NNI/MANTH/NanoEarth/NNF: Panel Discussion

Topic: Aligning NNCI with National Research Priorities

- Priorities are defined “bottom-up” as well as “top-down”
 - → effective communication across **multiple** channels is essential
 - University/industry consortia, visits to Capitol Hill, ...
- Opportunities and threats from industry
 - Massive investments by major IT companies
 - IT interns are paid higher salaries than senior staff!
 - Challenging staff recruitment and retention
- Synergy between data revolution, materials research, AI
- Changing priorities require major capital investments
 - How will facilities evolve in response to “quantum”, 3D printing?
 - At the same time, “workhorse” tools must be maintained/updated