SAND2018-8484C

Sandia National Laboratories

AMET CINT Discovery Platform™

Active Mechanical-Electrochemical-Thermal Platform for In-Situ Nanoscale Materials Characterization

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What is it?

The Active Mechanical-Electrochemical-Thermal (AMET) Discovery Platform™ was developed at the Center for Integrated Nanotechnologies (CINT) for in-situ nanoscale characterization of process-structure-property relationships of materials. The AMET platform integrates MEMS actuation with environmental cell technology to mechanically strain samples in a range of environments not previously achievable. And at just 4mm x 6mm x 1mm, the platform can be used with many techniques, including: transmission electron microscopy, scanning electron microscopy, and x-ray microdiffraction.

How does it work?

- The sample is affixed, over an 80 nm thick electron transparent Si_3N_4 window, to a buried piston attached to a MEMS actuator (thermal or electrostatic).
- A lid, with a matching Si_3N_4 window, is aligned to the base using sapphire beads and/or optical fibers and glued in place.
- An inner seal is created that isolates the sample chemical environment, and an outer hermetic seal isolates the actuators operating in air.
- Fill ports in the lid allow for the addition of many chemical environment options, including: vacuum, gases, and liquids.
- Buried electrical traces are used to control the actuator displacement, run the buried inner heater or exposed outer heater, or for patterning electrical contacts in the environmental chamber.
- The sample can then be strained *in situ* while in a controlled operating environment (chemical, electrical, temperature).

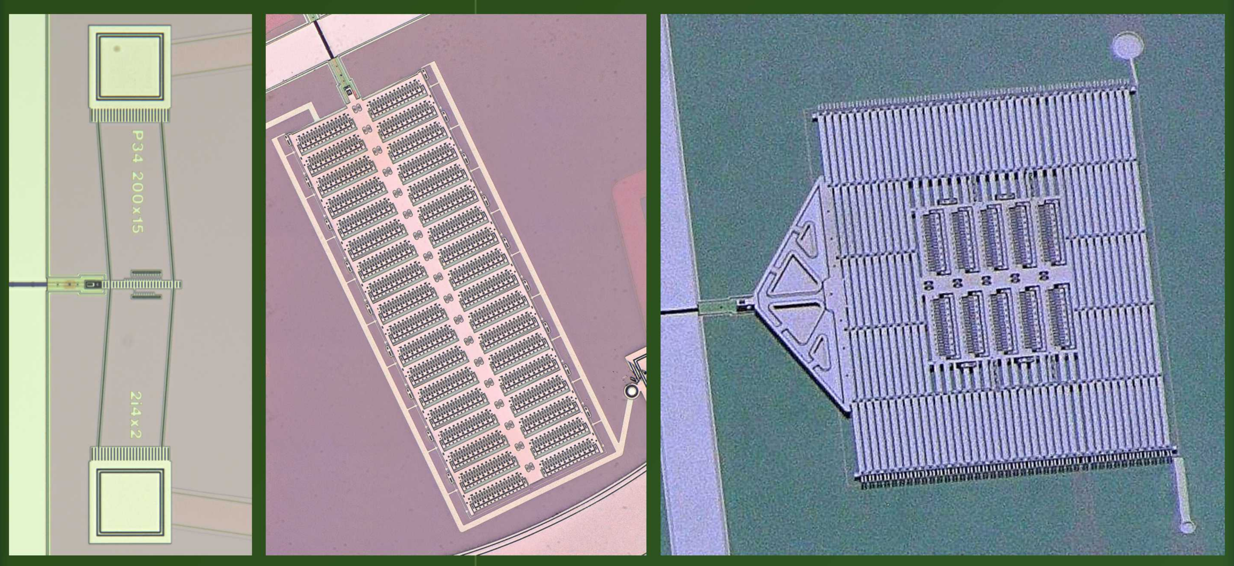
In-Situ Nanoscale Experimentation

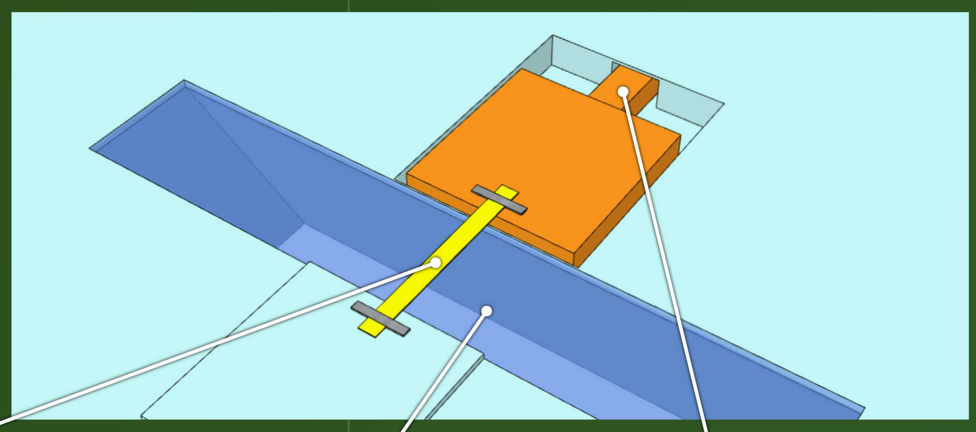
- Time
  - Fast
  - Slow
- Applied Field
  - Mechanical
  - Magnetic
  - Electric
  - Photons
  - Radiation
- Chemical Environment
  - Vacuum
  - Gas
  - Liquid
  - Solid
- Temperature
  - Cooling
  - Heating
- Adding/Removing Material
  - Depositing layers/particles
  - Depositing energy/electrons
  - Implanting ions/electrons

Adapted from Carter and Williams Transmission Electron Microscopy Companion Volume

MEMS Actuator/Sensor Options

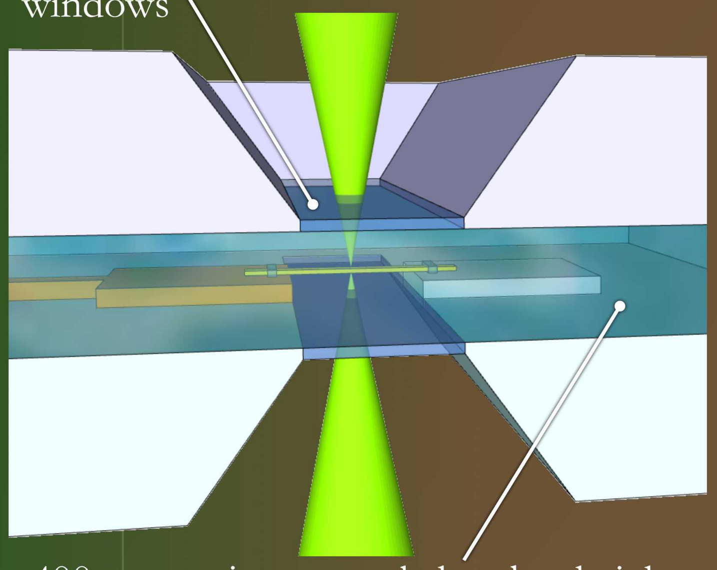
-Thermal -Electrostatic comb drive (ECD) -ECD+capacitive sensor





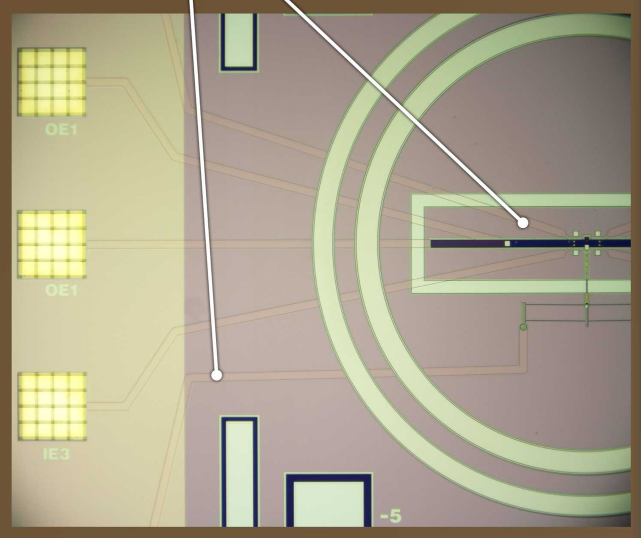
Sample affixed over Si_3N_4 window to the buried piston of the actuator

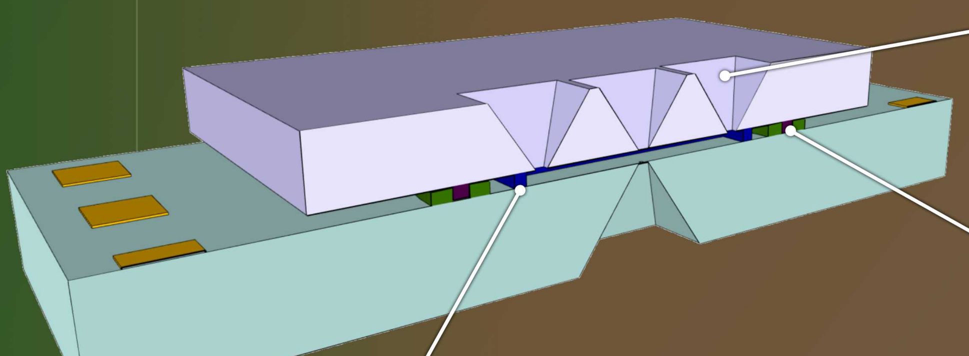
40 nm thick electron transparent Si_3N_4 windows



400 nm environmental chamber height

Buried electrical traces and electrical leads to the sample area



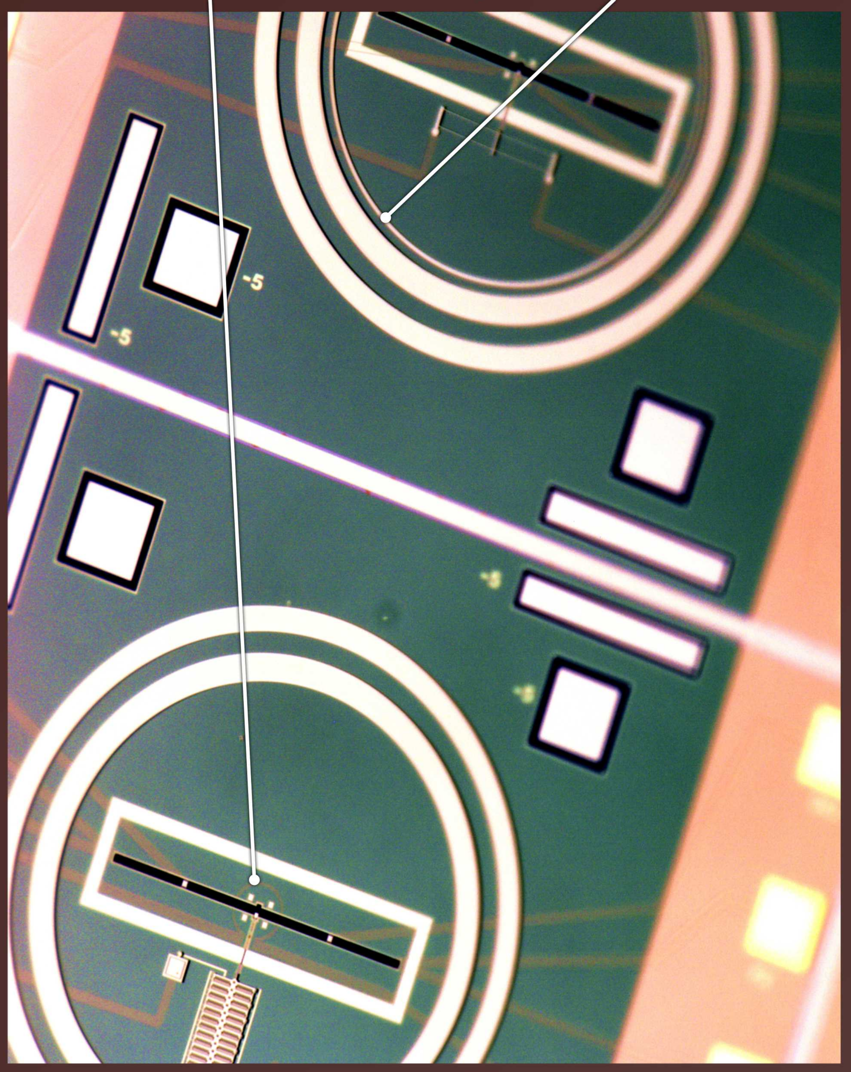


Fill ports in lid for chemical environment options: vacuum, gases, and liquids

Inner seal isolates sample chemical environment, outer hermetic seal isolates actuators operating in air

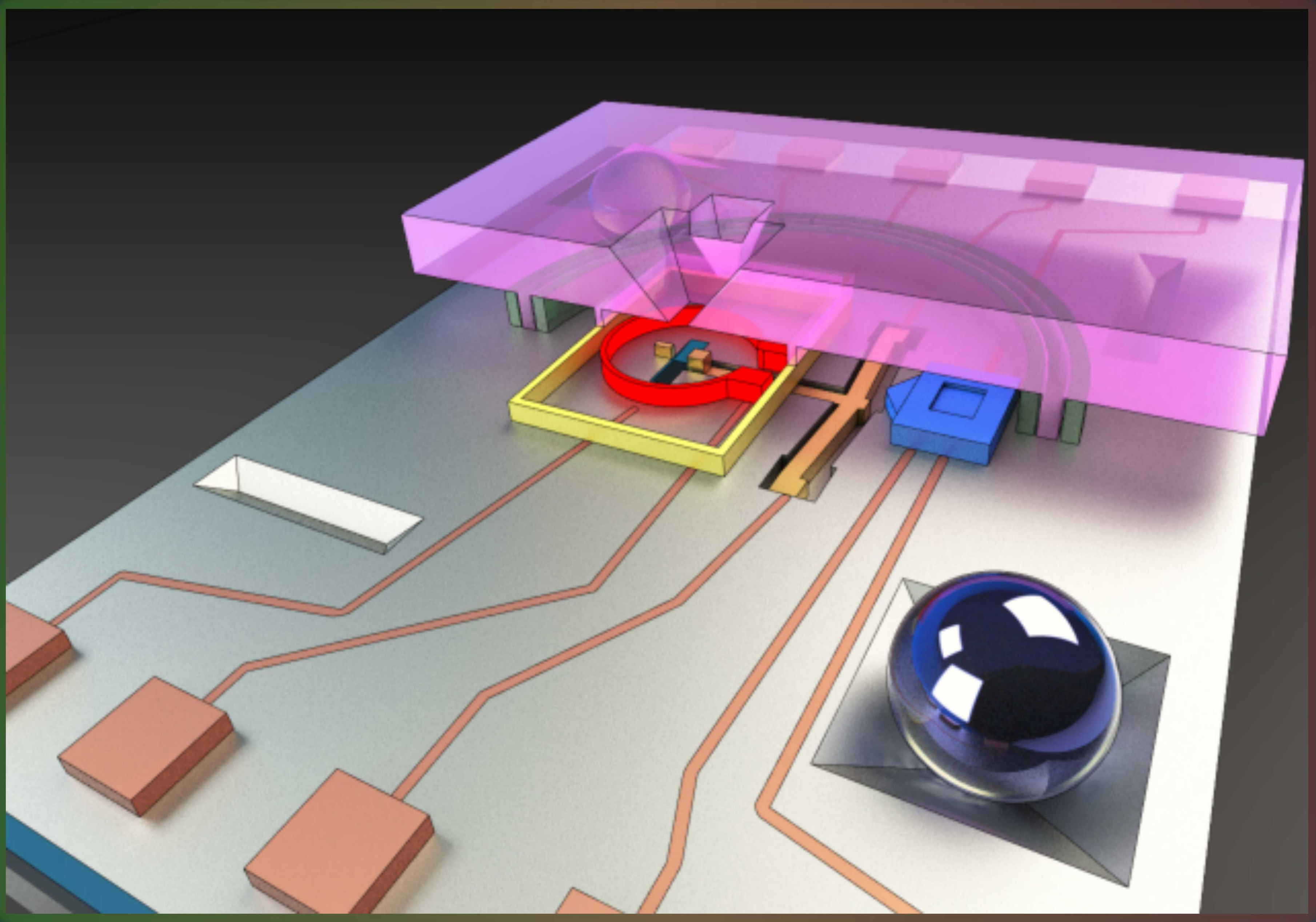
Heater Options

Buried inner heater Exposed outer heater



Developing the next generation

In-situ nanoscale characterization techniques have long been in development. Control of single environmental aspects, such as temperature, chemical surroundings (vacuum, gas, liquid, solid), and applied field (strain, magnetic, electric, radiation, etc.) significantly advance the range and capabilities of in-situ experimentation. However, full simulations of all relevant operating conditions have not yet been realized primarily due to impediments like the high operating vacuum and limited available space of many characterization techniques. At CINT, we are developing capabilities that marry two or more of these single techniques to produce the next generation of in-situ experiments.



What is the impact?

By enabling control of the chemical, electrical, and thermal environment when mechanically straining samples *in situ*, we can begin investigating previously unexplored material systems and processes.

In many material systems, such as biomaterials and geological minerals, mechanical behavior may be altered by or dependent on its operating environment, particularly the chemical surroundings. However, quantitative in-situ electron microscopy mechanical straining of nanoscale samples with high resolution has only been used to probe fundamental mechanical behavior of materials in vacuum. With the AMET platform, in-situ nanoscale tensile testing of individual cellular components, for example, is now possible.

Historically, nanoscale experiments probing environmentally-dependent mechanical processes, such as stress corrosion cracking, could only be performed *ex situ*. Thus, the fundamental mechanisms and processes involved could only be inferred from pre- and post-experiment characterization. The AMET platform eliminates erroneous inferences by enabling direct observation of these processes at the nanoscale.

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SAND No. ______________

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science.