Continuous Stiffness Measurements (CSM)

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President

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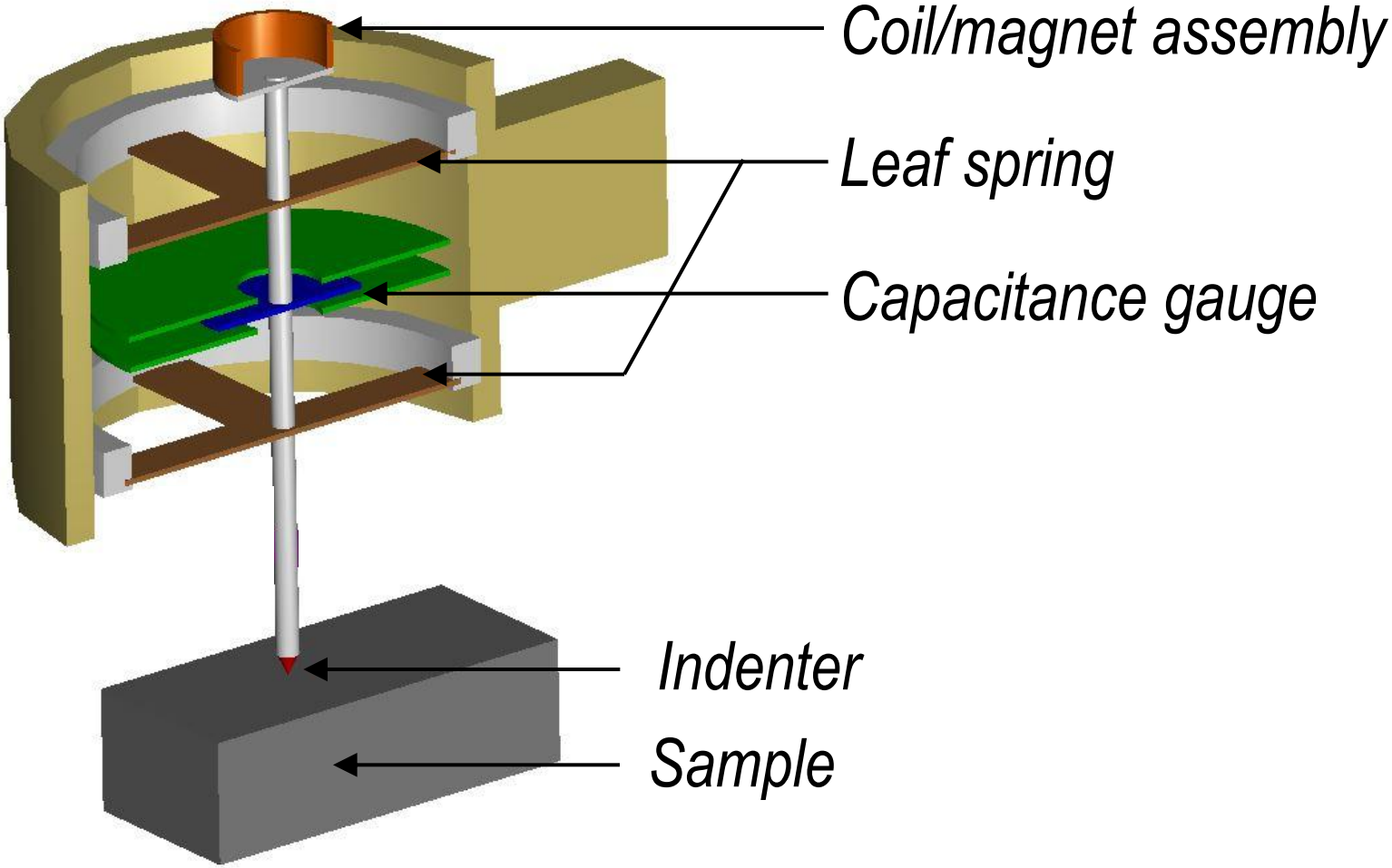
NANO Indenter ® G200 (XP or DCM) Schematic



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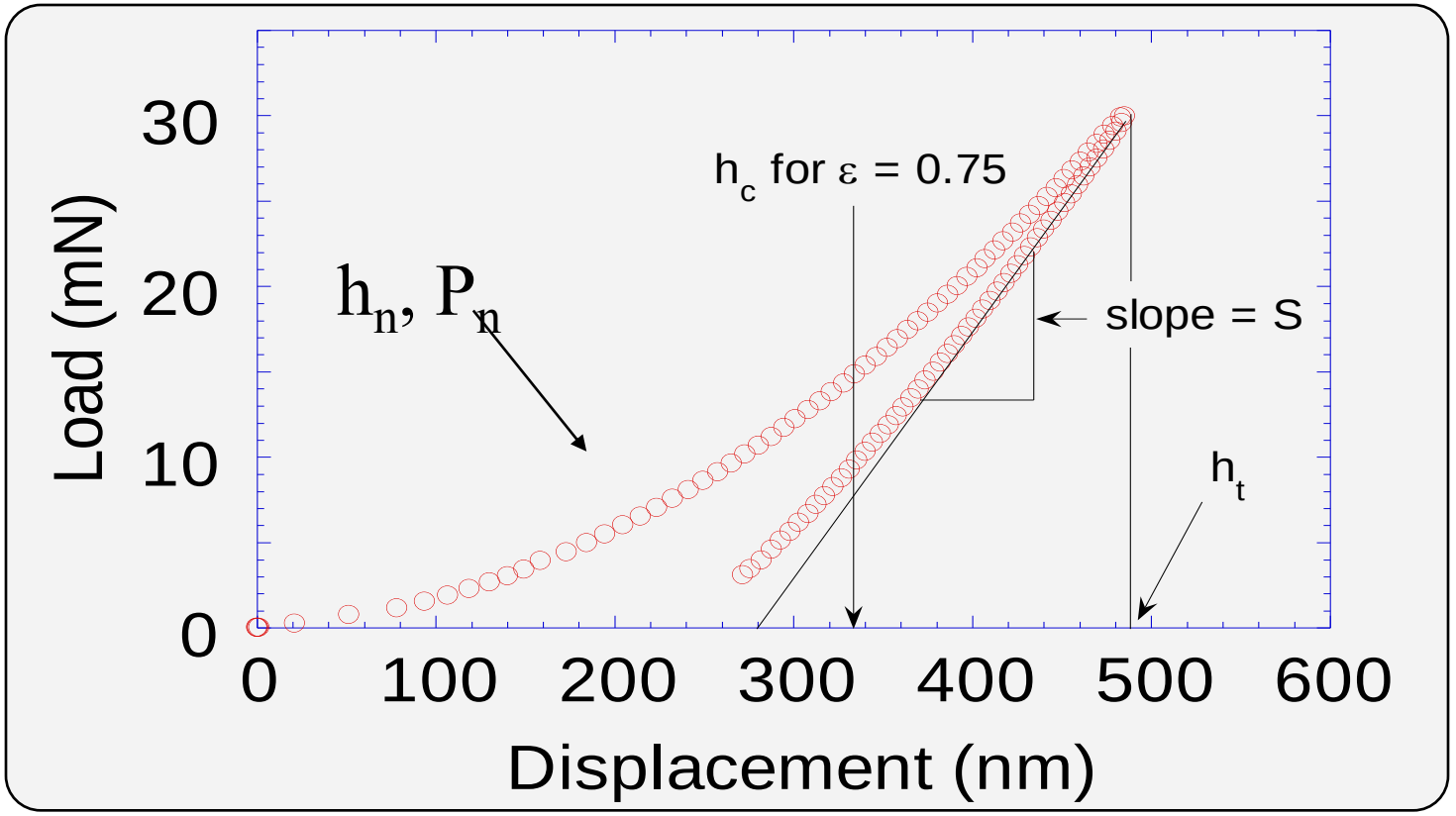
Stiffness From Unloading



Summary of IIT (Nanoindentation) Analysis

$$\frac{1}{E_r} = \frac{\left(1-\nu^2\right)}{E} + \frac{\left(1-\nu_i^2\right)}{E_i}$$

$$\sigma_y \approx H/3$$

$$H = P/A$$

$$E_r = \frac{\sqrt{\pi}}{2}\frac{S}{\sqrt{A}}$$

$$A = f(h_c)$$

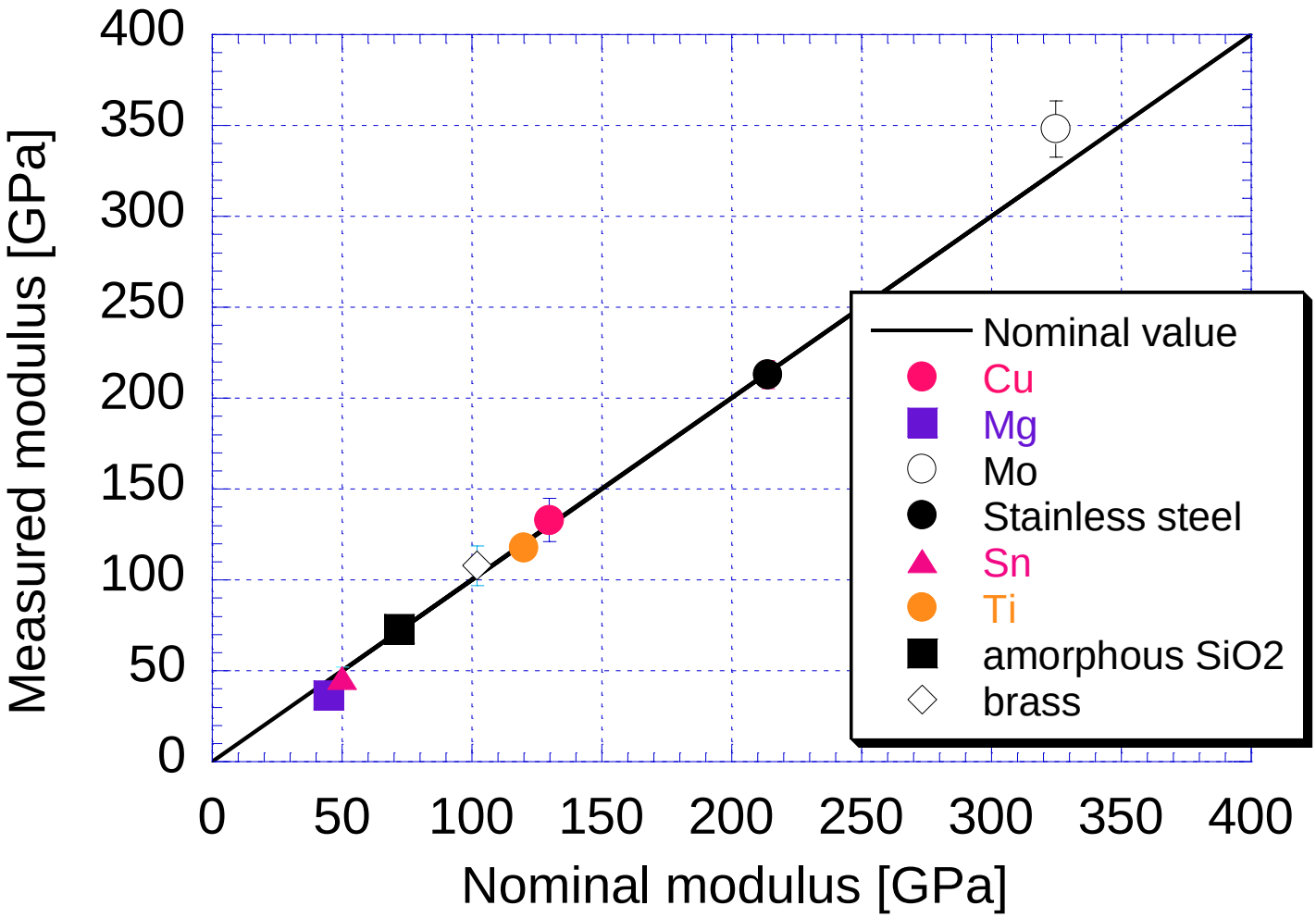
$$h_c = h - 0.75P/S$$

$$S = \left.\frac{dP}{dh}\right|_{h_{\max}}$$

Nomenclature:

E	Young's modulus
H	hardness
σ_y	Yield stress
E_r	reduced modulus
ν	Poisson's ratio
i	(as subscript) indenter
S	contact stiffness
A	projected contact area
h_c	contact depth
h	displacement
P	applied force (load)

Getting Young's Modulus by Indentation



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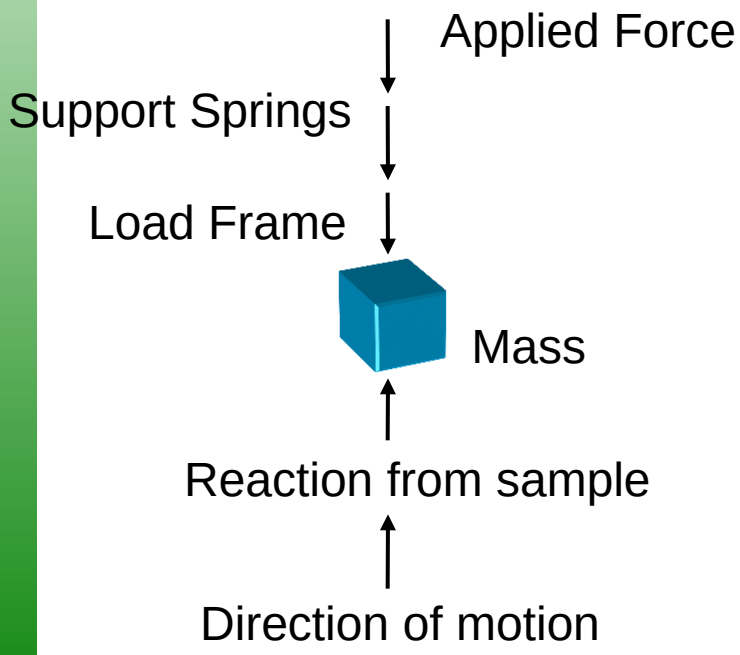
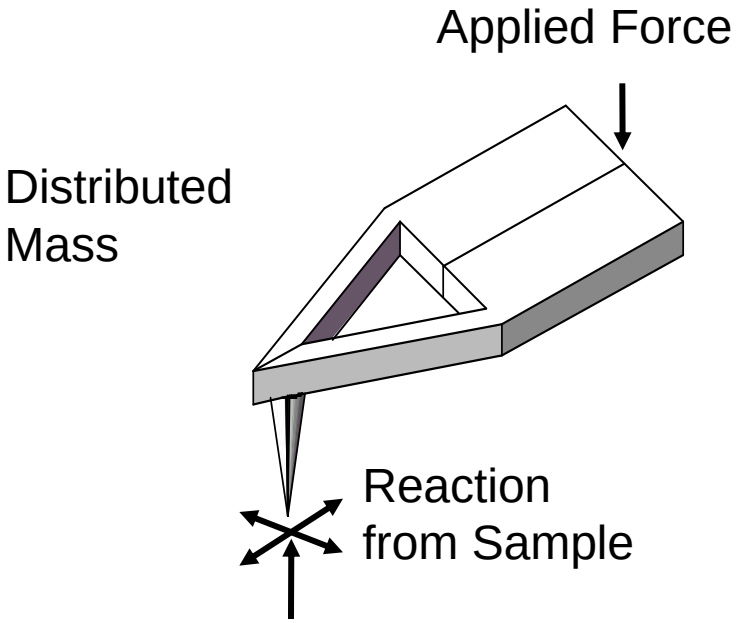
One Dimension vs Many

Two Springs - One Dimensional Motion



Quantitative

One Spring or a Cantilever - Many dimensions

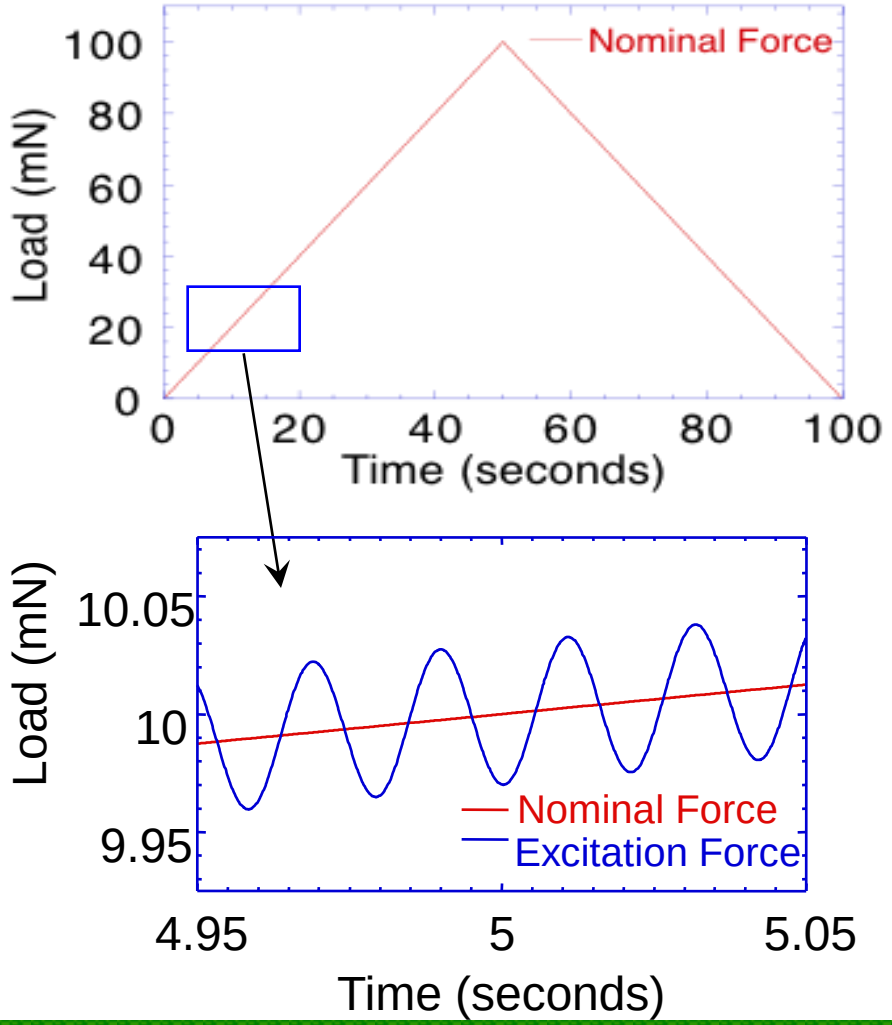


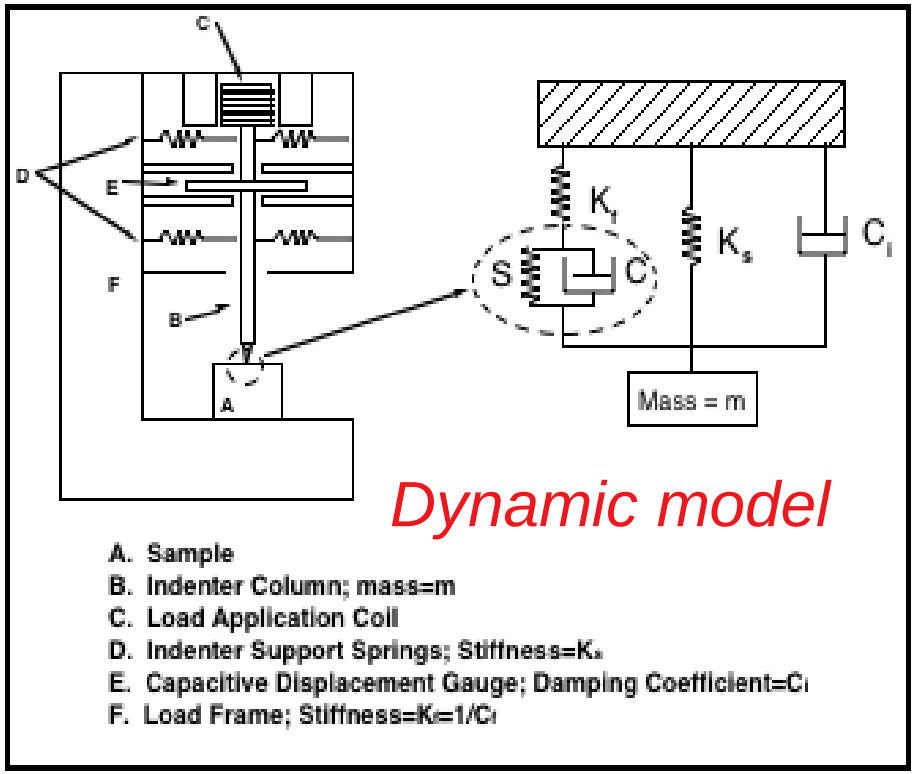
Many modes of vibration and multiple degrees of freedom

Difficult to Analyze

Continuous Stiffness Measurement

•Oliver & Pharr, *J Mater Res***7**, 1564 (1992)





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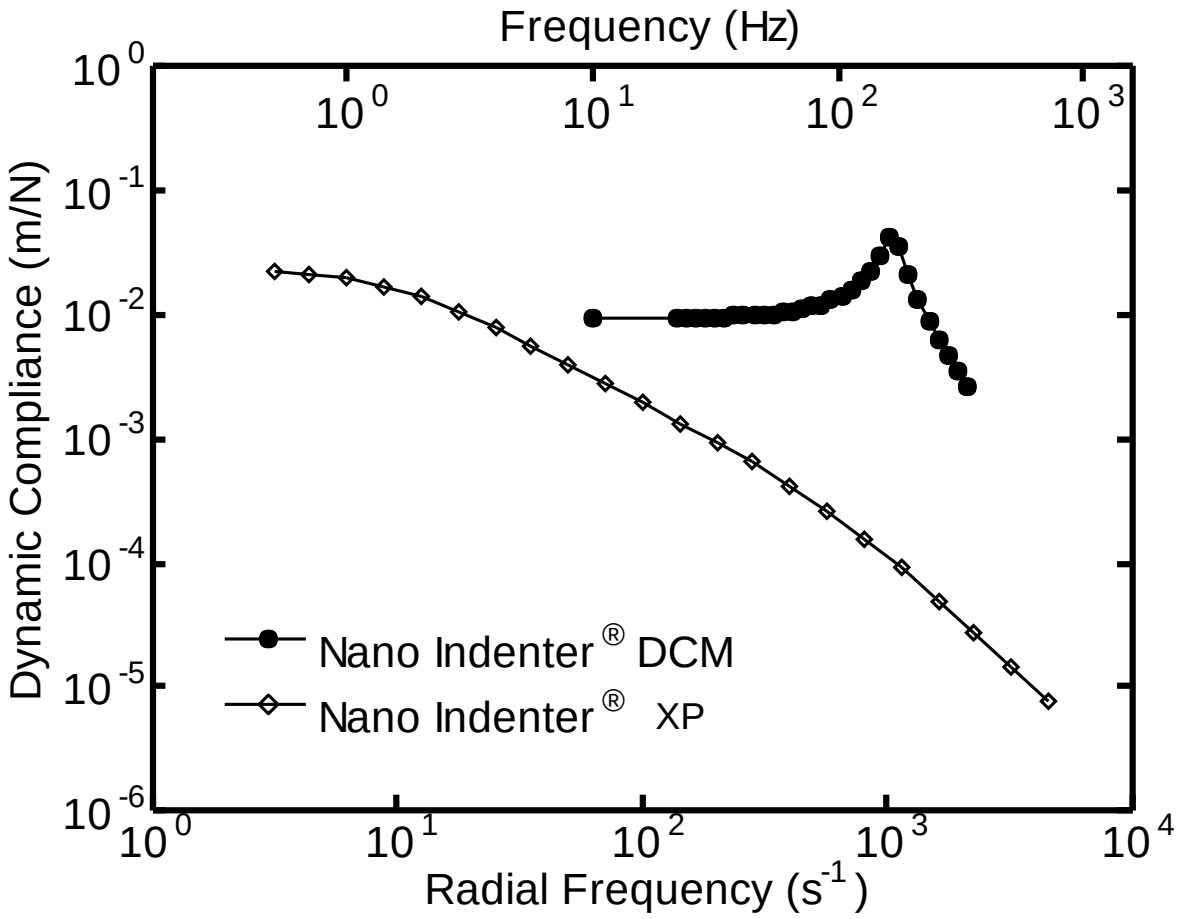
Measurement Actuator Dynamics

	XP	DCM
K_s (N/m)	80	100
m (gm)	10	0.01
C_i (N/m/s)	4	0.01



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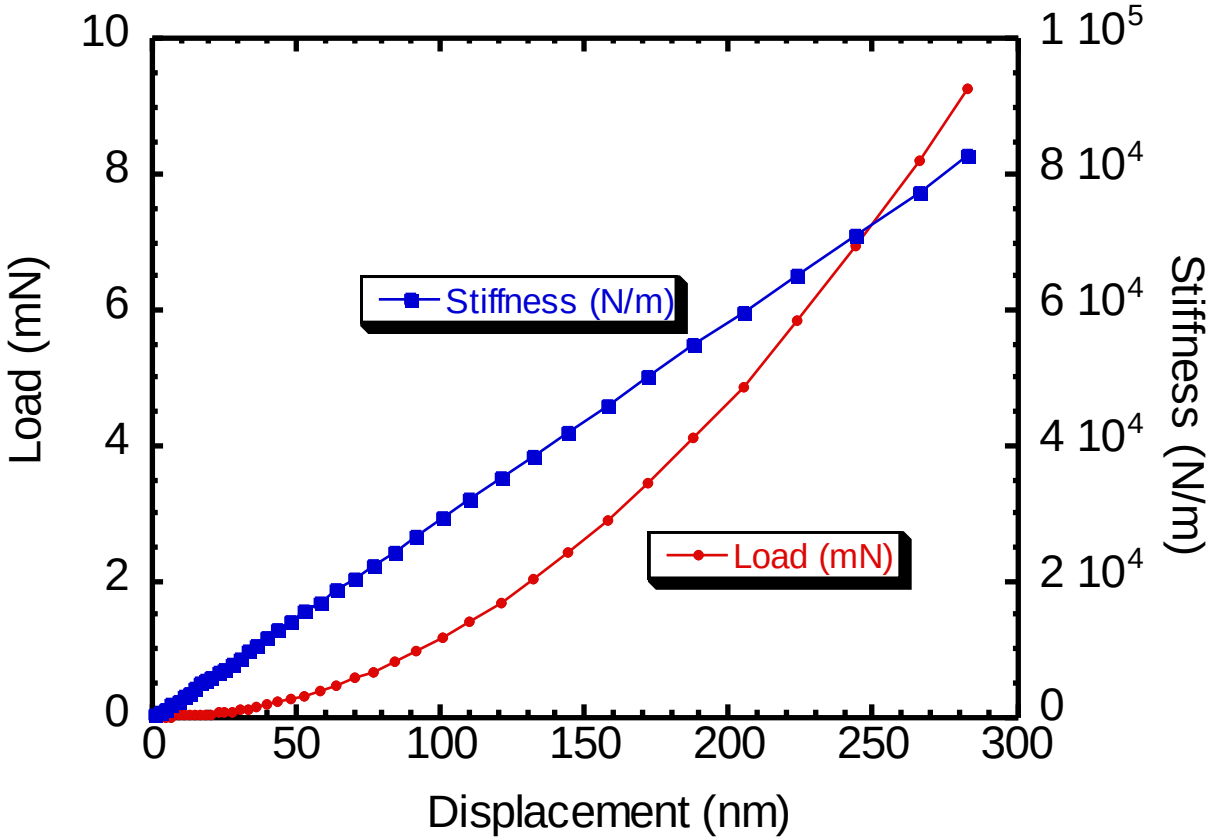
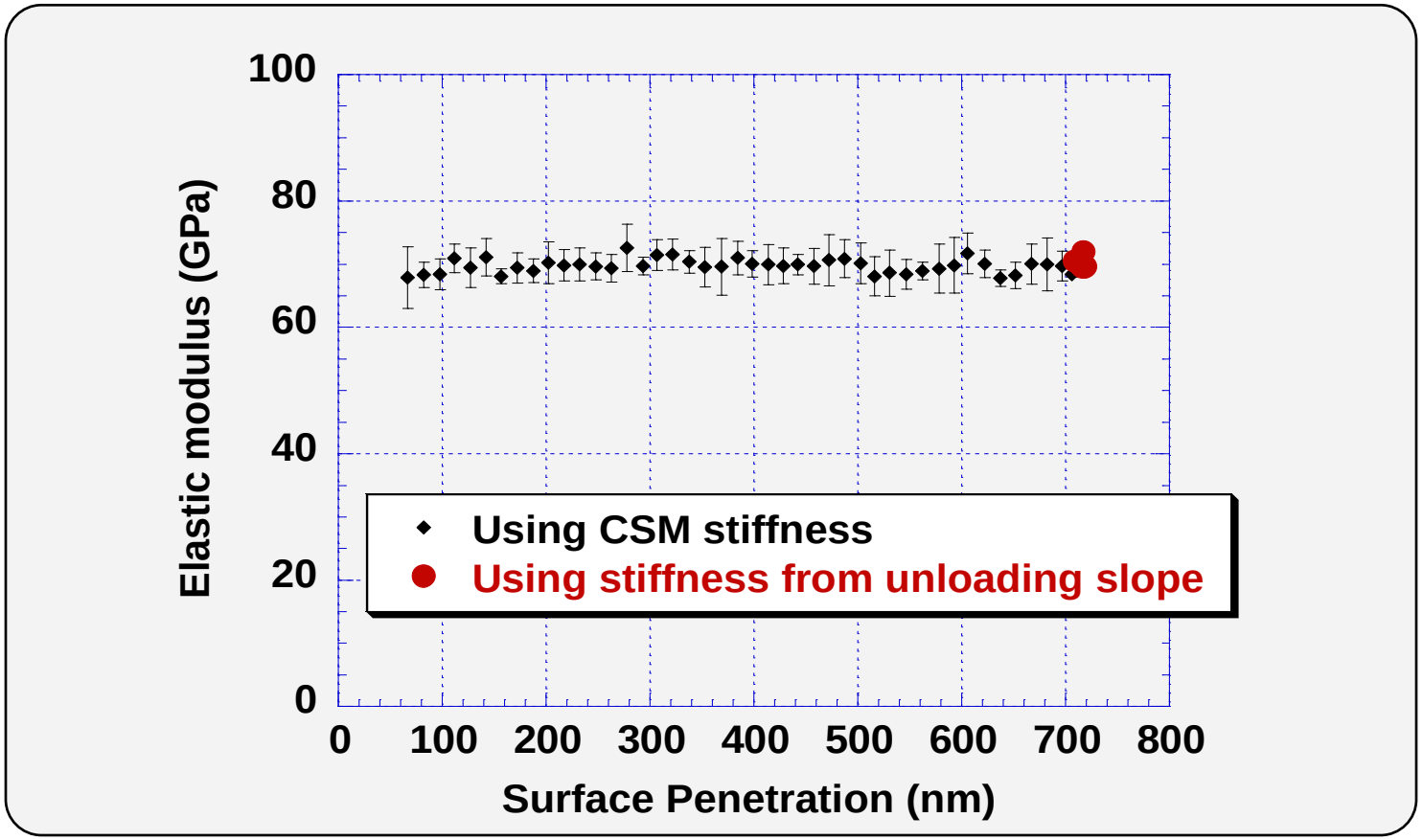
Stiffness from CSM



Elastic Modulus on Fused Silica



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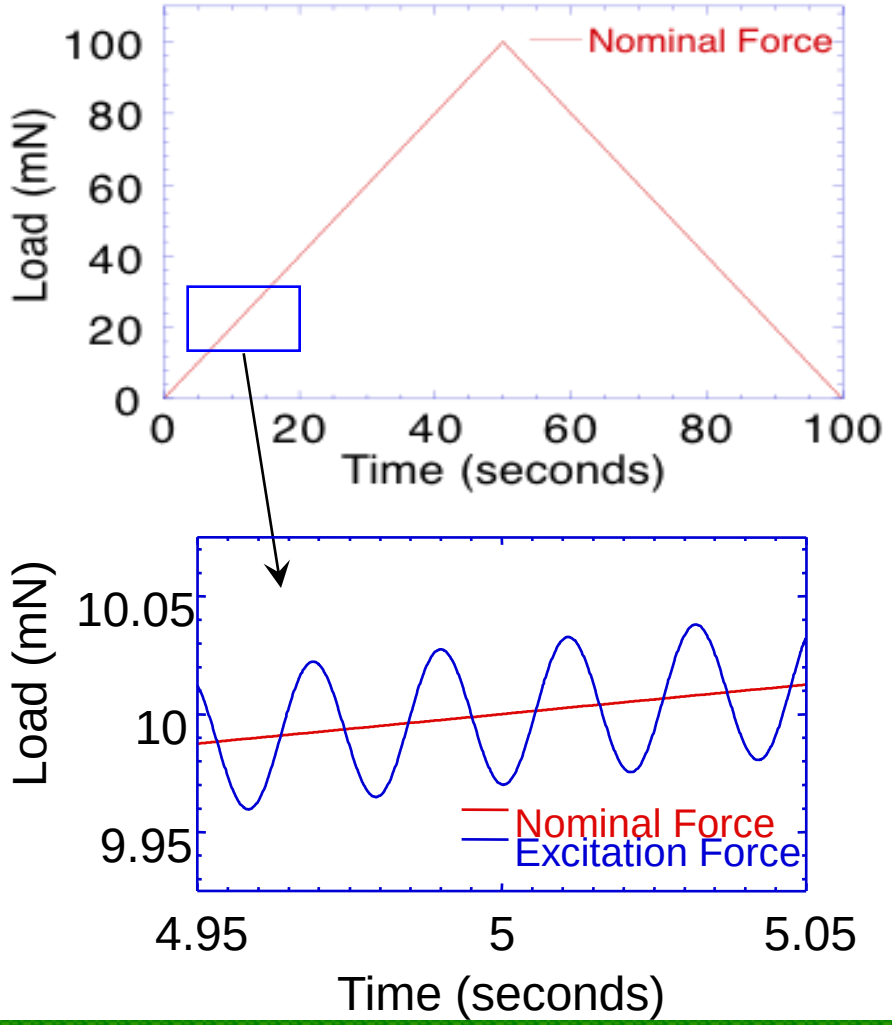
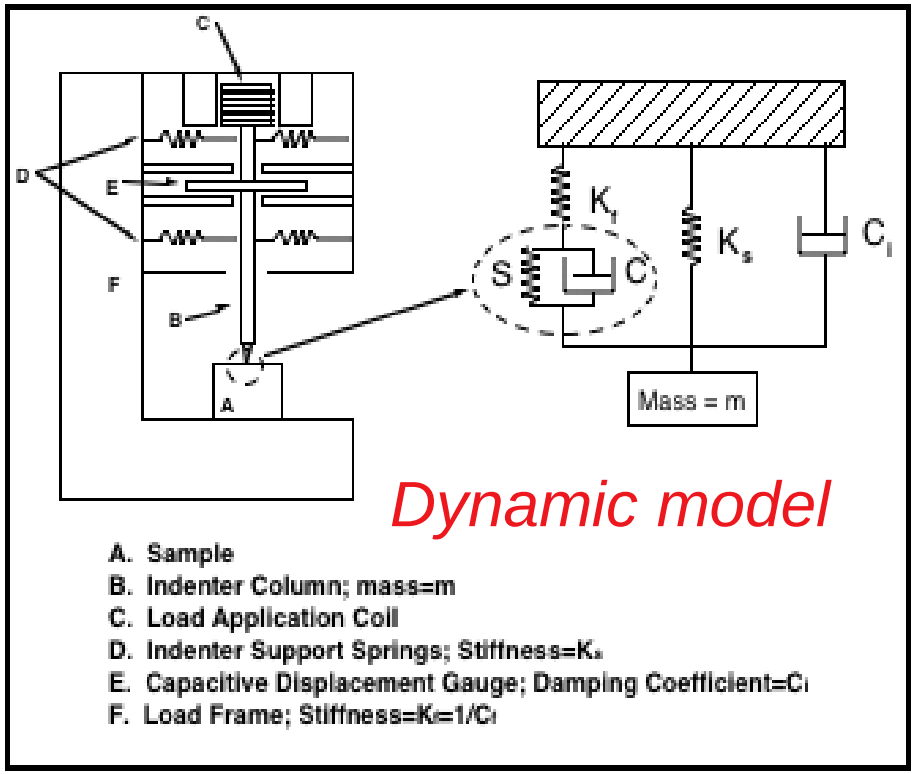
Continuous Stiffness Measurement

•Oliver & Pharr, *J Mater Res***7**, 1564 (1992)





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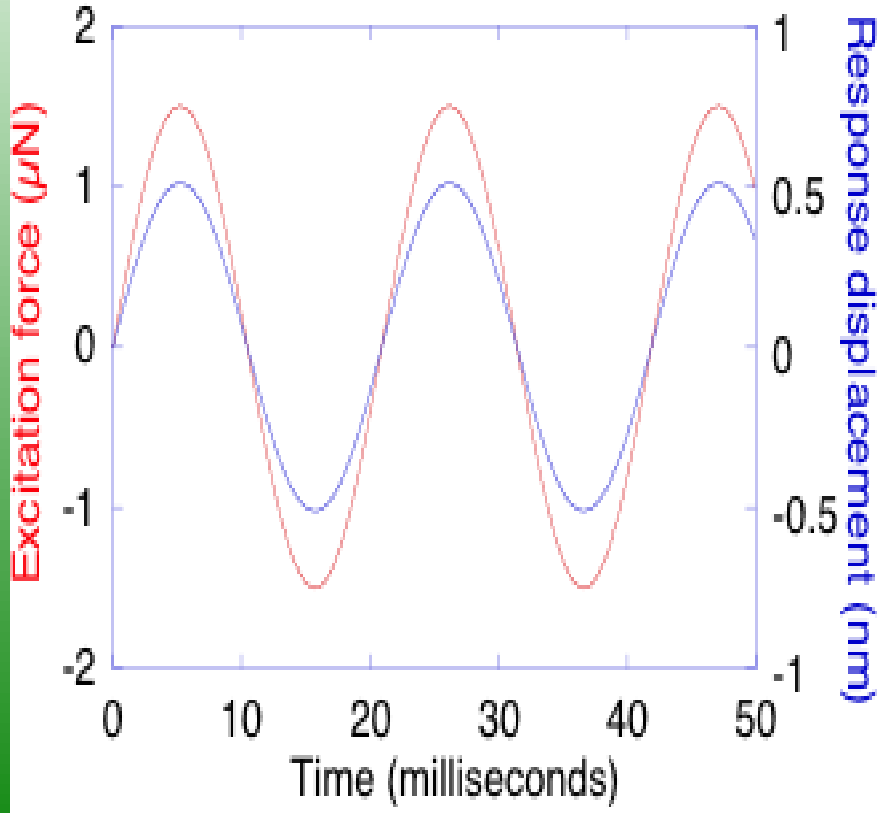
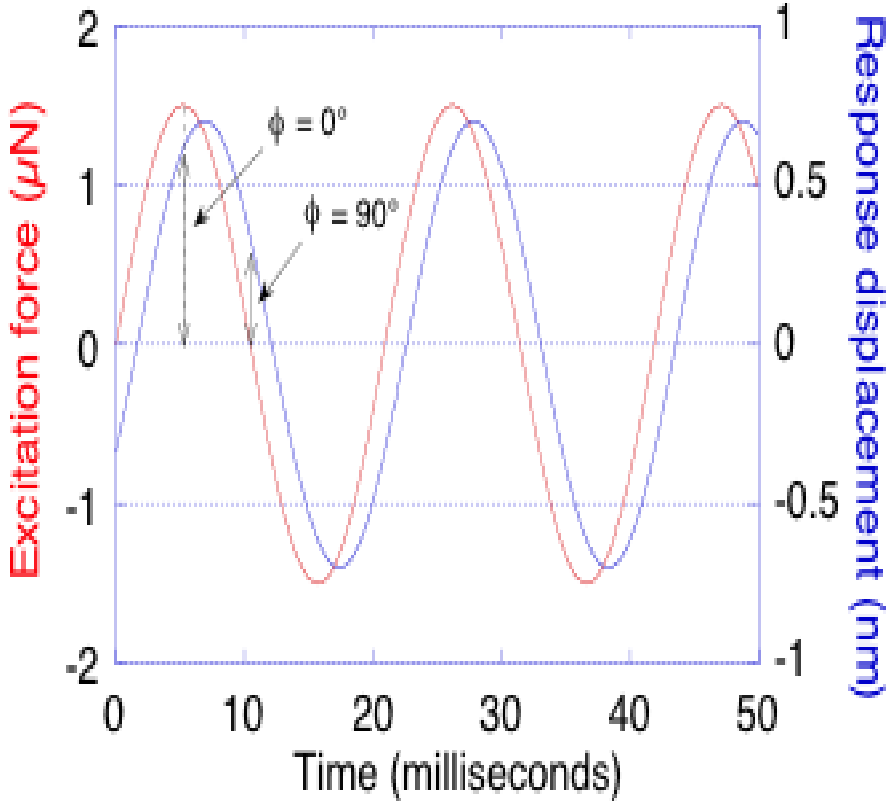
Material Response

Elastic



Viscoelastic



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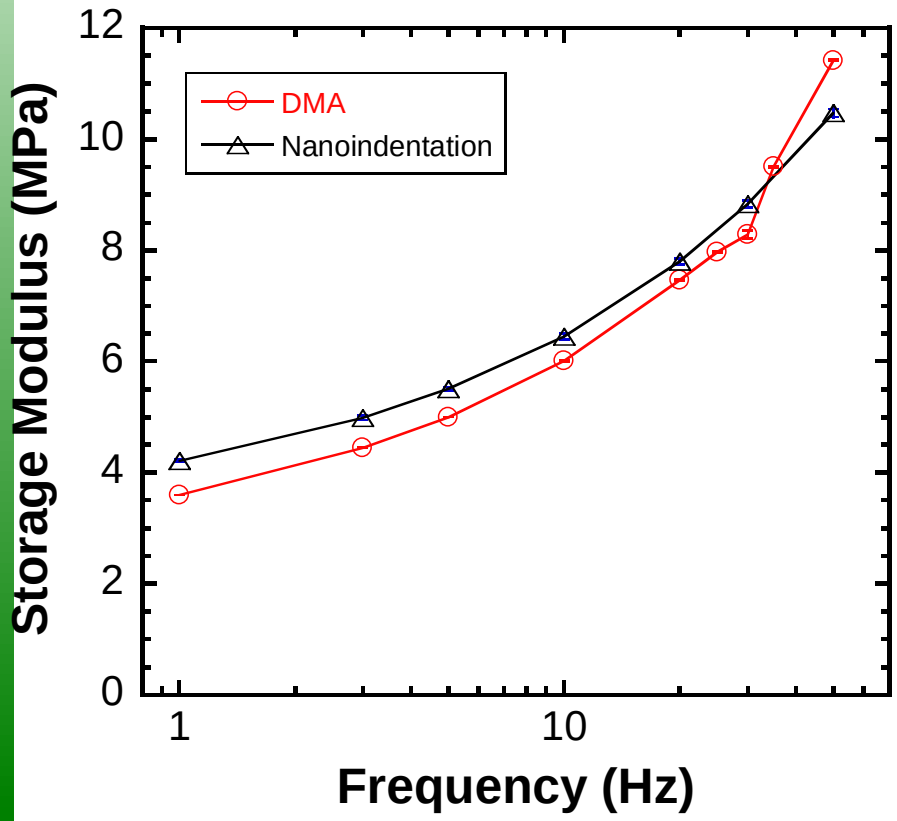
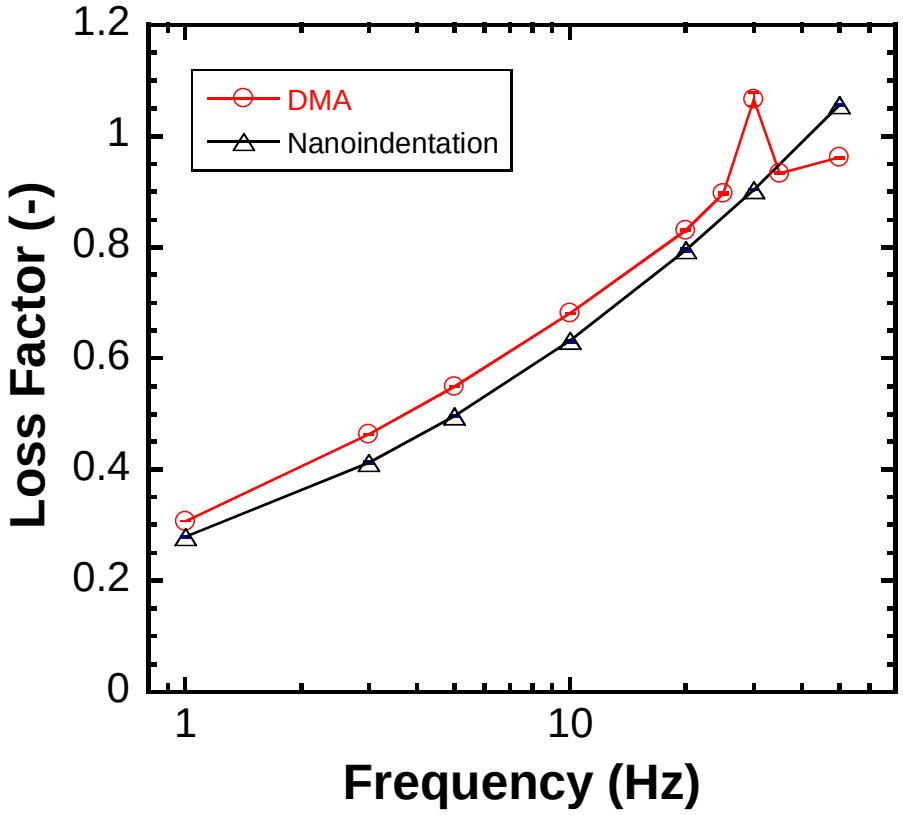
DMA VS. Nanoindentation

Highly plasticized polyvinylchloride, the complex modulus at 22 °C





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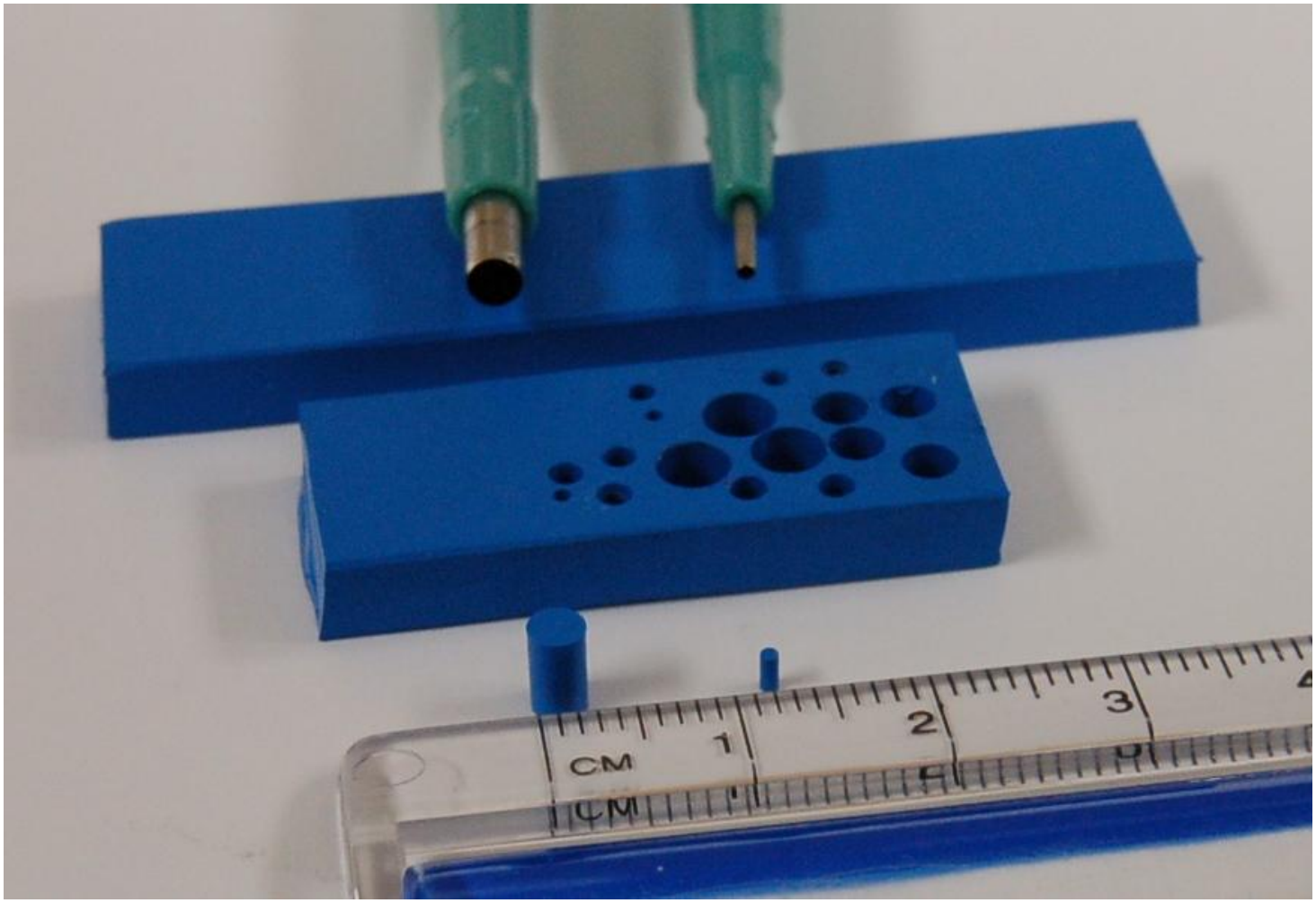
Compression Samples



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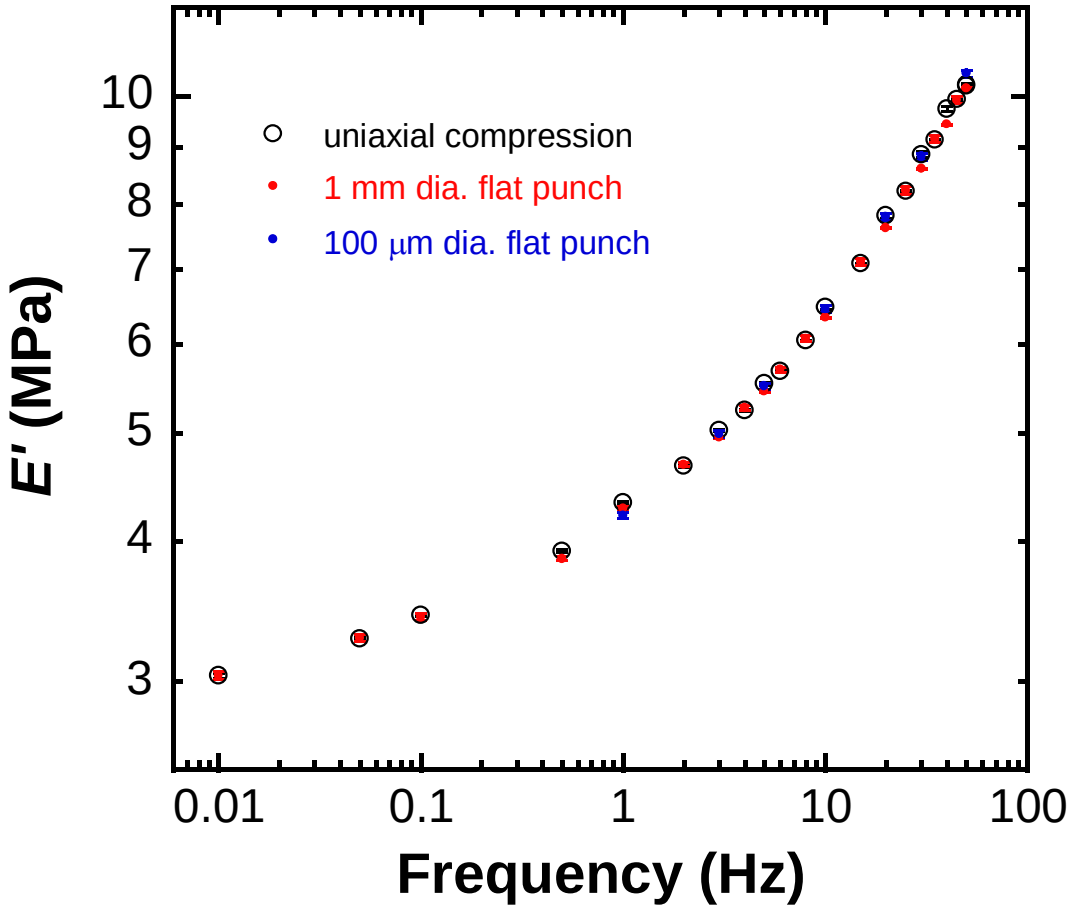
Compression & Indentation



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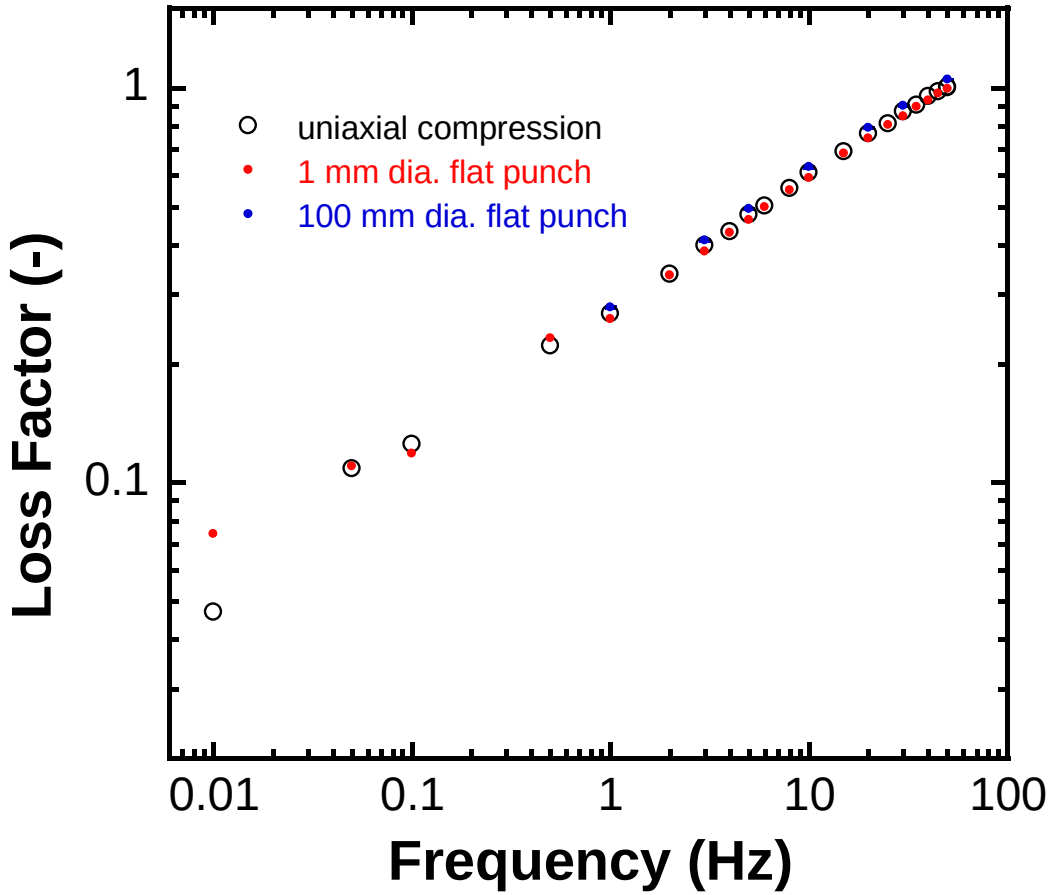
Compression & Indentation



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QUESTIONS?