# Mechanical-Environmental-Thermal MEMS Platform for In-Situ Nanoscale Materials Characterization

Claire Chisholm[1], Andrew J. Leenheer[2], William M. Mook[1], Michael Shaw[2], Khalid Hattar[1], Paul C. Galambos[2], and Katherine L. Jungjohann[1]

[1.] Sandia National Laboratories, Center for Integrated Nanotechnologies, Albuquerque, NM 87185 USA
[2.] Sandia National Laboratories, Microsystems Science & Technology, Albuquerque, NM 87185 USA

Small-scale characterization techniques, such as electron and x-ray microscopy, provide great insight into spatial, chemical, electronic, and magnetic properties of materials. Often these techniques act as initial and final points of characterization for ex-situ experiments. However, a sample could take one of many evolutionary paths during an experiment, resulting in inferred mechanisms or processes. Performing these experiments under constant observation, for example inside a microscope, eliminates many potentially erroneous data interpretations. Unfortunately, in-situ experimentation is not a straightforward task, with many technical impediments to overcome, particularly the high vacuum and spatial limitations required by small-scale characterization techniques. The first attempts at in-situ transmission electron microscopy (TEM) techniques have been in development by the community almost as long as we've had TEMs, enabling control over single aspects of the operating environment through modified TEM columns and specialty holders [1-2]. Control of single environmental aspects 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 [3-5]. However, full simulations of all relevant operating conditions have not yet been realized. In many material systems, for example, biomaterials, geological minerals, and corrosion-susceptible metals, mechanical behavior may be altered by or dependent on its operating environment, particularly the chemical surroundings [6-7]. However, quantitative in-situ TEM mechanical straining of nanoscale samples with high resolution has only been used to probe fundamental mechanical behavior of materials in vacuum [4]. This in-situ microscopy effort is striving to bring the field closer to full environmental control.

Here we present the design and development of a device (Fig. 1) capable of small-scale mechanical testing of a material in an enclosed, controlled environment (chemical, electrical, and temperature) where mechanical strain is applied with MEMS actuators (thermal and capacitive). The device is enclosed and includes electron transparent windows, such that it can be used in ambient or high-vacuum conditions. This, as well as its small dimensions (~1mm x 4mm x 6mm), allows for use with in-situ characterization techniques such as TEM, STEM, and x-ray microscopy, and x-ray micro-diffraction.

The implementation of this combination of small-scale mechanical and environmental characterization techniques aims to meet the scientific challenge of investigating structure-property relationships in previously unexplored combinations of extreme environments with nanometer resolution [8].

References:

[1] E Ruska, Kolloid-Zeitschrift **100** (1942), p. 212.
[2] PR Swann, Kristall und Technik **14** (1979), p. 1235.
[3] N de Jonge and FM Ross, Nature Nanotechnology **6** (2011), p. 695.
[4] M Legros, Comptes Rendus Physique **15** (2014), p. 224.
[5] JA Hinks, Nuclear Instruments and Methods in Physics Research B **267** (2009), p. 3652.
[6] KL Frieda and SM Block, Science **338** (2012), p. 397.
[7] F Remvik and P Skalle, International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts **30** (1993), p. 1115.
[8] 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. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government. SAND2018-6867 A. Special thanks to Chris Sheehan for providing the rendered schematic of the platform.

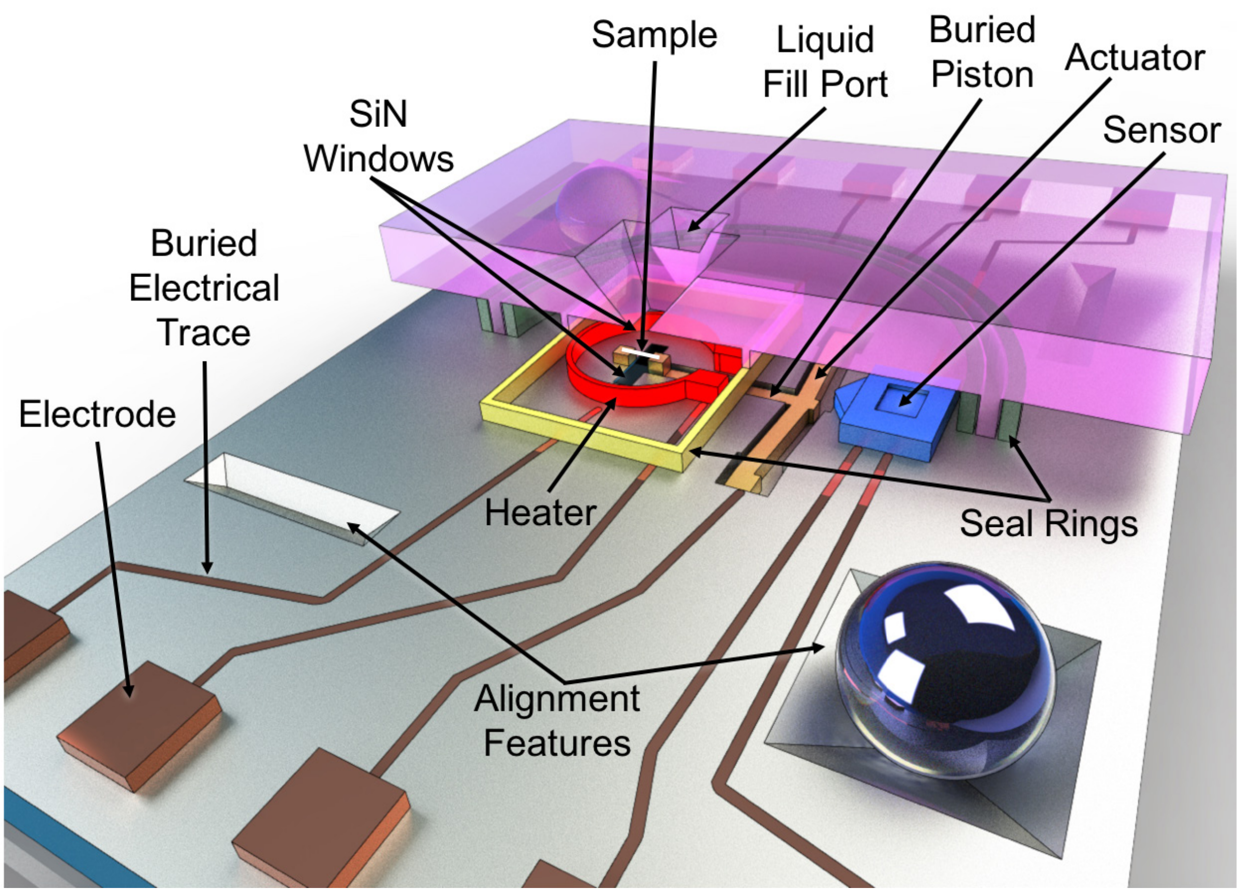


**Figure 1.** Labeled schematic of mechanical-electrical-thermal MEMS platform base.