

APPLICATION NOTE

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ACTUATION & SENSING

APPLICATION

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INTRODUCTION

At its essence, instrumented indentation testing involves applying a known force to the surface of a test sample and measuring the resulting penetration into that surface. The accuracy and repeatability of calculated properties depend directly on the quality of the fundamental force and displacement data.

ELECTROMAGNETIC FORCE ACTUATION

All NANO **Indenter** systems use electro-magnetic actuation. This means that force is imposed on the indenter shaft by passing current through a coil that sits within an annular magnet as illustrated in [figure 1](#).

This method of actuation has a number of important advantages, including:

Superior dynamic range: With a force resolution of 50 nN and a maximum available force of 500mN, the NANO **Indenter xp** has a dynamic range that is unparalleled in the industry. Our NANO **DCM** extension has a force resolution of 1 nN and a maximum available force of 10 mN.

No drift in force: [figure 2](#) shows the force on the test surface as a function of time over a 30-second period in which the indenter is held in contact with a sample of fused silica at the indicated force. The standard deviation in force during this period is 16 nN.

Linear relationship between current and applied force: The electromagnetic force is directly proportional to the current in the coil, and the motion of the indenter has no influence on the applied force, except through the slight deflection of the springs supporting the indenter shaft.

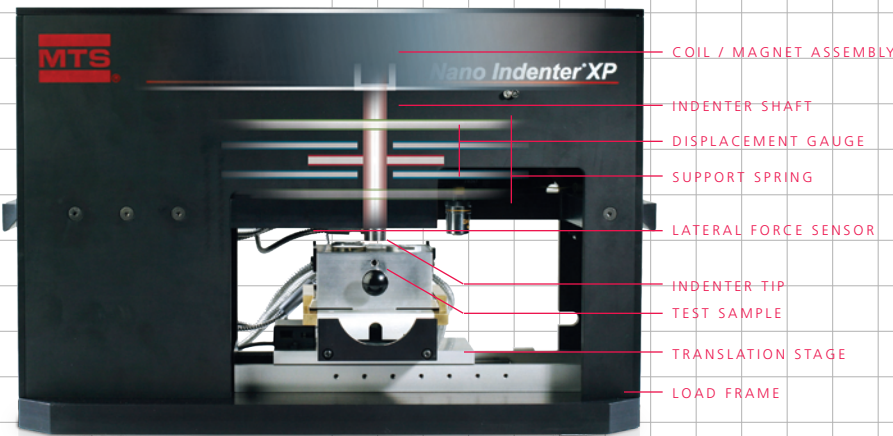
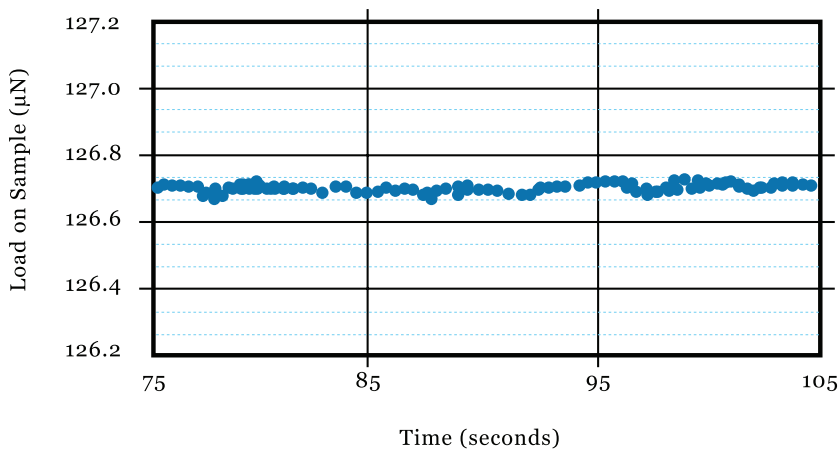


figure 1: Equipment schematic (NANO **Indenter xp** shown)

figure 2: Force vs. time while indenter is held in contact with fused silica under a constant force



RELATED PRODUCTS:



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It should be noted that another popular mechanism for force actuation in mechanical testing is electrostatics. In nanoindentation systems that use this mechanism, a DC voltage is applied across the same capacitive plates that are used for displacement sensing. This voltage application generates a force normal to the plane of the plates. Such a mechanism is disadvantageous for nanoindentation systems for several reasons, the most important of which is the nonlinear and interdependent relationship among voltage, position, and force on the indenter. The force acting between parallel capacitive plates depends not only on the applied voltage, but also on the distance between the plates. The consequence is that when the voltage is applied, the plate affixed to the indenter moves. This changes the capacitive gap, which in turn changes the force that one is trying to control.

DISPLACEMENT SENSING

Displacement is sensed using the three-plate capacitive arrangement shown in [figure 1](#). All three plates are circular disks. The two outside plates are fixed to the head and have holes in the center just large

enough to accommodate the indenter shaft. The center plate is fixed to the indenter shaft and is free to move vertically between the two outside plates. The position of the indenter column within the gap is determined by observing the difference in voltage between the center plate and either of the two outside plates. This displacement sensor is calibrated using laser interferometry. Our flagship instrument, the **NANO Indenter xp**, has a displacement resolution of 0.01 nm and a travel of 2 mm. This combination of range and resolution is unparalleled in the industry.

MINIMIZING, MONITORING, AND ACCOUNTING FOR THERMAL DRIFT

In general, the real displacement into the test surface may be different from the displacement as obtained directly from the capacitive gauge due to thermal drift, which is the thermal expansion or contraction of the test material and/or indentation equipment. **NANO Indenter** systems are purposefully designed to minimize the influence of thermal drift, accurately monitor its effects (however small), and compensate for those effects. Furthermore, we give the user the power to control the acceptable level of thermal drift for his or her testing application.

Minimization: The system is thermally isolated from its environment by a cabinet enclosure. Furthermore, the indenter column is made of Invar, which has a very low coefficient of thermal expansion. These and other measures minimize the effect of any temperature change on the displacement data.

Monitoring and Accounting: The instrument automatically determines, reports, and applies a thermal drift correction for each indentation test. Near the conclusion of the indentation experiment, the indenter is held at a small constant force for at least 50 seconds in order to make an accurate determination of drift. A drift rate is calculated, for example, in nm/sec. Displacements for the entire test are then corrected according to the time at which they were acquired. Typical values of thermal drift are less than 0.05 nm/sec. (It should be noted that the user may easily override the application of this correction if so desired.)

User Control: Before any series of tests, the user has the power to set the acceptable level of thermal drift for initiating testing. For example, one user may decide that a low drift rate of 0.02 nm/sec is critical; the instrument then waits until this drift rate is achieved before starting the tests. Another user, testing at large displacements, may set the acceptable level for test initiation at 0.1 nm/sec.

WHAT IS AN NMAT?

NMAT stands for Nano Mechanical Actuating Transducer. We believe that the actuating-transducer mechanism used in our **NANO Indenter** systems, with its superior range and resolution, will have many other applications in small-scale mechanical testing. In fact, it is also the heart of our **NANO Bionix**® and **NANO UTM** universal testing systems. We look forward to hearing how such a device might help meet your unique testing needs.



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Inspired science.

Characterizing surfaces down to the level of a few nanometers has become increasingly important for a wide range of manufacturers and researchers. Properties at the nano scale can affect the performance of a variety of scientific and consumer products. **NANO Indenter** systems from **MTS NANO INSTRUMENTS** use the most advanced technology available to acquire fast, accurate mechanical data on a variety of surfaces at the submicron scale.