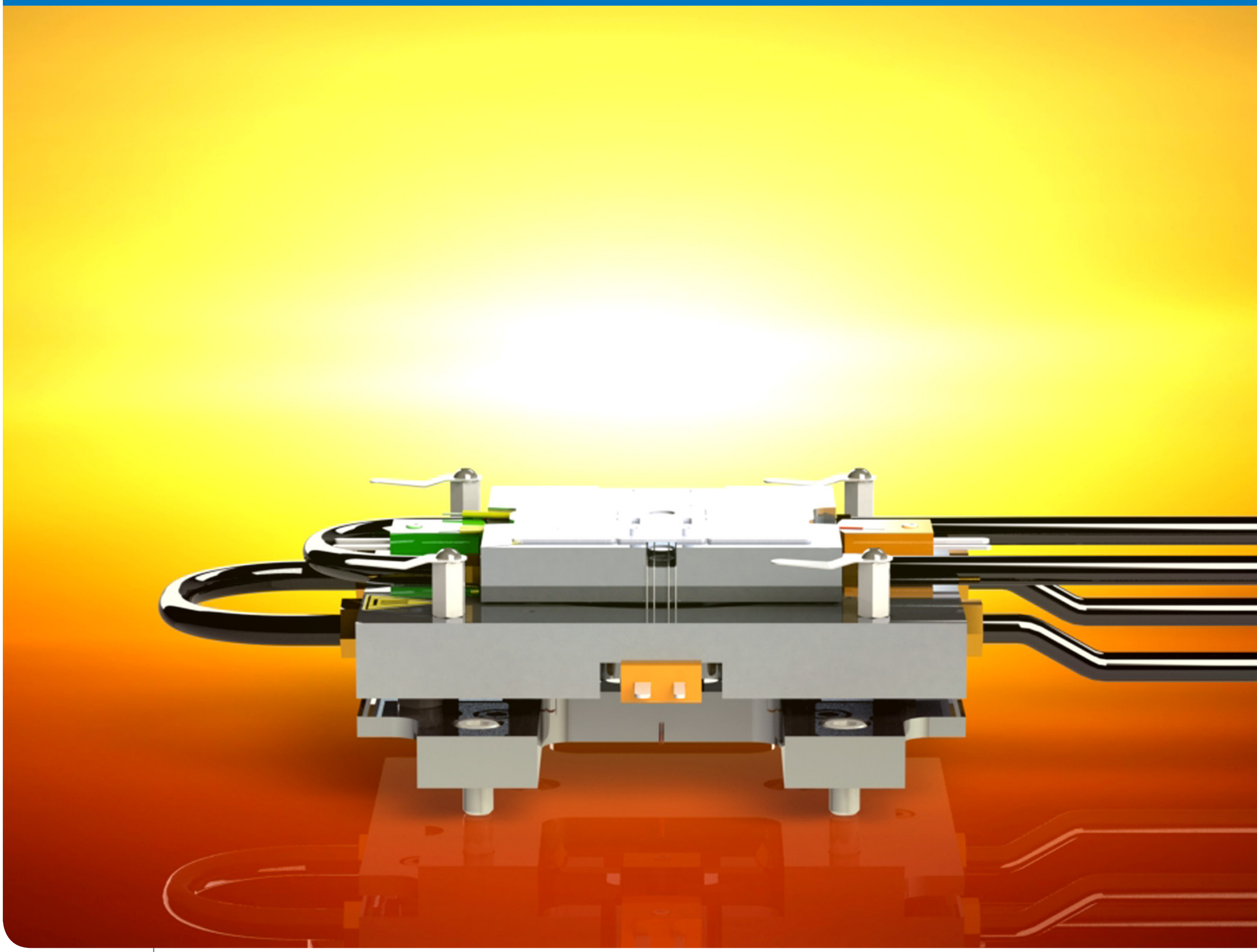


xSol High-Temperature Stage

Nanomechanical Characterization at Elevated Temperatures up to 800°C and Beyond

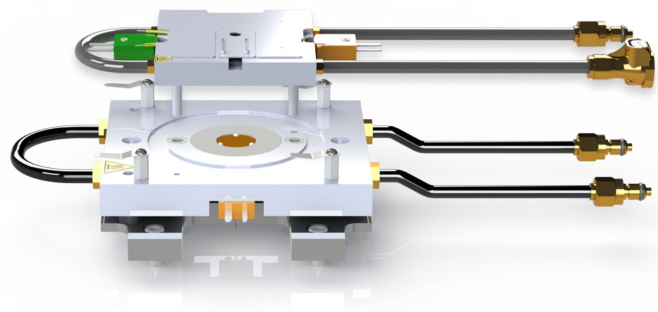
Innovation with Integrity

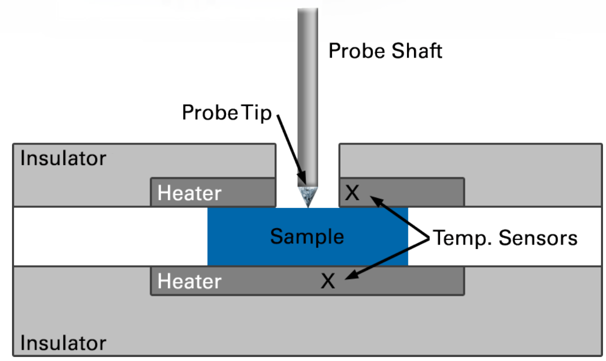
Tribology and Mechanical Testing

xSol High-Temperature Stage

Quantitative, Accurate, and Reliable Nanomechanical Characterization at Elevated Temperatures

To develop high-temperature materials capable of reliable performance in extreme operational environments requires understanding and tailoring nanoscale mechanical properties. Bruker's xSol® High-Temperature Stage enables high-resolution nanomechanical measurements to be performed over a broad temperature range. The thermally stable xSol stage design provides superior feedback-controlled temperature accuracy, fast stabilization times (under tight PID control), and a thermally stable stage design that enables quantitative, accurate, and reliable nanomechanical characterization at elevated temperatures up to 800°C and beyond.

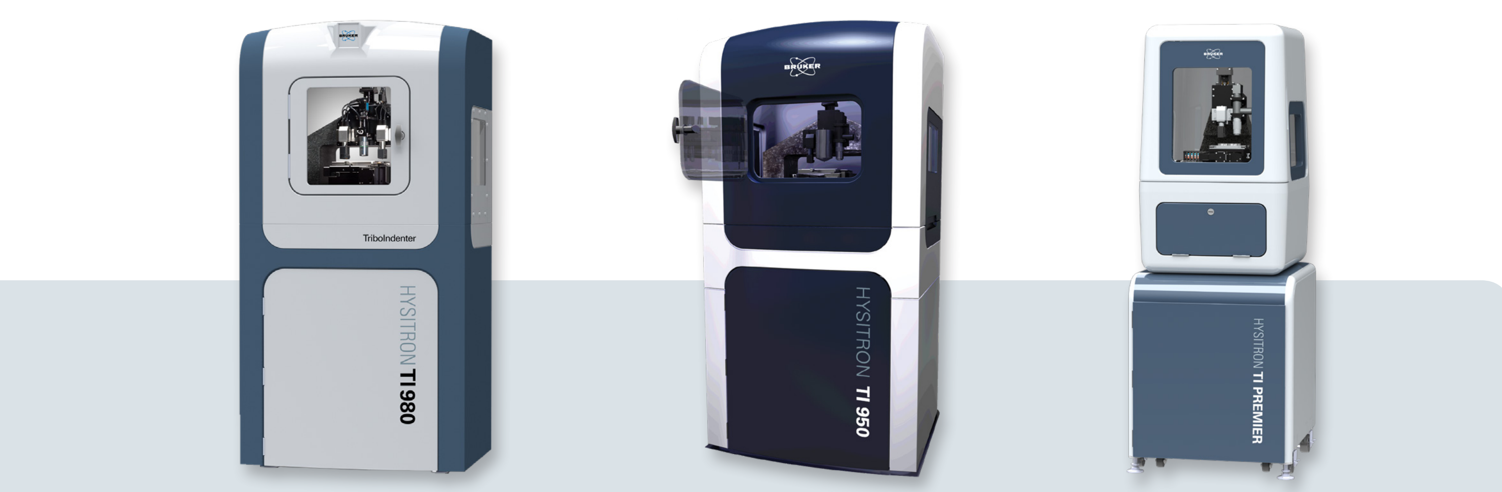




Schematic of the xSol High Temperature Stage.

Expanding the Capabilities of our Industry-Leading Nanomechanical Test Instruments

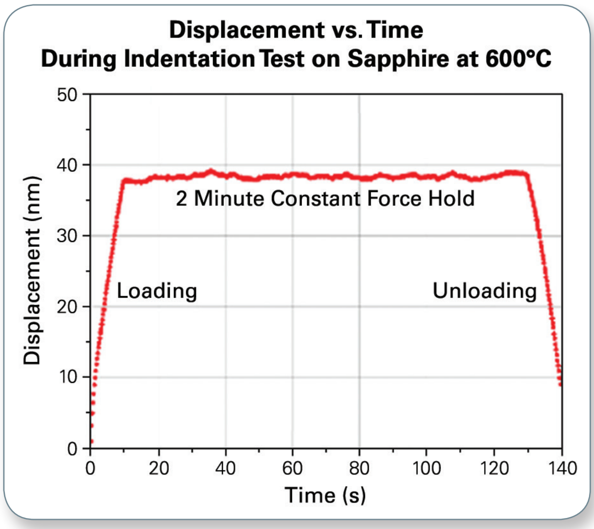
Bruker's xSol High-Temperature Stage has been specifically designed to enhance the core nanoscale characterization capabilities of the Hysitron® TI Series systems. The xSol stage can be utilized in conjunction with in-situ SPM imaging, nanoindentation, nanoscratch, and nanowear to obtain comprehensive knowledge of nanoscale mechanical and tribological behavior at non-ambient temperatures. It can be further expanded to include precise control of humidity and cooling. Combined with nanoDMA® III, time-temperature-superposition studies of viscoelastic materials and prolonged, elevated-temperature creep experiments can be accurately and reliably performed.



Up to 800°C and Beyond

Superior Testing Stability

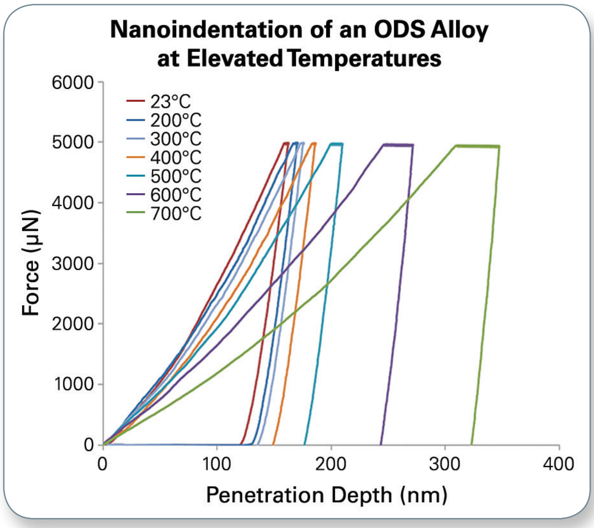
Bruker's xSol stage utilizes a proprietary design constructed with a unique combination of low-thermal expansion and thermally insulating materials to achieve minimal thermal drift during testing. PID feedback loops and high-precision resistive heating elements assure tight temperature control with fast equilibration times. Insulating ceramics surround the heated core of the stage, creating an internal region of uniform temperature. Dissipated heat is transported outside of the instrument enclosure through the xSol's liquid-cooled metal base. The coolant is held at a constant temperature, ensuring dimensional stability in the base and preventing heat from dissipating into other areas of the system, assuring ultra-precise measurements at all times.



High thermal stability of the xSol heating system shown over an extended period of time.

Temperature Uniformity

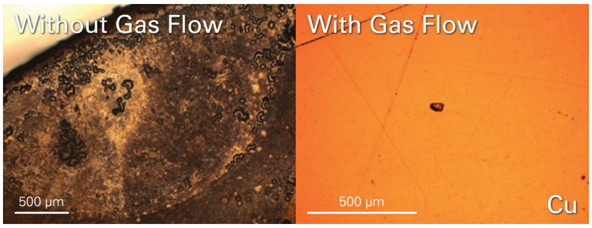
To achieve accurate nanomechanical measurements as a function of temperature, precise control and knowledge of the sample surface temperature is required. The xSol stage incorporates a dual, independently controlled heating element architecture that heats from the top and bottom of the sample, forming a micro-environment in the stage's interior. The test probe is designed to maximize the thermal resistance of the shaft so that heat conduction through the shaft is negligible. When the probe tip enters the heated test chamber prior to performing a measurement, thermal equilibrium between the sample surface and the probe develops within seconds. Sample temperature uniformity combined with isothermal tip-sample contact allows for quantitative, high-resolution nanomechanical measurements to be performed over a broad range of temperatures.



Example of force-displacement indentation curves obtained for the temperatures up to 700°C from the quasi-static indentation performed with 10 sec. of loading, 5 sec. of hold, and 1 sec. unloading.

Customized Atmospheres

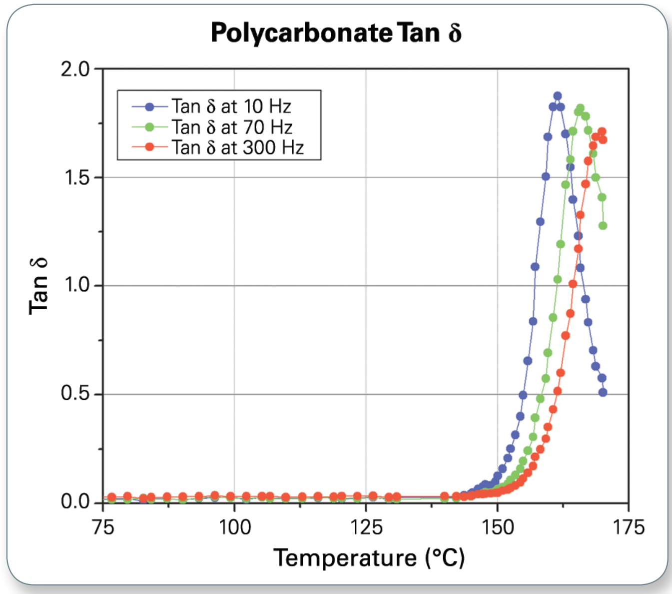
Bruker's xSol stage incorporates a microcavity that enables control of the gaseous atmosphere surrounding the heated sample. This micro-environment can be purged with customizable gas mixtures to prevent reactive chemistries on the sample surface, such as oxidation. Additionally, the pre-heated gas flow within the microcavity greatly improves thermal stability by assuring tip/sample thermal equilibrium.



Cu sample after 600°C exposure without gas flow (left) and with gas flow (right).

Compatible with a Powerful Suite of Characterization Techniques

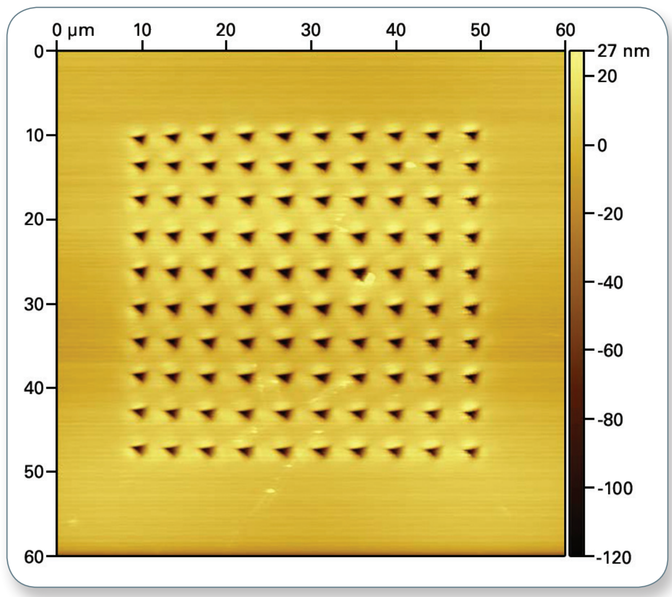
The xSol stage is compatible with Bruker's in-situ SPM imaging, nanoindentation, nanoscratch, nanowear, and nanoDMA III techniques, enabling a comprehensive knowledge of nanomechanical and tribological behavior at elevated temperatures. Dynamic testing can be performed at various testing frequencies and temperatures to conduct time-temperature superposition studies of nanoscale volumes of material. Creep measurements over long time periods can be performed utilizing nanoDMA III's reference frequency technique. Combining the xSol with accelerated property mapping (XPM™) allows rapid testing and localized material properties to be thoroughly characterized and tuned for their intended operating temperature.



nanoDMA III tan-delta in a function of temperature and frequency.

xSol High Temperature Stage Features

- Nanomechanical characterization capabilities up to 800°C and beyond, enabled by the thermally stable stage design
- No thermal gradient within the sample, due to the dual heating-element design
- No need for UHV, thru built-in micro-environment atomspheric control
- Sub-angstrom/sec. drift rates at 800°C, via innovative thermal expansion cancellation design and stable temperature feedback control algorithms
- Easy mechanical sample mounting between the heating elements, eliminating the need for high-temperature adhesives
- High-temperature SPM imaging capabilities, for precise test positioning accuracy and surface topography measurement
- Compatibility with Bruker's microscale and nanoscale characterization transducer
- In-situ drift compensation and accurate results over a broad range of temperatures and extended time durations, via nanoDMA III reference frequency algorithms
- Compatibility with Bruker's XPM, for rapid testing throughput under extreme environmental conditions



SPM image of silicon taken at 800°C following XPM testing.

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