NANO INSTRUMENTS

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DYNAMIC INDENTATION

APPLICATION

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INTRODUCTION

Dynamic indentation is the process of superimposing a small sinusoidal oscillation on the primary indentation loading signal and analyzing the response by means of a frequency-specific amplifier. By measuring the amplitude ratio and phase shift between the force and displacement oscillations (and accurately accounting for the contribution of the test equipment), a continuous measure of the stiffness and damping of the contact is obtained. The founders of MTS Nano Instruments first patented this technique in 1989, and we continue to develop new applications.

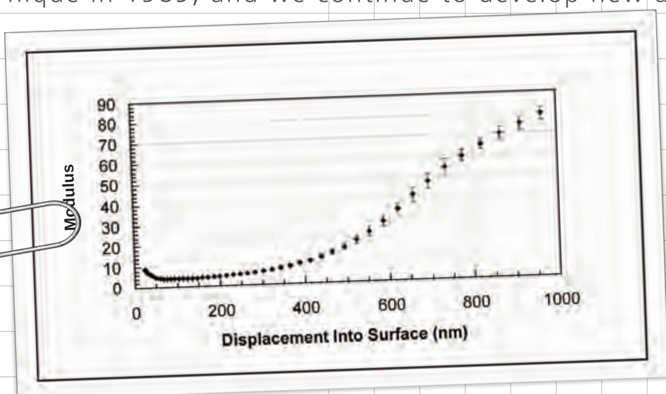
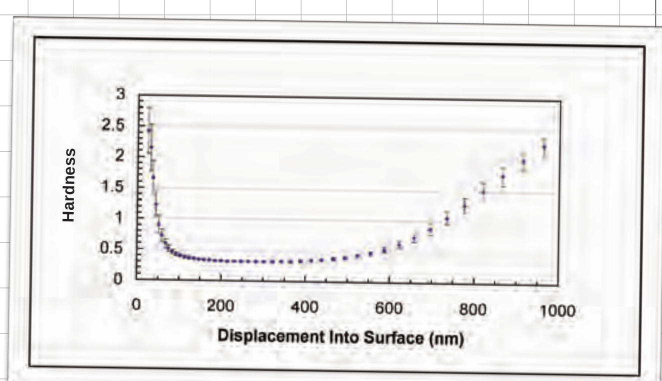


figure 1: Modulus vs. Displacement for a soft film on a silicon substrate obtained using dynamic indentation. Average of 10 tests. Error bars represent 1σ.

Only Nano Indenter systems have a proven ability to use dynamic indentation to return elastic modulus and hardness as a continuous function of surface penetration.

figure 2: Hardness vs. Displacement for a soft film on a silicon substrate obtained using dynamic indentation. Average of 10 tests. Error bars represent 1σ.



HARDNESS AND MODULUS VS. PENETRATION

One of the most practical uses of dynamic indentation is the determination of elastic modulus and hardness as a continuous function of penetration depth. This ability dramatically simplifies the mechanical evaluation of thin films. Figures 1 and 2 show such results for a soft film on a silicon substrate. These tests were performed on a NANO **Indenter** XP. Information gleaned from these plots includes:

- There is a thin capping layer that increases the measured modulus and hardness at indentation depths less than 100 nm. (This was confirmed by the supplier.)
- The silicon substrate begins to affect the measured modulus at a depth of about 150nm. It begins to affect the measured hardness at about 300nm. (Modulus measurements are generally more substrate-sensitive, because the elastic deformation field extends far beyond the plastic.)
- The best values for the properties of the film of interest are taken to be the minima. Thus, the modulus of the film is 3.9 GPa and the hardness is 0.31 GPa.

It should be noted that similar tests for a hard film on a soft substrate would show elevated properties near the surface and then a gradual decrease in properties as the substrate exerts more influence.

RELATED PRODUCTS:

NANO **Indenter** XP

TestWorks®

MTS®

STORAGE AND LOSS MODULUS OF POLYMERS

Dynamic indentation can also be used to measure storage and loss modulus as a function of frequency for polymer materials. Figures 3 and 4 show the storage and loss modulus for polydimethylsiloxane (PDMS) using (1) a Nano Indenter DCM and (2) a commercially available dynamic-mechanical analysis instrument (DMA). (DMA is a well-established technique for determining storage and loss modulus of bulk polymer samples.) The comparison is outstanding. In fact, the properties measured using the two instruments diverge at frequencies greater than 40 Hz due to the inadequate frequency response of the DMA instrument! In this respect, the Nano Indenter DCM offers a distinct advantage because its available frequency range is 1 – 300 Hz.

Only NANO **Indenter** *systems have a proven ability to measure storage and loss modulus values that are comparable with those returned by DMA. that performs a similar function.*

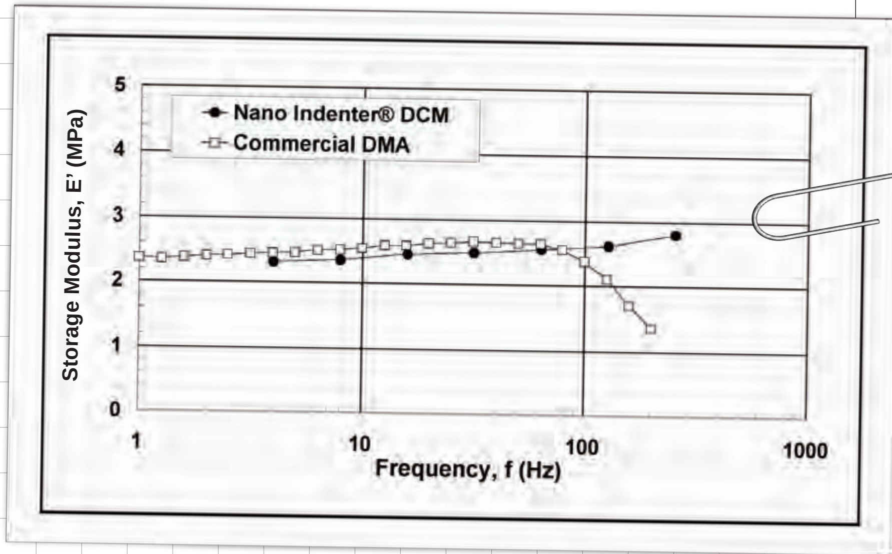


figure 3: Storage modulus vs. frequency of polydimethylsiloxane (PDMS) as measured by a NANO **Indenter** DCM and commercial DMA. Fall off after 40 Hz is due to inadequate frequency response of DMA instrument.

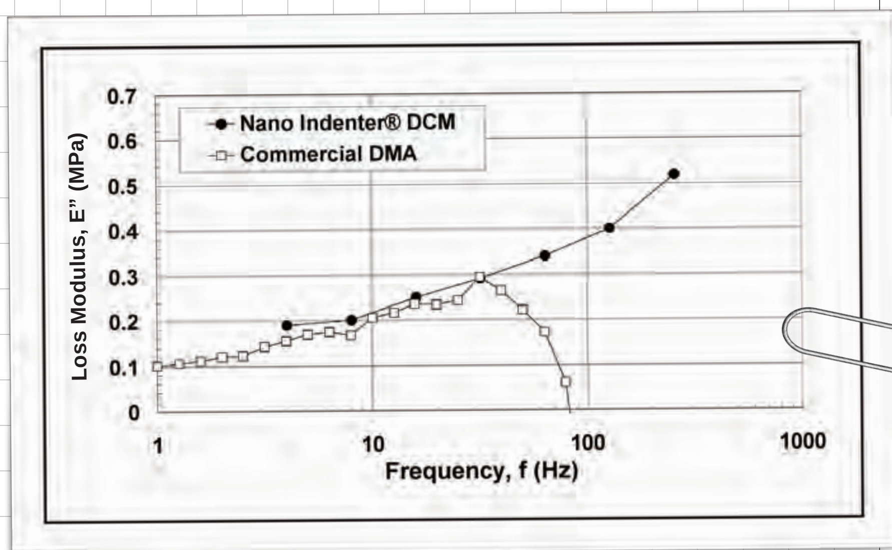


figure 4: Loss modulus vs. frequency of polydimethylsiloxane (PDMS) as measured by a NANO **Indenter** DCM and commercial DMA. Fall off after 40 Hz is due to inadequate frequency response of DMA instrument.

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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.

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