MONT: Montana Nanotechnology Facility

Overview and Core Facilities

Coordinated access to 5 campus facilities:

- Montana Microfabrication Facility
- Imaging and Chemical Analysis Lab
- Center for Biofilm Engineering
- Center for Bio-Inspired Nanomaterials
- Metabolomics, Proteomics and Mass Spectroscopy facility

MONTANA STATE UNIVERSITY
MONTANA MICROFABRICATION FACILITY

ICAL

MPMS

CBIN

CBE

MONT Facility at MSU

National Nanotechnology Coordinated Infrastructure

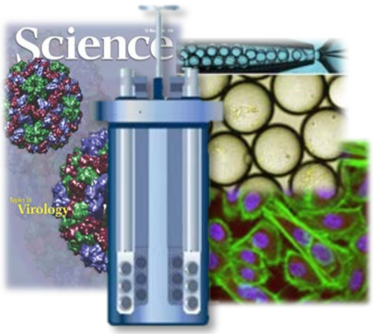
NSF

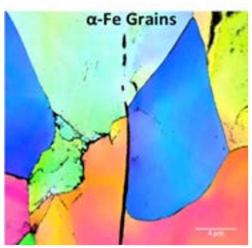
MONTANA STATE UNIVERSITY

Montana Nanotechnology Facility

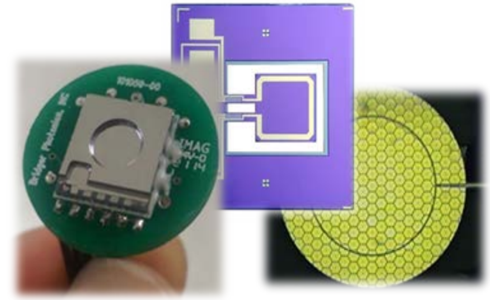
MONT: Montana Nanotechnology Facility

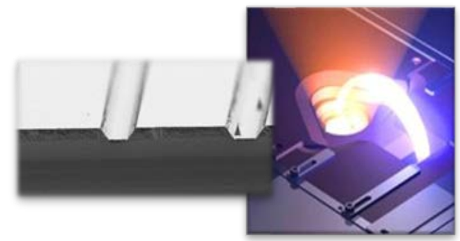
Focus Areas





- **Optical MEMS and Nanosystems** – with local industrial collaborations
- **Biology and Nanotechnology** – Biofilms and Microfluidics
- **Novel optical and high temperature materials**
- **Nanocharacterization** SEM, nanoAuger, XPS, XRD, ToF-SIMS
- **Education and Outreach** emphasizing undergraduate research, K-12 students/teachers, web-based education, local Tribal colleges



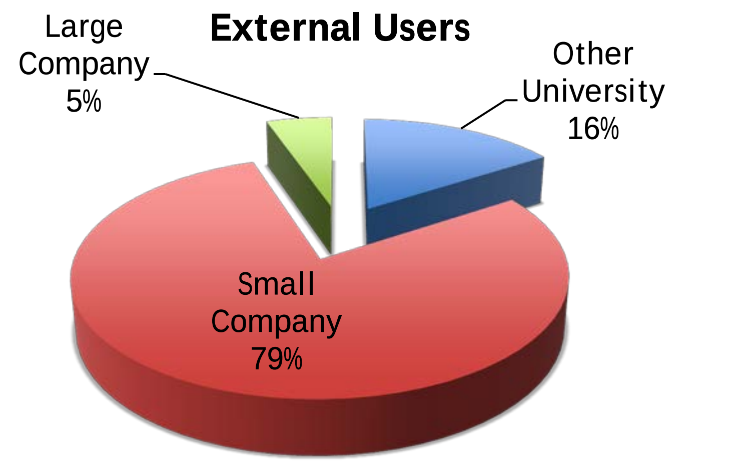


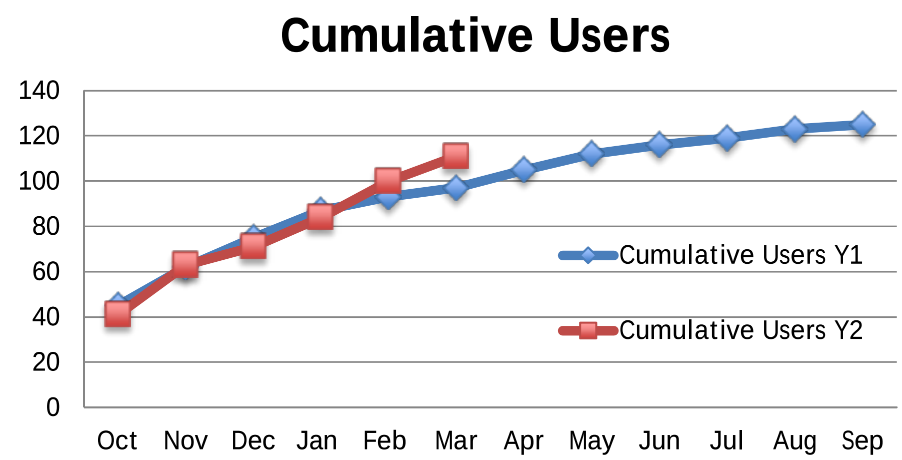
National Nanotechnology Coordinated Infrastructure

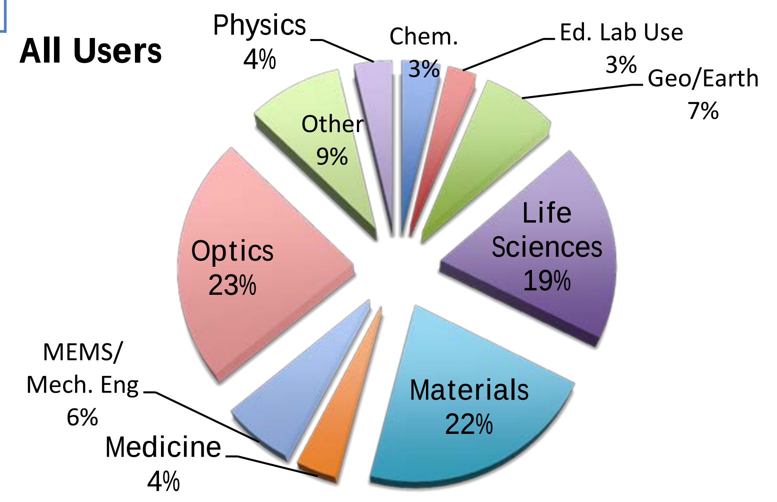
MONTANA STATE UNIVERSITY | Montana Nanotechnology Facility

MONT: Site User Data

Yearly User Data Comparison		
	Year 1(12 months)	**Year 2 (6 months)**
Total Users	125	111
Internal Users	96	92
External Users	29 (23%)	19 (17%)
Total Hours	3599	1975
Internal Hours	2852	1626
External Hours	747 (21%)	349 (18%)
Average Monthly Users	10	19
Average External Monthly Users	2 (20%)	3 (16%)
New Users	36	12
New External Users	1 (3%)	0







MONT: Facility Upgrades

- **Added Staff**: litho/microfluidics, characterization, user liaison
- **New Equipment**: NanoAuger (PHI 710), EVG aligner, Filmetrics, Electroplating Bath, Thick Film Laminator, Raman Confocal Spectromicroscope
- Recently awarded grant from Murdock Charitable Trust that also includes College of Engineering investment for **cleanroom expansion** for new PVD tool and soft lithography activities
- Partnering with GaTech for **facility management software**

We have leveraged our NNCI award to secure State and Private investment in our facility.

Total investment in first 1.5 years is

>6X

our NNCI capital expenditures.

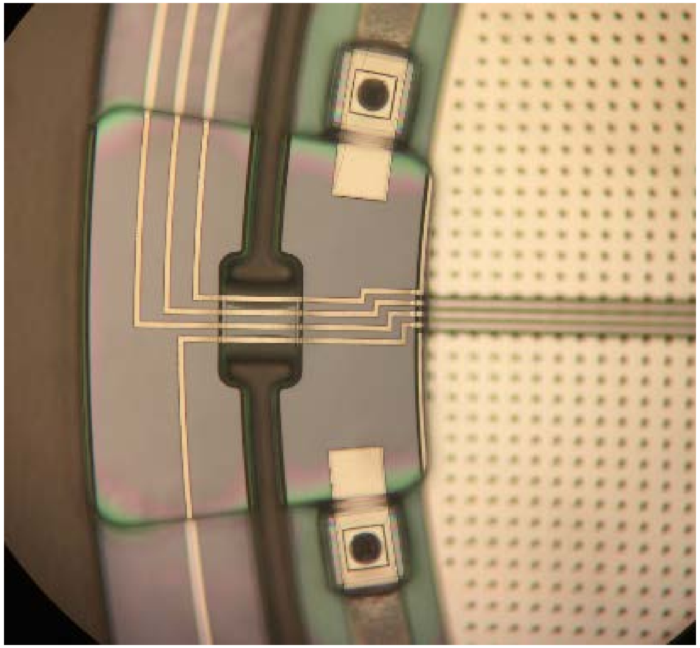
National Nanotechnology Coordinated Infrastructure

NSF

MONTANA STATE UNIVERSITY | Montana Nanotechnology Facility

Hybrid Silicon-Polymer Optical MEMS Devices

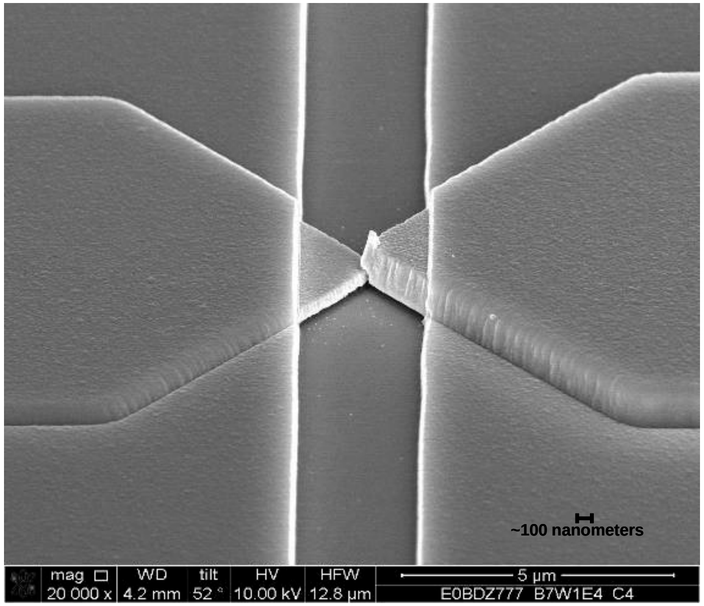
Ph.D. Student Tianbo Liu, Electrical and Computer Engineering



Electrical traces embedded in 50 µm thick SU-8 torsional flexure supporting a variable-focus scanning mirror.

Liu, Tianbo, and David L. Dickensheets. "MEMS 3-Dimensional Scanner for Handheld Confocal Microscope," *(OMN 2017),* IEEE, 2017.

MONT: Research Highlights



Bridger Technologies, Inc., Bozeman, MT, develops **DNA based pathogen sensors**.

BTI uses the MONT facilities for SEM imaging and surface spectroscopy, as well as wirebonding and packaging tools.

BTI's patented BEAR™ 'Conductive DNA' technology is based on an increase in electrical properties of bio-electronic circuits exposed to the genetic fingerprints of any viral or bacterial pathogen. Only 65 nanometers separates each of the hundreds of electrode pairs of BTI's bio-chip.

MONT: Education and Outreach

- **72 undergraduates** used MONT for courses on Microfabrication and Photovoltaics
- Photovoltaics summer course for **secondary science teachers** (>60 so far)
- Summer REU in 2017, cooperatively with ECE department (**4 MONT REU students**, attended Convocation at GaTech)
- **K-12 Outreach**: NanoDays, Community Science Night, Browning, Blackfeet Reservation

REU students in MONT Labs, July 2017

Browning Middle School student exploring ferro fluid.

National Nanotechnology Coordinated Infrastructure

NSF

MONTANA STATE UNIVERSITY

Montana Nanotechnology Facility

MONT: Education and Outreach

- In cooperation with Carleton College Science Education Resource Center (SERC):
  Web-based educational and instructional resources
    - Important nanotechnology processes (http://serc.carleton.edu/18410)
    - Nanotechnology applications
    - Ethics and societal impacts of nanotechnology
    - Teaching resources – integrating discussion of ethics and society into all of our educational activities http://serc.carleton.edu/geoethics/index.html
  – Web-based outreach
    - http://serc.carleton.edu/8640

Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS)

David W. Mogk, Montana State University

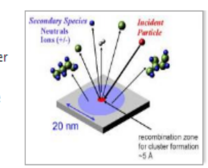
What is Time-of-Flight Secondary Ion Mass Spectrometry

Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) is a surface-sensitive analytical method that u
to remove molecules from the very outermost surface of the sample. The particles are removed from atomic
These particles are then accelerated into a "flight tube" and their mass is determined by measuring the exac
time-of-flight). Three operational modes are available using ToF-SIMS: surface spectroscopy, surface imagi
of ToF-SIMS include:

- Mass resolution of 0.00x amu. Particles particles with the same nominal mass (e.g. Si and C_2H distinguished from one another because as Mr. Einstein predicted there is a slight mass shift
- Mass range of 0-10,000 amu; ions (positive or negative), isotopes, and molecular compounds and up to ~amino acids) can be detected.
- Trace element detection limits in the ppm range.
- Sub-micron imaging to map any mass number of interest.
- Depth profiling capabilities; sequential sputtering of surfaces allow analysis of the chemical stratigraphy on material surfaces (typical sputtering rates are ~100 A/minute).
- Retrospective analysis. Every pixel of a ToF-SIMS map represents a full mass spectrum. This allows an analyst to retrospectively produce maps for any mass of interest, and to interrogate regions of interest (ROI) for their chemical composition via computer processing after the dataset has been instrumentally acquired.

Fundamental Principles of Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS)

ToF-SIMS uses a focused, pulsed particle beam (typically Cs or Ga) to dislodge chemical species on a materials surface. Particles produced closer to the site of impact tend to be dissociated ions (positive or negative). Secondary particles generated farther from the impact site tend to be molecular compounds, typically fragments of much larger organic macromolecules. The particles are then accelerated into a flight path on their way towards a detector. Because it is possible to measure the "time-of-flight" of the particles from the time of impact to detector on a scale of nano-seconds, it is possible to produce a mass resolution as fine as 0.00X atomic mass units (i.e. one part in a thousand of the mass of a proton). Under typical operating conditions, the results of ToF-SIMS analysis include:



▶ Show caption

1. a mass spectrum that surveys all atomic masses over a range of 0-10,000 amu,
2. the rastered beam produces maps of any mass of interest on a sub-micron scale, and
3. depth profiles are produced by removal of surface layers by sputtering under the ion beam.

ToF-SIMS is also referred to as "static" SIMS because a low primary ion current is used to "tickle" the sample surface to liberate ions, molecules and molecular clusters for analysis. In contrast, "dynamic" SIMS is the method of choice for quantitative analysis because a higher primary ion current results in a faster sputtering rate and produces a much higher ion yield. Thus, dynamic SIMS creates better counting statistics for trace elements. Organic compounds are effectively destroyed by "dynamic" SIMS, and no diagnostic information is obtained.

Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) Instrumentation – How Does It Work?

ToF-SIMS instruments typically include the following components:

- An ultrahigh vacuum system, which is needed to increase the mean free path of ions liberated in the

MONT: Network Activity

- **Webinar Series** (MONT focused so far)
  - 3 webinars, 134 participants (12 companies, 7 universities)
- Partnering with **GaTech** to port **SUMS Facility Automation** to MONT
- **MONT users** also using **Cornell, Minnesota, UCSD**
- NNCI Participation
  - 2016 **NSF Nano Grantees Conference** (Avci, Dickensheets)
  - **NNCI Annual Meeting** (Mogk, Dickensheets)
  - **REU Convocation**
  - Dickensheets, Mogk, Avci, Plumb are all in **working groups**
- **Dave Mogk** worked with **Michael Hochella** (Va Tech) and **Nancy Healy** (Ga Tech) on **Nano-Geo Workshop for Goldschmidt 2017**

Panel Discussion – Redefining Traditional Users

- Our "non-traditional" users include:
  - "Nontraditional" disciplines: **biofilm**, **geology**, **optical materials** ($LiNbO_3$, glasses, coatings, …)
  - **Microfluidics** (catch-all for folks studying bacteria, human cells, viruses, flow mechanics, etc.)
  - **Undergraduates** and MS students
- Fabrication
  - Offer what you have (perhaps in flexible ways – try to understand what the user really needs)
  - Be aware of what other's have (other facilities, other PIs)
  - **Be the matchmaker** – promote dialogue (seminars, discussions)
  - Be generous, to help extend specialized capabilities in PI's labs
  - When adding new shared-use capabilities:
    - Is there critical mass? How many users, how often? Does our standard fee model work? Are there creative ways to make the financial side work?
    - When possible, **empower PIs** to build the facility they want
  - When and how do you say "no, we can't"?
  - Variable user expertise – bootstrapping new users and users with finite time horizon
- Characterization
  - **Sample preparation** – what should we provide? What should we allow?
  - Variable user expertise – **helping occasional users be productive**

Our Team:

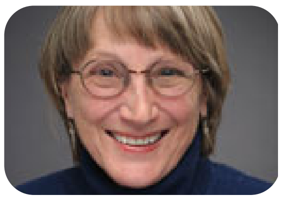
David Dickensheets

Recep Avci
ICAL

Phil Stewart
CBE

Mark Young
CBIN / VPR

Dave Mogk
Geology / E&O



Carolyn Plumb
Assessment

Phil Himmer
MMF Manager

Nancy Equall
ICAL Manager

Sean Fox
Education Specialist
Carleton College
Science Education Resource Center

MONTANA STATE UNIVERSITY
Mountains and Minds

CARLETON COLLEGE NORTHFIELD, MINN. EST 1866

Questions?

National Nanotechnology Coordinated Infrastructure

NSF

MONTANA STATE UNIVERSITY | Montana Nanotechnology Facility