UEC On-Site Meeting 8/10/16
In Person Attendees: Molly, Eric, Evgheni, Kathrin, Hans, Brad
Virtual Attendees: Lane, Megan, Nazanin, Rafael

Meeting called to order at 6:00 pm

1. **Record meeting attendance (Brad)**
2. **Presentation of equipment changes/issues (downtime) and Director needs in 2017 (Hans)**

    - See attached slides (Welcome to the 2016 CNMS User Meeting)
    - When are new project PIs emailed asking if they need help starting their projects?

4. **User Meeting Final Discussions (Molly)**
    - See attached slides

5. **Town Hall Agenda Overview (Molly)**

    - See attached slides (Welcome to the 2016 CNMS Town Hall Meeting)
    - User meeting moved to a tier 1 responsibility

6. **Goals for 2017: 6- month, 12- month horizons (Molly)**

    - See attached slides (Welcome to the 2016 CNMS Town Hall Meeting)
    - Identify needs of users, reviewers, and staff for online proposal portal
    - Implement online proposal system
    - Organize 2017 shared user meeting with SHUG Aug 1-2, 2017. (plenary speakers should be finalized in November)

7. **Identify improvements in UEC operation: telecons, other tools (Molly)**

    - Everyone agreed Bluejeans is working well and wants to continue using it for monthly meetings.

8. **Schedule for Sept-January telecons (Brad)**

    - Everyone needs to complete the survey so a day/time can be agreed on.

9. **Student Poster Award Winner Announcement to UEC (Evgheni & Eric)**

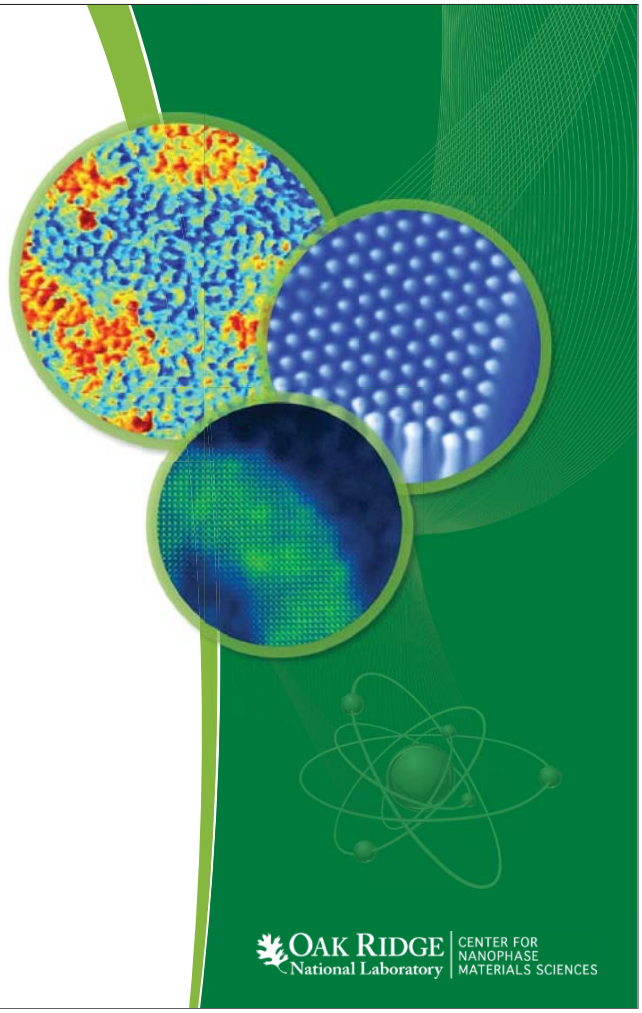
    - Scores were still being tabulated

Meeting adjourned at 7:54 pm.

Welcome to the 2016 CNMS User Meeting

Hans Christen

CNMS Director



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Thank you, UEC!

- This meeting belongs to you as users.
- This meeting is your chance to speak up.
- Interactions with other users illustrate opportunities and successes

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CNMS User Executive Committee

- Chair: Marian (Molly) Kennedy (Clemson U.)
- Vice Chair: Lane Martin (UC-Berkeley)
- Secretary: Yang Zhang (U. Illinois)
- Past Chair: Nazanin Bassiri-Gharb (Georgia Tech)

- Eric Formo (U. Georgia)
- Enrique Gomez (PSU)
- Megan Robertson (U. Houston)
- Rafael Verduzco (Rice)
- Alex Belianinov (CNMS)
- Evgheni Strelkov (NIST)
- Kathrin Dörr (Halle)

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3:00p	Wednesday, August 10	**Registration Opens**	
4-6p	**Poster Session and Student Poster Competition** - SNS Atrium		
7:30a	Thursday, August 11	**Registration** - Posters available for viewing	
8:00	**WELCOME AND ANNOUNCEMENTS**- *Iran Thomas Auditorium, SNS* **Hans Christen**, CNMS Director		
8:20	**PLENARY LECTURE I** "Opportunities and Challenges in Printed Electronics" **C. Daniel Frisbie**, *University of Minnesota*		
9:05	**Poster Session with Coffee**		
	Track A *SNS Auditorium*	**Track B** *Room C-156*	**Track C** *Room C-152*
	Directed Assembly of Materials and Interfaces ***Chairs:*** *Enrique Gomez, Scott Retterer*	**Observing and Controlling Matter at the Nanoscale** ***Chairs:*** *Eric Formo, Stephen Jesse*	**Exploring Electronic and Ionic Processes in Functional Materials** ***Chairs:*** *Evgheni Strelcov, An-Ping Li*
9:50	**Bharat Jalan, U. Minnesota**	**Matthew McDowell, Georgia Tech**	**Ilya Sochnikov, U. Connecticut**
10:25	Brett Lewis, U. Tennessee	Maxim Ziatdinov, ORNL	Dipanshu Bansal, ORNL
10:45	Enrique Gomez, PSU	Liangbo Liang, ORNL	Valentino Cooper, ORNL
11:05	**James Rondinelli, Northwestern U.**	**Eric Stach, BNL**	**Xiaoguang Zhang, U. Florida**
11:40	Lunch on your own; Posters available for viewing		
1:00	**Bryan Boudouris, Purdue U.**	**Yong Chen, Purdue U.**	**William McGehee, NIST**
1:35	Rachael Ford, Caltech	Benjamin Lawrie, ORNL	P. R. Pudasaini, U. Tennessee
1:55	Roger Narayan, NCSU	Travis Humble, ORNL	Yang Zhang, U. Illinois
2:15	Break		
2:40	**Joshua Sangoro, U. Tennessee**	**Jaan Mannik, U. Tennessee**	**Marina Leite, U. Maryland**
3:15	Sophia Suarez, Brooklyn College	Jingjie Zhang, U. Virginia	Viktoriia Babicheva, Georgia State U.
3:35	Break		
4:00	**User Group Town Hall Meeting** - Iran Thomas Auditorium, SNS *including announcement of Student Poster winners*		
4:30	**PLENARY LECTURE II** "Revising the Narrative of Ceramic and Ceramic-Polymer Composite Processing to a Fast, Sustainable Manufacturing Approach" **Clive Randall**, *The Pennsylvania State University*		
5:15	Adjourn / Closing Comments		

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News from CNMS

- Triennial Review held April 2016
  - Included review of input from previous user meeting (UEC report included in review documentation)
  - Included review of user satisfaction survey
  - User and UEC representation at review
    - User talks from Jonathan Boreyko (VT), Harald Plank (Graz), Lane Martin (Berkeley), and Vincent Meunier (RPI)
  - Highlighting importance of connections to SNS/HFIR

- Alignment of in-house research along clearly defined "themes"
  - Input from the Scientific Advisory Committee, which includes UEC representation
- Significant investments in CNMS equipment
- Additional ORNL investments in equipment

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Defining the in-house research to focus on key challenges in nanoscience

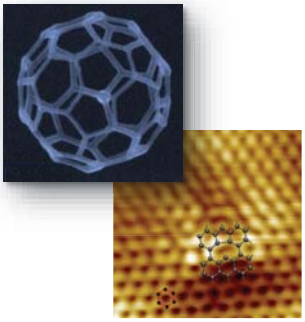
Understanding and Controlling Formation

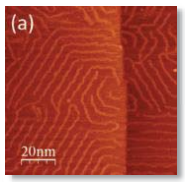
How do we place individual atoms where we want them to be

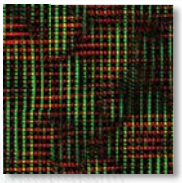
How do we create or eliminate individual defects

How do we control and direct self-assembly

How do we reproducibly and scalably produce complex and hierarchical matter







How do defects and nanostructure influence energy transport and energy conversion (electrons, photons, excitons, phonons)?

How can we understand and direct mass transport (ionic motion, deformations, droplets)

Understanding and Controlling Function

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Defining the in-house research to focus on key challenges in nanoscience

Imaging and local manipulation coexist

lerstanding and Controll
Formation

Guided self-assembly is key to creating scalable approaches

How do we place individual a
where we want them to l

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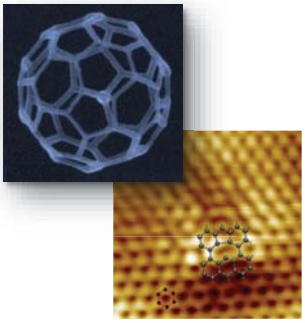
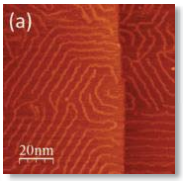
ow do we control and direct self-assembly

How do we create or eliminat
individual defects

How do we reproducibly and scalably produce complex and hierarchical matter





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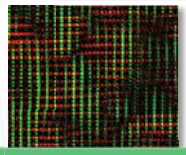


Nanostructures are dominated by heterogeneities

lerstanding and Controll
Function

Electromechanical phenomena are most critical at the nanoscale

The four CNMS research themes

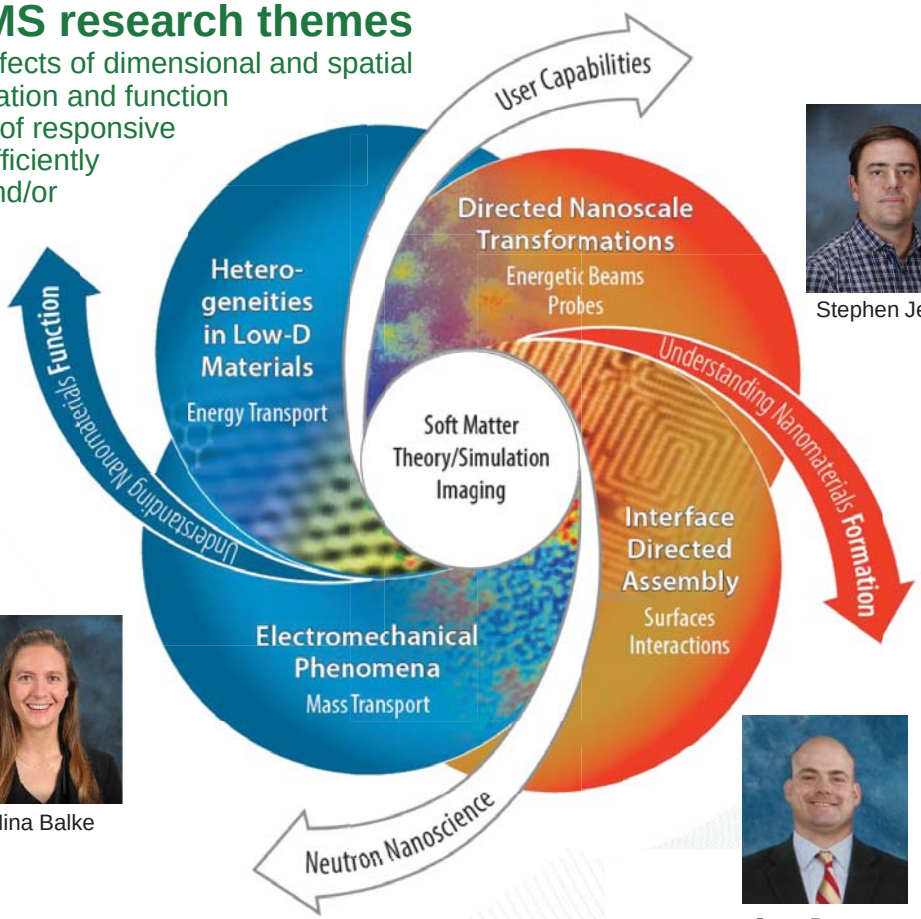
Understanding the effects of dimensional and spatial confinement on formation and function to enable the design of responsive nanomaterials that efficiently capture, transport, and/or convert energy

An-Ping Li

Stephen Jesse

Nina Balke

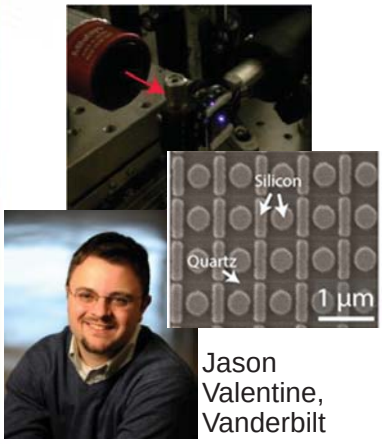
Scott Retterer



Our user community is much broader than our in-house research

Metamaterials for advanced applied photonics

Blue light generated by non-linear interaction of near infrared light with periodic lattice of nanofabricated structures.

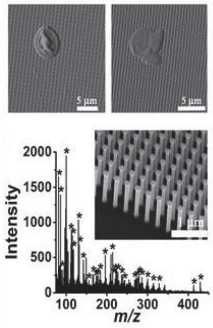


Jason Valentine, Vanderbilt

Work at CNMS included the fabrication of the structure and some optical characterization.

Single cell mass spec

LDI-MS analysis of single cells (~30 fL volume) on nanofabricated post arrays.

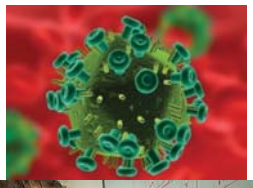


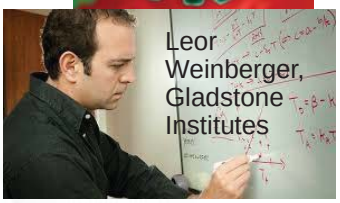
Akos Vertes, George Washington University

The researchers performed nanofabrication and device characterization at CNMS. The work led to the commercial availability of the REDIchip.

Understanding proviral latency in HIV

Understanding how stochastic fluctuations in small molecular populations lead to proviral latency in HIV, the primary clinical problem in AIDS treatment





Leor Weinberger, Gladstone Institutes

Work at CNMS focused on understanding the fluctuations using time-lapse noise spectroscopy techniques developed at the CNMS.

R. Dar *et al.*, *PNAS* (2012)

9 *Y. Yang et al., Nano Letters (2015)*

B. Walker et al. *Angew. Chem. Int. Ed.* (2013)

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Equipment additions (FY15,16)

- Soft matter:
  - Dielectric spectroscopy
  - Rheometer
  - RSA-G2 analyzer
  - MALDI-TOF
- Electron microscopy:
  - Titan upgrades:
    - Protochips Atmosphere 200
    - EDS detector
    - Gatan OneView camera
  - Camera for Nion UltraSTEM 100
- Functional measurements
  - miBot manipulators
  - QuantumDesign PPMS
  - Raman replacement/upgrade
- Scanning probes:
  - Controller for VT-STM
  - Interferometer for Cypher AFM
  - Unisoku upgrade for high-field STM
- Chemical imaging:
  - ANASYS NanoIR2
  - Mass spectrometry for HIM
  - MALDI-TOF
- Computing
  - Cray CS4000
- Nanofab
  - 3D Direct-Write NanoScribe
  - Parylene coater
  - AFM
  - SUSS MicroTec contact aligner

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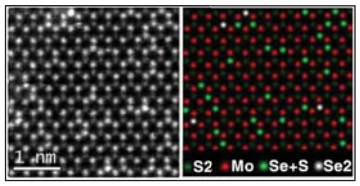
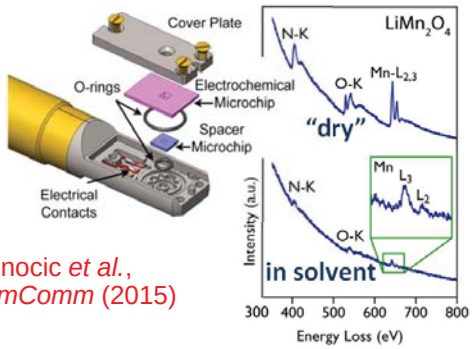
Aberration-corrected Scanning Transmission Electron Microscopy (AC-STEM) and Electron Energy Loss Spectroscopy (EELS)

Z-contrast STEM and image analysis provides an atomic-scale map of individual dopants

Y. Gong *et al.*, *Nano Letters* (2014)



Quantitative EELS measurements are possible in a liquid cell



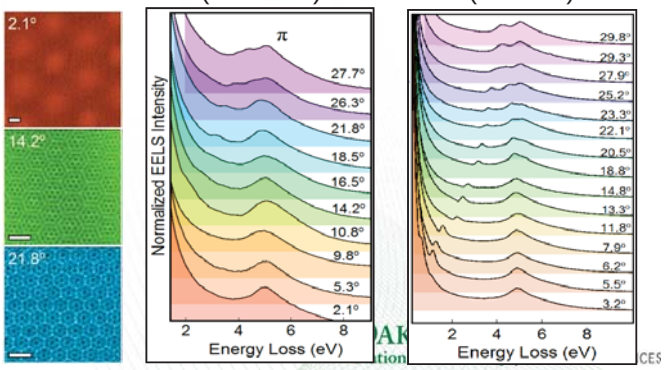
R. Unocic *et al.*, *ChemComm* (2015)

ORNL's new MAC-STEM (monochromated AC-STEM) will enable quantitative imaging of optical excitations and phonons at the nanoscale

With ~1Å probe and <10meV energy resolution, the MAC-STEM becomes the nanoscale/real-space counterpart to neutron scattering

Example: Imaging optical excitations in bilayer graphene

Non-Monochromated (350 meV) | Monochromated (60 meV)



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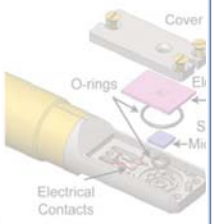
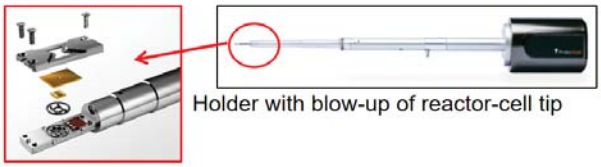


R. Unocic *et al.*, *ChemComm* (2015)

Upgrades to FEI Titan-S TEM/STEM

Protochips Atmosphere *In Situ* Gas Reaction Holder:
- closed-cell configuration for flowing gas mixtures
- temperatures up to 1000°C
- pressures to 1 atm.



Holder with blow-up of reactor-cell tip

Gas manifold for controlled delivery of up to 3 gases or specialized gas mixtures

Gatan OneView CMOS Camera:
- 4k X 4k pixels at full resolution
- high speed for *in situ* image capture
- Flexible trade-off of resolution vs. frame rate
  25 fps @ 4k X 4k pixels to 300 fps @ 512 x 512 pixels

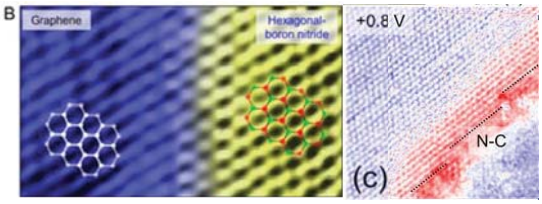
EDAX energy dispersive X-ray spectrometer (EDS)
- temporary 30mm^2 SDD currently installed - waiting for upgrade to 60mm^2 active area SDD (EDAX and FEI working to optimize integration of new system)
- Complements EELS for full suite of analytical capabilities

Opportunities in scanning probe microscopies

CNMS develops new STM and 4-probe STM based imaging and spectroscopy modes that reveal local electronic, magnetic, and transport properties

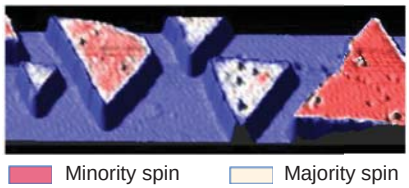
- tunneling thermopower microscopy
- scanning tunneling potentiometry
- spin-polarized STM

STM image and spectroscopy revealing confined electronic states at Gr/h-BN heterojunctions

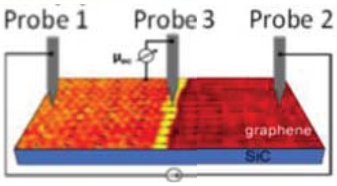


J. Park et al, *Science* (2014); *Nature Comm.*(2014)

SP-STM reveals spin polarization of Co/Cu



Scanning tunneling potentiometry to map conductivity across grain boundaries



K.W. Clark et al, *Nano Lett.* (2013); *PRX* (2014)

New ORNL purchase (FY2016): Scienta Omicron LT NANOPROBE

- True atomic resolution, 10-hr stability ("manipulate-and-characterize")
- sub-meV energy resolution in spectroscopy (from the current 10s of meV)
- Noise level of less than 10 pA (from the present 100pA)

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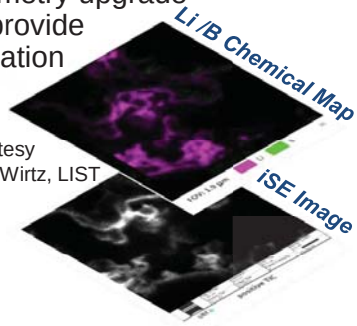
Leading capabilities in chemical imaging

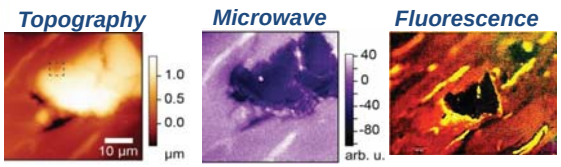
A mass spectrometry upgrade to the HIM will provide chemical information at nanometer resolution



Courtesy Tom Wirtz, LIST

The combination of scanning probes and optical spectroscopies provides a broad range of information

- AFM-Raman (NT-MDT Integra)
- AFM-Fluorescence (Asylum Bioscope)
- AFM-NanoIR (Anasys, FY2016)



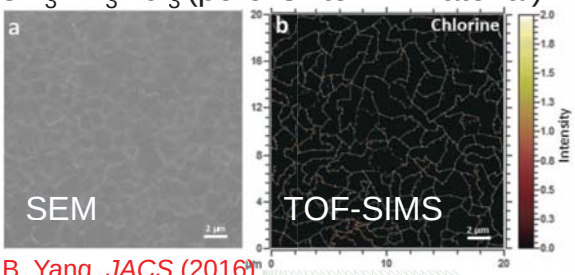
A. Tselev, *Fuel* (2014)

ORNL's new **AFM/TOF-SIMS** combines focused-ion-beam TOF-SIMS with scanning probe microscopy for co-registered chemical and physical analysis of materials

30keV BiMn cluster ion gun, 20keV Ar gas cluster, dual-source O and Cs ion guns

Co-registered SPM

$CH_3NH_3PbI_3$ (perovskite PV material)



B. Yang, *JACS* (2016)

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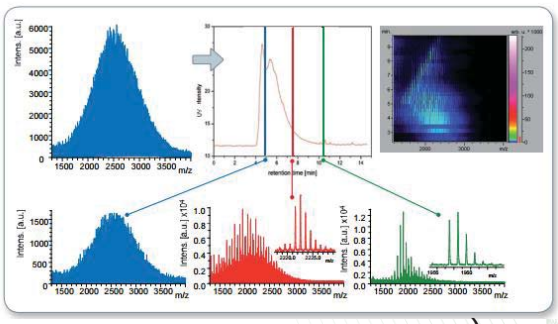
MALDI-TOF: Bruker Autoflex Speed LRF

- Can be operated in linear, reflector mode, or single reaction monitoring (Fast-SRM).
- Unmatched analytical speed using smartbeam™-II, a 2 kilohertz laser and system electronics for intensive or high throughput applications.
- Imaging capability with down to 5 μm spot size
- Expanded mass range capabilities to handle intact proteins and molecules such as large polymers.
- Novel FlashDetector™ technology increases resolution (R>26,000) and sensitivity (<2 ppm) and prevents signal saturation for complex samples.



Complex Copolymer Analysis (PEO-PPO)

https://www.bruker.com/fileadmin/user_upload/8-PDF-Docs/Separations_MassSpectrometry/Literature/Brochures/1827310_autoflex_speed_brochure_03-2014_eBook.pdf

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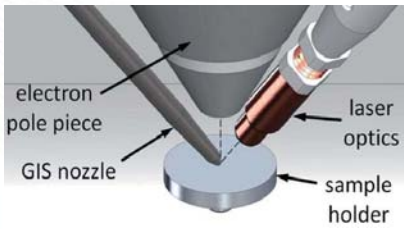
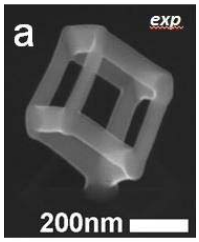
CNMS emphasizes 3D direct-write nanofabrication

E-beam induced deposition (EBID)



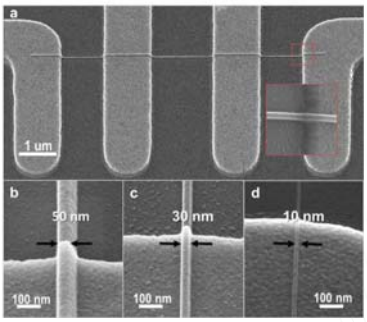


J.D. Fowlkes *et al*., *Nanoscale* (2013)

Ion-beam induced deposition (IBID)

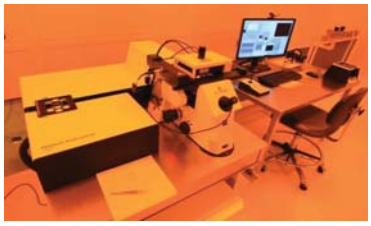
IBID benefits from smaller minimum probe diameter and beam penetration

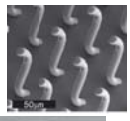
Issues related to He-implantation can be alleviated with laser irradiation



Direct Laser Write based on 2-photon polymerization (liquid, solid precursors)

- Nanoscribe Photonics Professional GT installed and operational in FY2016
- User projects and in-house science underway





- Arbitrary complex 3D trajectories, spatial resolution to 100 nm
- Overall sizes to millimeter scale
- Applicable to non-flat, flexible substrates and larger scale 3D elements (e.g. made by conventional 3D printing)

Combination with atomic layer deposition (ALD) and EBID/IBID will enable the formation of hierarchical multiscale 3D structures

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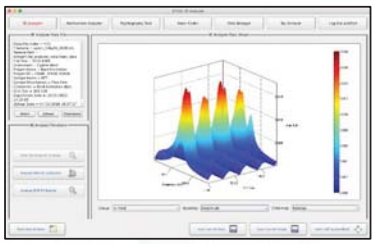
Towards real-time analysis of imaging data

- Modern data analytics approaches and statistical methods are often beyond the reach of individual researchers.
- As multidisciplinary user facility, CNMS is uniquely positioned to provide the "missing link"
- CNMS researchers have made significant progress in the statistical analysis of data (e.g., unsupervised multivariate statistical techniques, etc.)

150 attendees
representing 8 DOE labs, 16 universities;
33 presentations; 50 posters

- Collaborations with the Oak Ridge Leadership Computing Facility (OLCF) and ORNL's Compute and Data Environment for Science (CADES) established the Bellerophon Environment for Analysis of Materials (BEAM), which will
  - Enable collaborative development of user-inspired codes
  - Address currently intractable large-scale data analytics problems
  - Provide new insight into nanomaterial structure and function



Near real-time functional fitting of SPM data has become possible ("accessing Titan from your microscope")

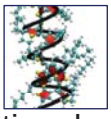
Strategic vision for CNMS

Providing access to state-of-the-art nanoscience research capabilities by building on CNMS foundational strengths and the ORNL environment

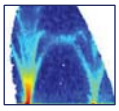
Understanding the effects of dimensional and spatial confinement on both formation and function of nanomaterials

In numbers:

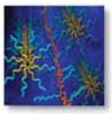
- 575 unique users per year
- >400 proposals submitted per year
- >650 active projects per year
- >350 refereed papers per year
  - ⅓ in journals with IF ≥ 7.4



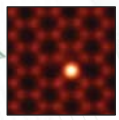
Computational sciences



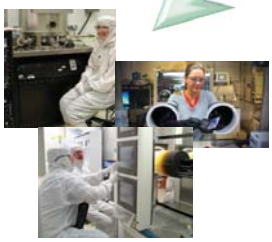
Neutron scattering



Soft matter



Imaging



User community

We need your feedback and your help

- Let us know what you need from us – use the suggestion box on-line and the yellow form in your meeting package
- Participate in the UEC
- Help us make sure that the best proposals get time at CNMS (volunteer to review proposals)
- Help us highlight your work
- Please let others know what you do here
  - Credit lines in papers
  - Mentioning CNMS in your talks

Thank you for being part of the 2016 CNMS User Meeting

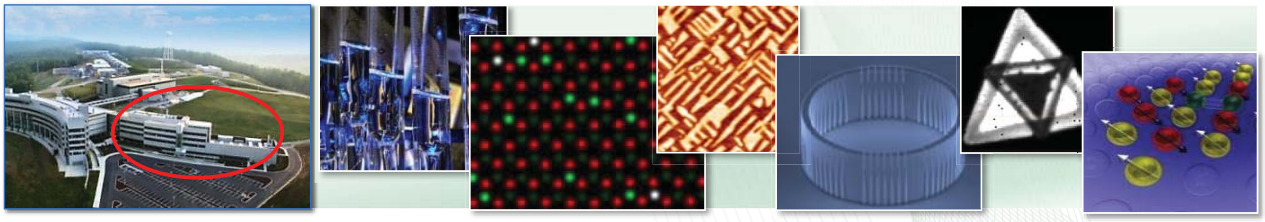
CNMS is a national user facility with a mission to advance nanoscience

About CNMS:

- Free access to staff expertise and equipment (if intent is to publish)
- Two proposal calls per year; proposals for short-term projects are accepted continuously
- Simple 2-page proposal
- Joint proposals with neutron sources (SNS, HFIR)

Research areas:

- **Synthesis –** Soft matter (precision synthesis, selective deuteration), 2D materials, hybrid structures, epitaxial oxides
- **Nanofabrication –** direct-write (3D) fabrication, multiscale fluidics, 1000 sq. ft. cleanroom
- **Advanced Microscopy –** AFM, STM, aberration-corrected and in-situ TEM/STEM, atom-probe tomography, data analytics
- **Chemical Imaging** – multiple approaches based on mass spectrometry or optical/time-resolved spectroscopies
- **Functional Characterization –** laser spectroscopy, transport, magnetism, electromechanics
- **Theory and Modelling –** including gateway to leadership-class high performance computing



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