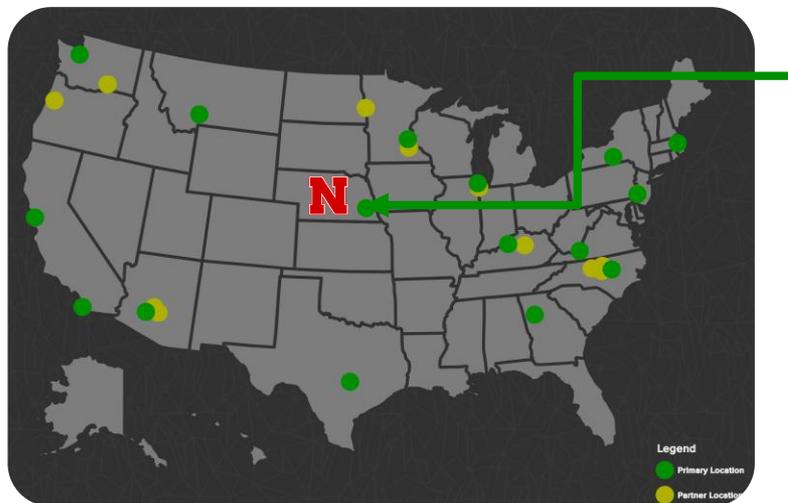


NEBRASKA NANOSCALE FACILITY: NNF

NNCI 2019 Annual Conference Harvard University

Christian Binek^{*}, Jacob John,[†] Terese Janovec[§]

^{*}Director: NNF & NCMN, [†]Coordinator & Program Manager: NNF, [§]E/O Coordinator: NNF



NNF
NCMN



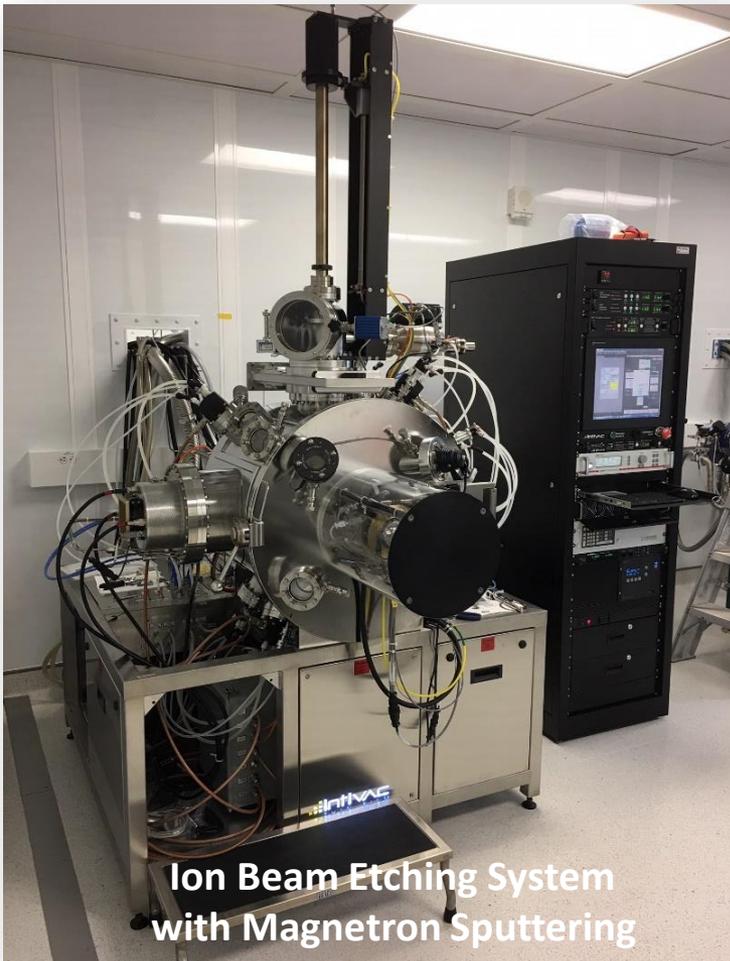
Specific Aims:

- Engage new university and industry users in our region in fabrication and characterization.
- Provide assistance to companies and start-ups
- Stimulate more and diverse students to enter engineering and science careers.

Voelte-Keegan Nanoscience
Research Center @
University of Nebraska

NNF: Facilities and Tools

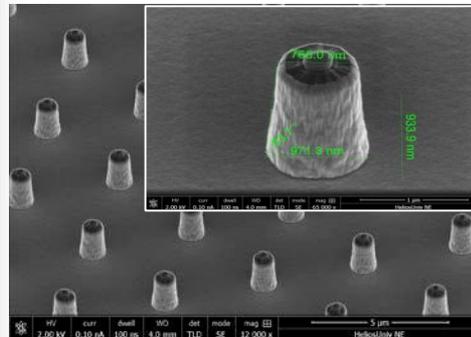
Ion-Beam Etching/Sputtering System Intlvac Nanoquest-II



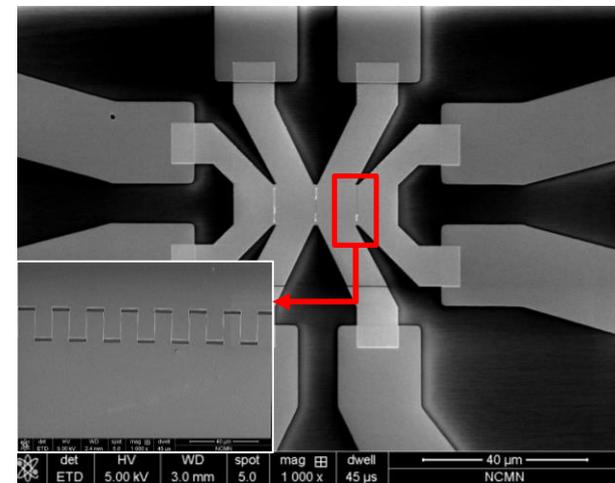
Ion Beam Etching System with Magnetron Sputtering

Characteristics

- ❖ Versatile platform for thin film milling and deposition
 - 14cm ion source
 - 11 magnetron sputtering guns for complex thin-film stack deposition
- ❖ UHV chamber with base pressure of 10^{-10} Torr
- ❖ Motion stage for multi-angle operation
- ❖ Stage heater 600° C



Ti nano-pillars fabricated with Ion beam milling



Nano-channel in Au film

NNF: Facilities and Tools

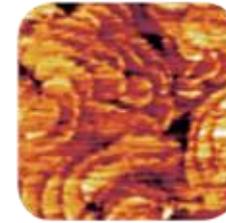
Attocube: Low-Temperature High-Magnetic-Field Scanning Probe Microscope



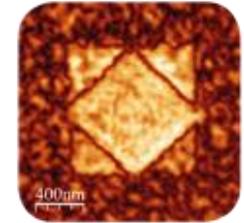
- ❖ NSF-MRI
- ❖ Temperature range: 4-300 K
- ❖ Magnetic field range: 0-9 T
- ❖ Multifunctional: AFM, MFM, PFM, ct-AFM



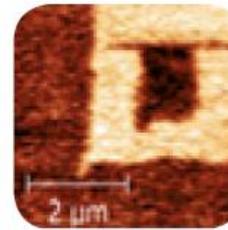
Surface
Topography



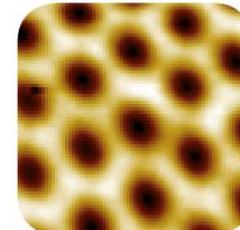
Conductivity
Map



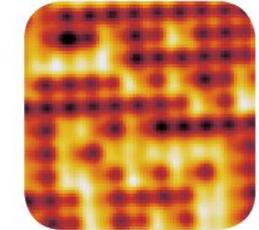
Ferroelectric
Domains



Magnetic
Nanostructures



Magnetic
Vortex



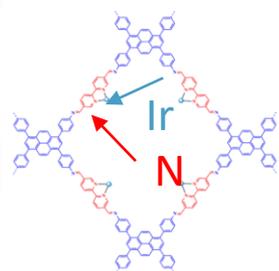
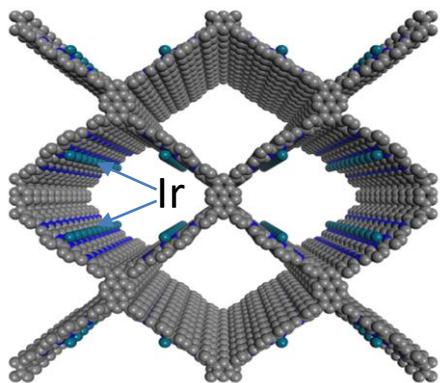
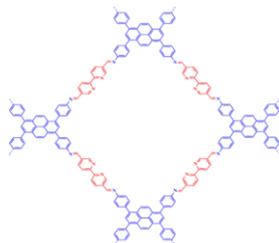
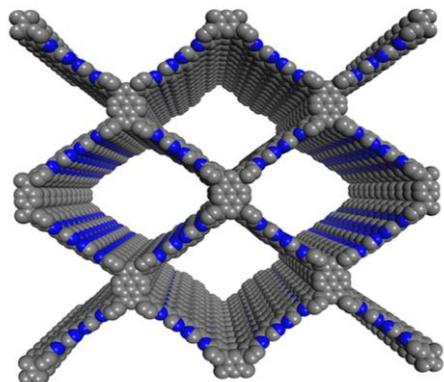
Magnetic
Domains

NNF: Research Highlight/External User

Iridium complex immobilization on covalent organic framework (COF) for effective C—H borylation



Univ. of South Florida using NNF **X-ray photoemission**

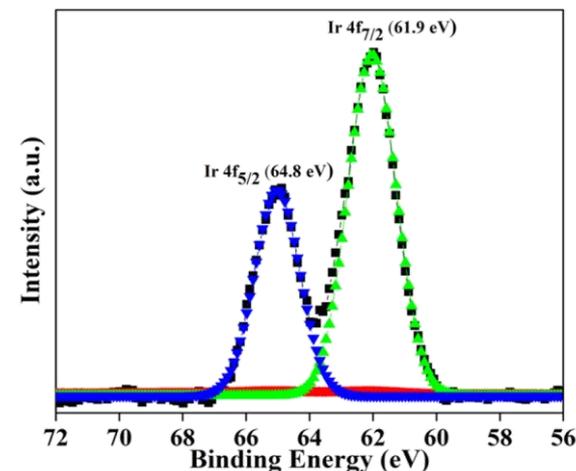


❖ XPS spectrum of Ir_{cod}(I)@Py-2,2'-BPyPh

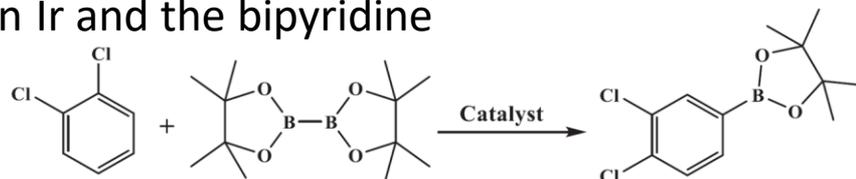
with binding energies of Ir 4f_{5/2} and 4f_{7/2} and blue shifted N 1s peak (not shown)



- Docking status of Ir
- Strong interaction between Ir and the bipyridine



Heterogeneous catalyst Ir_{cod}(I)@Py-2,2'-BPyPh for transformation of C-H bonds

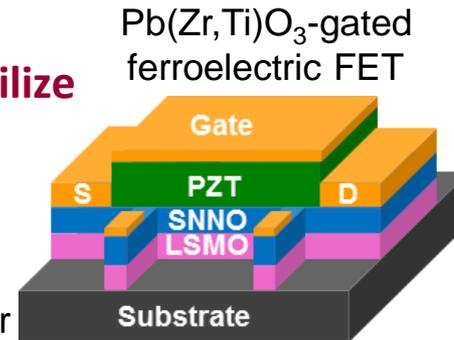


NNF: Research Highlight / Quantum Materials

Interfacial Charge Engineering for Ferroelectric Control of Strongly Correlated Oxides

UNL researchers from engineering and physics utilize NNF Lithography and Electron Microscopy

Interfacial charge transfer between $\text{Sm}_{0.5}\text{Nd}_{0.5}\text{NiO}_3$ and $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$ to enhance field control in a Mott transistor

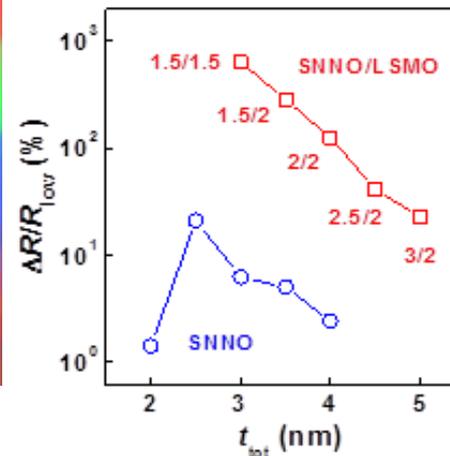
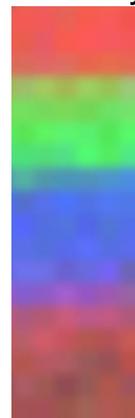
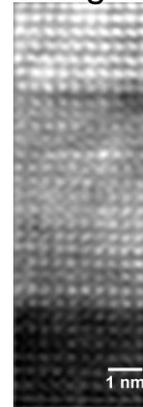
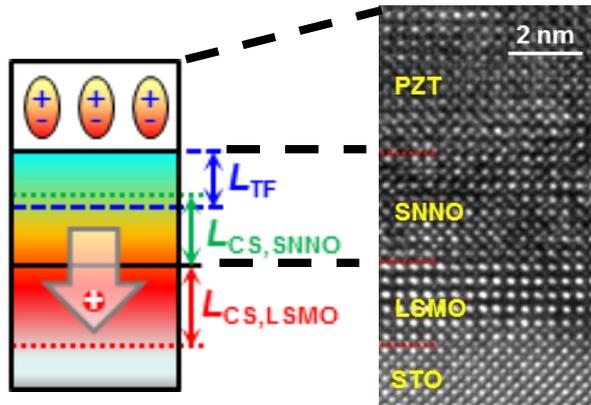


FEI Tecnai Osiris (S)TEM

Complex oxide heterostructures with atomically sharp interfaces

HAADF STEM image

w/EELS chemical map overlay



SNNO/LSMO bilayer channel exhibits up to 100X enhanced resistance switching

NNF: Diverse Education / Outreach and SEI

- **Traveling Nanoscience Exhibit**
14,000 total attendance



- 2 Museums in Iowa,
- 1 Community College,
- Tribal K-12 public school teacher/student workshop included
- 3 tribal community colleges scheduled for 2019-2020 targeting rural, underrepresented students.

- **Rain Remote Events**
190 students (14 schools)



RAIN Outreach

Nebraska Nanoscale Facility and 4-H Summer Partnership



Nebraska Nanoscale Facility (NNF), in partnership with the University of Nebraska Extension Office and 4-H program provided remote analysis services through RAIN to youth in Omaha this summer. Fourteen schools and various programs throughout Omaha participated in the Engineering with Nano Power experience. Students were introduced to how specialized nano equipment can be used to analyze environmental materials and new products being developed in our society. Using the XRF a variety of materials were examined and their compositions discussed in the classroom after utilizing the remote technical capabilities of the XRF. Youth were able to connect and relate with a real nanoscientist using the RAIN platform. A variety of questions helped students engage with the remote session such as: *Why is analyzing samples important? What can you do with the info? What does this analysis tell us and how do you become a nanoscientist?*

Over 190 students, 4th-8th grade, were able to experience the RAIN sessions, about 45% were females and 70% from underrepresented groups. We believe the RAIN sessions with enthusiastic teachers and scientists working together can have a positive impact on STEM identity formation and career orientation for youth!

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Students introduced remotely to

- nano equipment analysis
- Nanoscientists
- new products.

NNF: Diverse Education / Outreach and SEI

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Societal & Ethical Implication

NNF: E/O Assessment

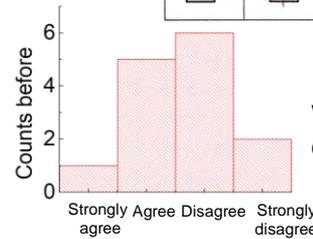
NNF Nanotech Workshop May 2018



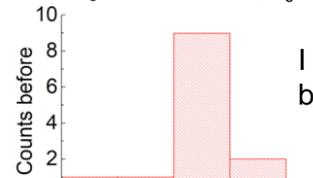
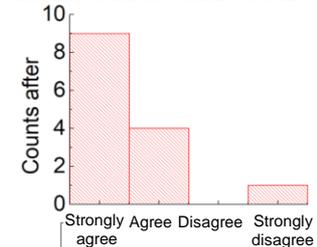
Attendees (30)	Responses (18)			
	Strongly agree	Agree	Disagree	Strongly disagree
I understand what work can be done using NNF.	61%	39%		
I understand how to become a user of NNF.	67%	33%		
I believe my work would benefit from using NNF.	56%	34%	5%	5%
I am interested in using NNF.	50%	45%		5%

Nanotech Facilities Minicourse May 2019

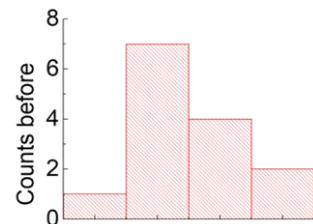
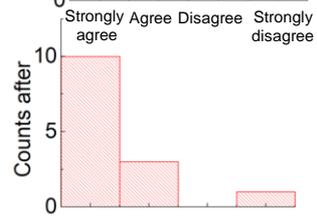
BEFORE the minicourse...					AFTER the minicourse...			
Strongly agree	Agree	Disagree	Strongly disagree		Strongly agree	Agree	Disagree	Strongly disagree
7	5	7	2	I understand what work can be done using NNF.	9	4	0	7
7	7	4	2	I understand how to become a user of NNF.	10	3	0	7
7	4	4	2	I believe my work would benefit from using NNF.	9	4	0	7
0	9	3	2	I am interested in using NNF.	4	7	0	7



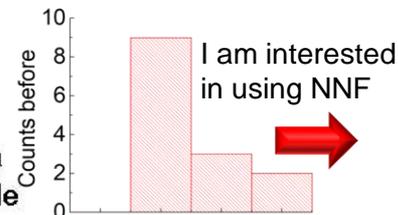
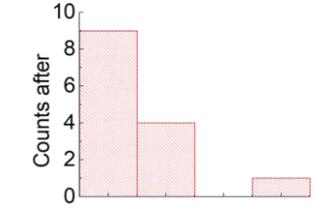
I understand what work can be done using NNF



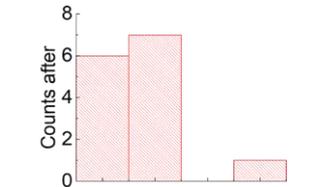
I understand how to become a user of NNF



I believe my work would benefit from using NNF

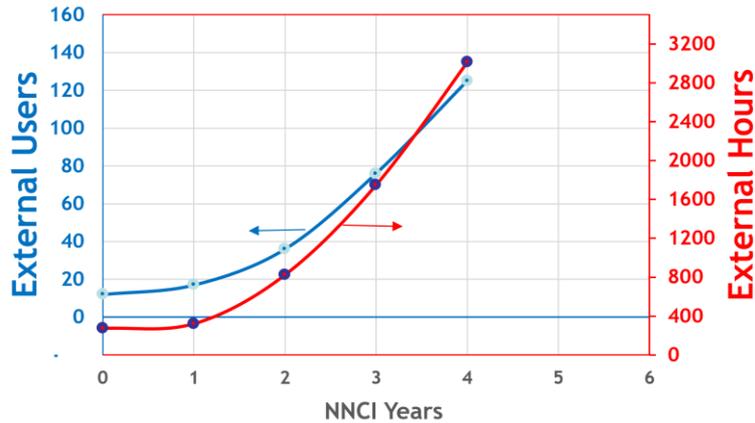


I am interested in using NNF

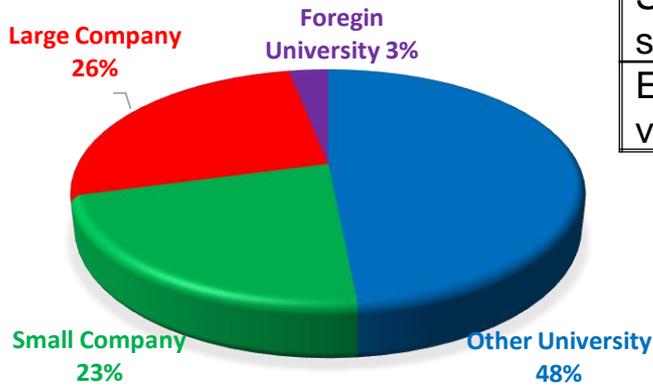


NNF: Impact

- Increased external use by # and hours

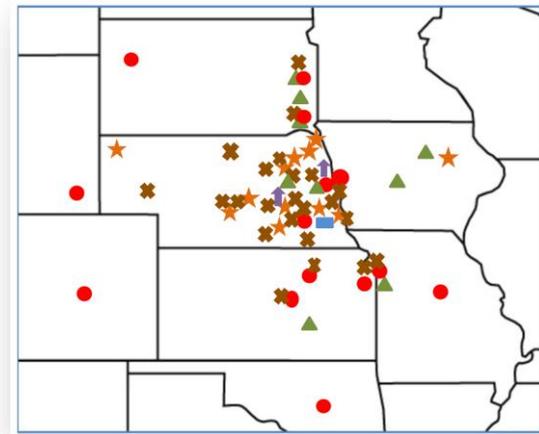


EXTERNAL USER AFFILIATION OCT 18 - MAR 19



User Assessment	
Satisfied with service	94%
Excellent or very good	80%

- Education and Workforce Development Activities



- After School Programs (Lincoln); Women's Undergraduate Conference (Lincoln); High School Student Camps (Lincoln); NanoDays (Lincoln)
- ▲ REU/Prof/Student Pair Program (9 Univ.)
- ★ Traveling Nanoscience Exhibit (10 museums/1 K-12 tribal/1 Community College)
- ↑ Nanotech Teacher Workshops/Conferences (Omaha, Lincoln, Winnebago)
- Minicourse (participants from 14 univ.)
- ✕ Nanotech Workshop (participants from 22 cities)

❖ 3 undergraduate outreach students go on for grad degrees @ Ohio State, Rice, and UNL

NNF: Impact on Local Industry

• Monolith Materials in Hallam, NE



- ❖ Clean production of carbon black and hydrogen from natural gas
- ❖ Hydrogen gas → Clean generation of electric power
- ❖ 125 M Watt
- ❖ CO₂ emission reduced by 1.1 M tons/yr.
- ❖ \$ 50M
- ❖ 300 employees



• NE Companies using NCMN/NNF Facilities



“Monolith Materials has been pleased to work with NCMN scientists as we partner with NPPD in building a hydrogen-burning power plant in Hallam. The electron microscopy analysis of carbon nanoparticles is important for our company as we develop the technology to manufacture these nanoparticles for inks, paints, electronics, and UV absorbers.”

... Ned Hardman, Ph.D.
Vice President,
Product Development



NNF: Network Collaboration

Network-Wide

- ❖ NNCI Metrics Committee (David Sellmyer)
- ❖ NNCI Workforce Development Committee (Terese Janovec, David Sellmyer)
 - Contributed to study of local CC needs/interests
- ❖ K-12 Teachers/RET, Students, and Community Outreach Committee (Terese Janovec)
- ❖ NNCI Working Group Members (J. Hua, S. Valloppilly, L. Yue, J. Li, T. Janovec)
- ❖ NNCI 2018 Annual Conference (David Sellmyer, Christian Binek, Terese Janovec)
- ❖ NANODAYS 2018 in Lincoln hosted (Terese Janovec)
- ❖ RAIN Network (Anand Sarella, Terese Janovec)

RAIN Outreach

Nebraska Nanoscale Facility
and 4-H Summer Partnership



Multi-Site

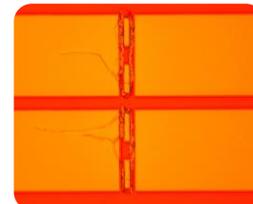
- ❖ NNCI NSF RET Proposal (Jeff Shield, S. Ducharme)
 - Six-week summer research experience
 - ASU, GA Tech, MN, Louisville, NE
- ❖ Lithography Workshop at Stanford (Jiong Hua)

On Behalf of the Network

- ❖ NNCI REU student from Japan hosted, Summer 2018 (attended NNCI REU convocation)
- ❖ NNCI REU students (2) sent to Japan, Summer 2017 & 2018

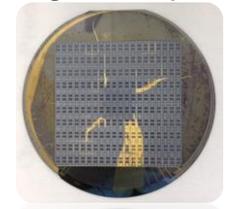
Exchange of problems/solutions

Resist damage after
100eV ion beam milling



difficulty to remove
remaining resists

Si wafer (450µm) etch through
using Bosch process



remaining resist SPR220-7
too thin to protect structures

NNF: Panel Discussion

- Aligning NNCI with National Research Priorities

- ❖ Effective change and evolution is often bottom-up driven

➔ There should be a user demand for new tools and services triggered by nat. research priorities backed up by funding opportunities such as NSF's quantum leap

➔ NNCI must recognize those demands/trends early and react wisely with strategic decisions

Challenge: Distinguish a transient "hot topic" or a repackaging of traditional approaches from a new long term trend

- ❖ NNF recognizes trend in materials science toward quantum materials and emerging quantum phenomena

- ❖ Fab., characterization, simulation and device implementation come with challenges

➔ Do all/most NNCI centers need He recycling and liquification?

- ❖ If so, how to pay for a central system? Is a full-time technician needed?

- ❖ Are closed cycle refrigerators such as the EverCool system more cost effective (\$150k +\$25k every 3 yr.) alternatives?

➔ Are new computational tools needed to better predict properties of, e.g., strongly correlated electron systems?