Earth and Environmental Science Research Community

NNCI Lead Institutions:

MONT, NanoEarth, Nano@Stanford, NCI-SW, SERC/Carleton College

Lead PIs:
Trevor Thornton, Mitsu Murayama, David Dickensheets

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Research Community: Earth and Environmental Sciences

A Continuation of Community Building

- 2017 Goldschmidt Conference
- 2018 Goldschmidt Conference
- 2018 NanoEarth Workshop


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REVIEW

Natural, incidental, and engineered nanomaterials and their impacts on the Earth system

MICHAEL F. HOCHELLA JR., DAVID W. MOGK, JAMES RANVILLE, IRVING C. ALLEN, GEORGE W. LUTHER, LINSEY C. MARR, B. PETER MCGRAIL, MITSU MURAYAMA, NIKOLLA P. QAFOKU, KEVIN M. ROSSO, NITA SAHAI, PAUL A. SCHROEDER, PETER VIKESLAND, PAUL WESTERHOFF, AND YI YANG

229 Citations, 10/28/2021

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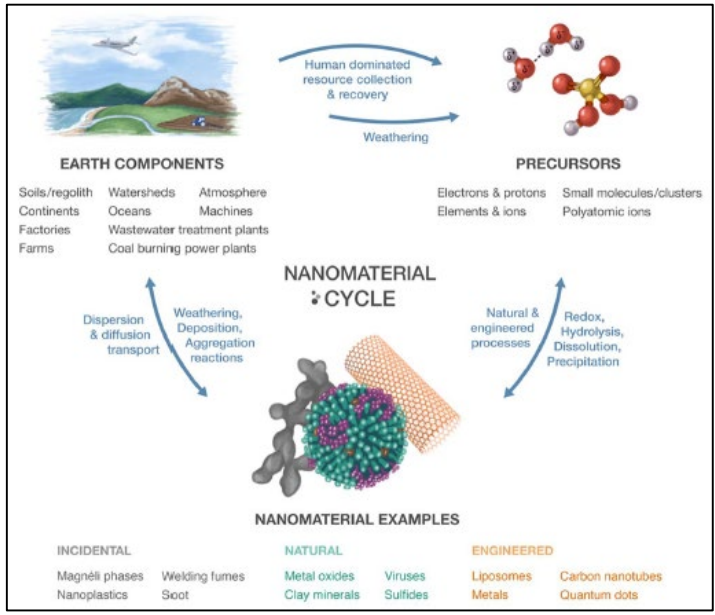
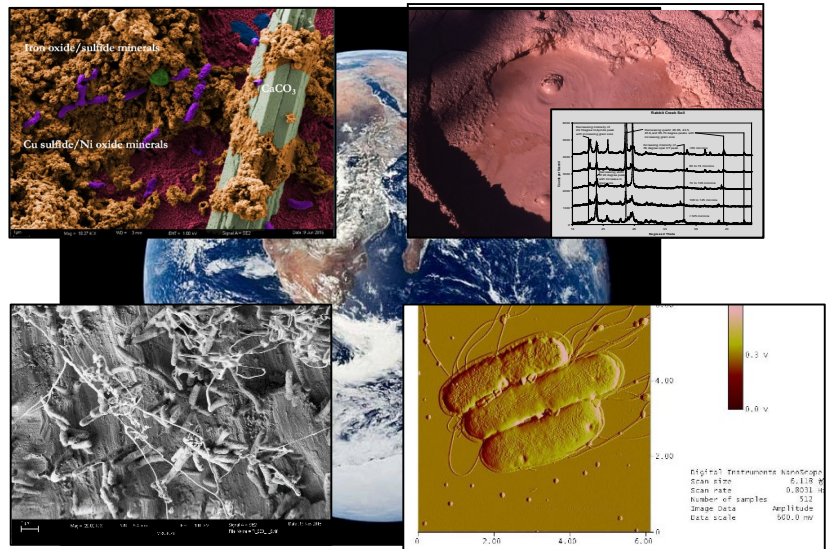
Research Community on nano-Earth Systems

Nano-ES intersects National Priorities targeting Climate Change; Energy Generation, Storage, Transmission; Clean Water; Environmental and Human Health; as well as NSF Convergence Research



- **Coordinated by MONT, nanoEarth, nano@Stanford, NCI-SW**
- **Annual workshop** with participants from all nano-ES sites, open registration
  - MONT hosted first workshop, Convened virtually in May 2021 **(Y6 of NNCI)**
- Week-long **staff exchange program (start in Y7)**
  - Staff Exchanges will be delayed due to COVID concerns
- NNCI **nano-ES Use/Toolset Inventory (Y6)**
  - In Y6 nano-ES will begin assessing NNCI "landscape" for serving users engaged in earth systems science: tools/expertise available, level of usage, gaps; understand unique needs e.g. for preparation of "dirty" samples
- **Joint REU program** with regular NNCI cross-site virtual activities **(start Y6?)**
  - Each of our sites will have at least one Nano ES REU participant
  - Consult with GEO-REU Network run by Val Sloan at the Univ Corporation for Atmospheric Research (UCAR); try to learn "best practices"
  - Facilitate connections for REU faculty in Nano ES
  - Advertise Nano-ES REU across NNCI sites



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MONT

Research Community: Earth and Environmental Sciences: 2021 Workshop

NNCI Conveners: David Mogk, MONT, Tonya Pruitt, NanoEarth,
Kate Maher, Nano@Stanford, Paul Westerhoff, NCI-SW
Monica Bruckner, SERC/Carleton College

https://serc.carleton.edu/nnci_spring2021/index.html

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Workshop Goals

- Introduce the geoscience community to new advances and opportunities to do research in nanoscience
- Help participants stay current about data, tools, services, and research related to nanoscience.
- Address the "big science questions" related to nanoscience in the Earth and Environmental Sciences
- Build collaborations; develop research networks to facilitate nanoscience research in the Earth and Environmental Sciences.
- Introduce education outreach efforts for Nano-EES.

Workshop Program

- 20 invited speakers
- 150 registrants
- Break out “listening” sessions for NNCI to get community feedback
- “Office Hours With Experts”, to provide high-quality interactions between NNCI labs and new users to design new research, build collaborations
- Recorded talks and PPTs posted on website

Research Community: Earth and Environmental Sciences: 2021 Workshop

Virtual format allowed for greater participation and inclusivity; reached a diverse and international audience.

Topical break-out sessions provided important feedback to NNCI leaders.

Interactive “office hours” provided direct information between experts and novices.

- *“The breakout session that I was in was informative as we learned the problems that researches are dealing with.”*
- *“The most valuable part of the workshop, for me, was meeting people with similar research interest and/or whom work at facilities that understand my nano needs. This really made me feel that I finally have a community with which I can discuss ideas, collaborate, and learn.”*
- *“Survey of available instrumentation and methods from different labs. Because one can learn what's available and get up to speed on current methods.”*

Workshop Facilitation, Communication, Design, and Active Learning Table

Table 7. The mean ratings for each statement targeting workshop facilitation, communication, design, and active learning (n=18)

Statement	Mean Rating
The design of the workshop facilitated exchange of expertise among participants	3.89
The workshop sessions were well facilitated	3.94
The pre-workshop communications gave me the information I needed to learn about and prepare for the workshop	3.94
The workshop events engaged me in active learning related to its goals.	3.59

Opportunities, ... and Outreach Table

Table 2. The mean ratings for each statement targeting new opportunities, data, implications, collaborations, and outreach (n=18)

Statement	Mean Rating
Introduce the geoscience community to new advances and opportunities to do research in nanoscience through the National Nanotechnology Coordinated Infrastructure (NNCI) program	3.89
Help participants stay current about data, tools, services, and research related to nanoscience	3.94
Address the "big science questions" related to nanoscience: nanomaterials in the Earth system, impacts on biogeochemical processes, characterization of nanomaterials and their chemical properties at the nanoscale, impacts of nanomaterials (natural and incidental) on the environment and human health.	3.78
Build collaborations; develop research networks to facilitate nanoscience research in the Earth and Environmental Sciences.	3.56
Introduce education outreach efforts for nano-ES.	3.67

https://serc.carleton.edu/nnci_spring2021/index.html

Listserv established with 225 members

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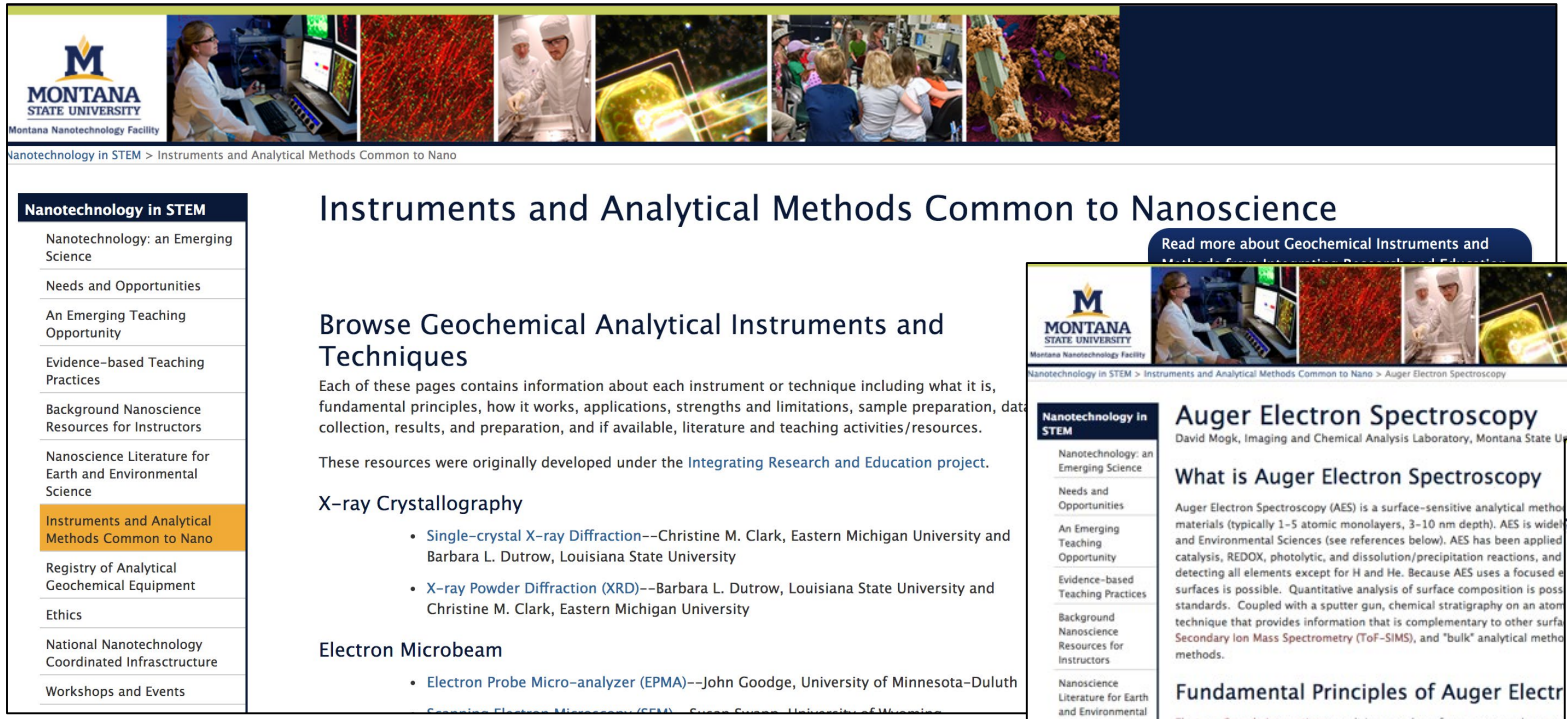
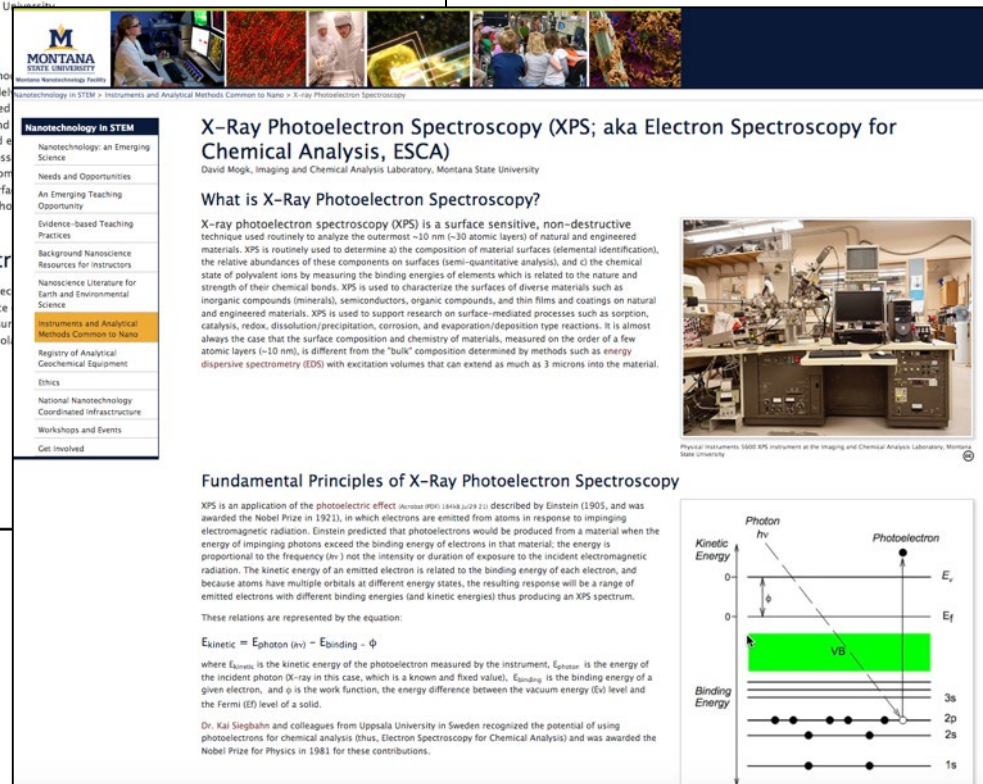
Expanded Tutorial Webpages on Analytical Methods used in Characterization of Nanoparticles





In aggregate, these “primers” on analytical instrumentation and methods are the most used webpages on the site

https://serc.carleton.edu/msu_nanotech/methods.html

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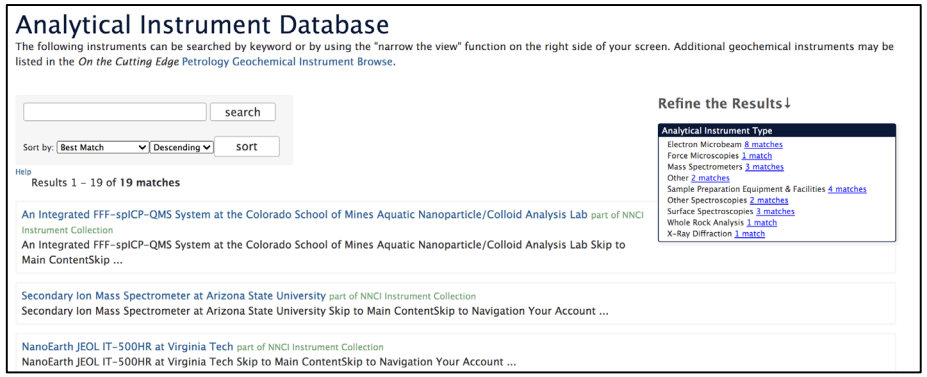
New: Registry of Analytical Instruments Available in the NNCI Used in the Earth and Environmental Sciences

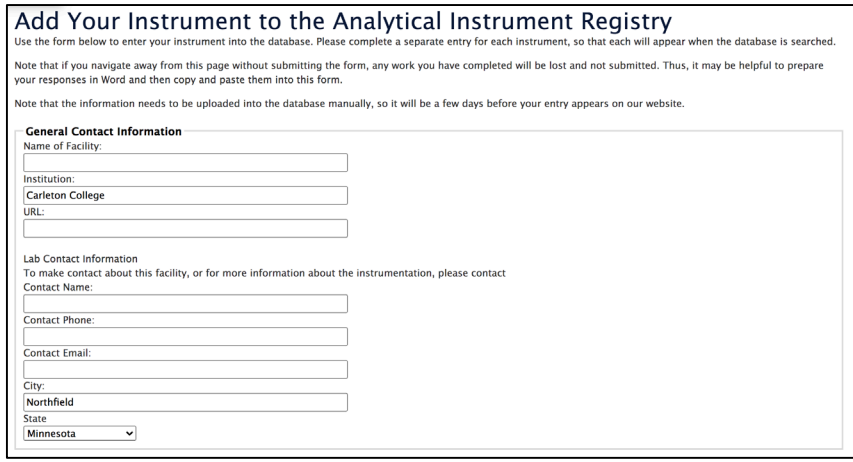
This website is a clearing house service:

- **For lab managers** to build their user base;
- **For researchers, instructors, and students** to gain access to analytical equipment; and,
- **To build capacity** by optimizing the use of existing analytical equipment and promote training of Nano-geoscientists.
- NNCI Tools does not represent EES Tool Areas or Sub-Fields
- **This Registry**
  - **Is More than a list,** a searchable database
  - More robust descriptions and metadata;
  - Focused on EES applications
  - Includes resources beyond NNCI to larger EES community

https://serc.carleton.edu/242625



User interface: search by instrument type or free text



Template for lab managers to enter key information

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Example: Instrument Registry Data Sheet

Auger Electron Spectroscopy System Integrated with EDS and EBSD at the Imaging and Chemical Analysis Laboratory (ICAL), MSU-Bozeman

Montana State University-Bozeman

https://physics.montana.edu/ical/index.html

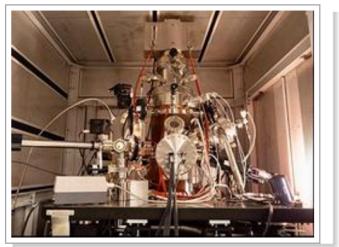
Contact Information

Sara Zacher (Lab Manager) or Recep Avci (Lab Director)
406 994 4199
ical@sympa.montana.edu
Bozeman
MT

Instrument Type

Auger Electron Spectroscopy System Integrated with EDS and EBSD

- Field Emission SEM scanning electron microscope--for high resolution imaging down to 5 nanometers
- AES Auger Electron Spectroscopy (or SAM Scanning Auger Microscopy)--for surface analysis of all elements of Z>3 (Li), and surface elemental mapping
- EDS energy dispersive spectrometer--for "bulk" compositional analysis of elements; X-ray elemental mapping
- EBSD detector for in situ phase identification using electron diffraction and determination of crystallographic orientation.



This Phi 710 NanoAuger Probe is a unique analytical system that includes: 1) Field Emission SEM imaging for spatial resolution down to 5 nanometeers; 2) AES detector for surficial compositional analysis for atomic monolayers on surfaces, with detection of light elements down to Li; 3) Ar-beam ion gun for "dusting off" surfaces of environmental contaminants and depth profiling capabilities; 4) EDS detector for "bulk" compositional analysis and X-ray elemental mapping of materials, and 5) EBSD detector for phase identification using electron diffraction and determination of crystallographic orientation. These numerous analytical methods can be used in near-real-time to fully characterize in situ the identity, crystal structure and orientation, bulk composition, and surface composition of sub-micron to micron particles. Charge compensation methods are used to analyze insulating materials because conducting coats cannot be applied to AES samples.

MODEL:

- Phi 710 NanoAuger Probe

Application:

Application:

Auger Electron Spectroscopy (AES) is a surface sensitive method used to analyze the composition of one or a few atomic layers (~1 nanometer) on material surfaces. All elements of Z>3 (Li) can be detected. Semi-quantitative analyses are obtained using published elemental sensitivity factors. Depth profiles of chemical stratigraphy on material surfaces is obtained using an Ar ion sputter gun. Full spectrum surveys are obtained to determine the inventory of elements on a material surface, and "multiplex" routines are used to scan specific energy windows to focus on specific elements. Micron-scale maps can be obtained to show the distribution of elements on material surfaces. The AES instrument at ICAL is built on a field emission SEM for high resolution imaging, and is also equpped with EDS and EBSD detectors. So near real-time data can be obtained in situ on the same spot for nano-scale morphology, bulk composition, surface composition, atomic structure (to identify the phase) and crystallographic orientation.

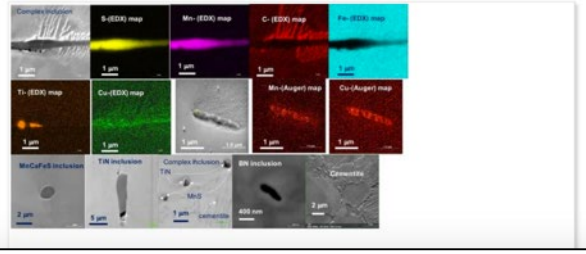
Applications include

- Study of surface mediated reactions such as sorption, catalysis, dissolution/preciptation products, REDOX reactions
- Analysis of thin films and surface coatings
- Imaging (size, shape, morphology)
- Crystallographic orientation
- Distribution in matrix (disseminated, aggregated...)
- Textural relations (intergrowths, overgrowths, epitaxial...)
- Interfaces

Typical Use:

AES is widely used in research in

- Energy (generation, storage, transfer)
- Microelectronics
- Metallurgy
- Earth and Environmental Sciences (applications are increasing as charge compensation methods are improved).



Conditions for Use:

As a regional user facility, ICAL encourages users to acquire training through our Short Courses so that the design and implementation of experiments is done to meet specific user-defined research objectives. Collaboration with ICAL staff is encouraged. Submitted samples can also be analyzed on a contract basis (i.e. lab personnel will do the work). ICAL is also available to do preliminary "proof-of-concept", exploratory experiments, including optimazation of instruments to address the defined tasks, data acquistion, and data interpretation to help support future funding and collaboration opportunities.

User Fees:

Contact the lab manager for details about user fees. In general, user fees are applied only to actual beam time for instrument use and staff time.

Instrument Priorities:

ICAL seeks to accommodate all users who rely on high-quality, rapid turn-around results for both academic research and research and development projects for industrial partners. The lab manager helps coordinate instrument access by: a) researchers with funded research projects; b) collaborations with academic colleagues; c) contract work with industrial partners, and d) education and outreach activities (class demonstrations, class projects, independent study and thesis research projects, etc.). ICAL is a node of the National Nanotechnology Coordinated Infrastructure program, and our mission is to extend use of these instruments to support research across the STEM disciplines in academic and corporate research. Some limited funds are available through the NNCI/MONT NSF award to support pilot research projects. Please visit https://nano.montana.edu/ for details.

Remote Use:

Remote operation is not directly possible for any of the ICAL instruments. But in response to the COVID lockdowns, we have implemented use of real-time video delivery to allow external users to observe analysis of their samples and to provide for direct interaction and decision-making as the experiments proceed.

Sample Preparation:

Samples are typically analyzed "as received". The AES operates under Ultra High Vacuum (UHV) so volatile materials should be avoided. Samples are commonly mounted on a conducting material such as indium, a Si wafer, or TEM-style Cu grid. Samples are typically exposed to a gentle Ar beam application to remove sorbed environmental layers.

Standard Collections/Lab Blanks:

Standardization for AES analysis is difficult and not commonly done.

Software:

AES data collection provides retrospective analysis as every pixel of the image contains the full Auger spectrum.

Educational Use:

Class demonstrations are available for undergraduates Class demonstrations are available for K-12 Undergraduate student research projects are invited Graduate student research projects are invited Tutorials and other educational materials related to the lab are available ICAL routinely offers class demonstrations and supports course projects across the STEM disciplines. We encourage interested users to take our 10 hour short courses in the operation of each instrument to become independent users of this facility as part of our professional training program.

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Thank you!

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