***Measuring the Elastic Modulus and Residual Stress of Doubly-Clamped Bridges by Nanoindentation***

Presenter: Bryan Crawford

NANOMECHANICS, INC.

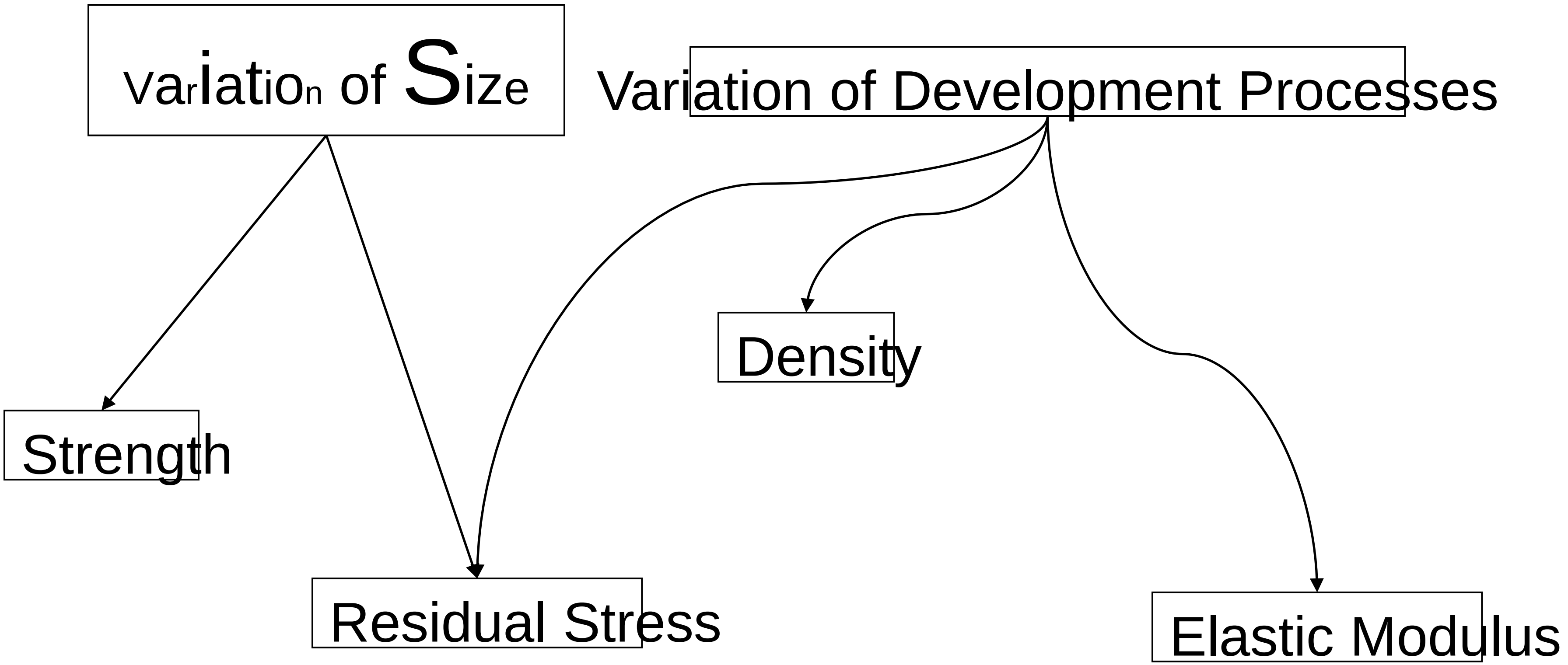
# Drivers: MEMS Development
# Fundamental Material Science

As MEMS move into mainstream, reliability must increase and extensive prototyping must decrease.

Strategies to achieve these advancements will rely on the accuracy of the mechanical properties used as inputs to the modeling process.

# Properties Change due to Size and Process

Production of Films with Well Controlled Geometries



# Advantages of the frequency specific technique:

1. A dramatic reduction in the signal-to-noise ratio.
2. Thermal drift is no longer an experimental concern.

# Samples: Free-standing aluminum thin films in the form of doubly-clamped bridges

**<u>Bridge Dimensions</u>**

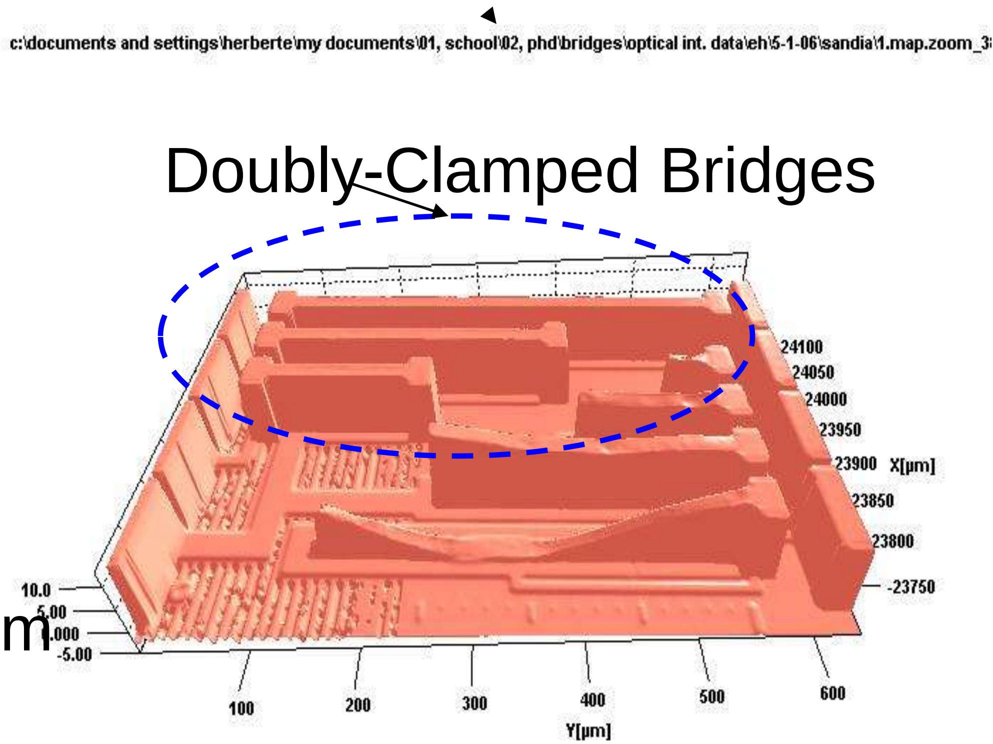
**Material:** Aluminum

**Width:** 20μm

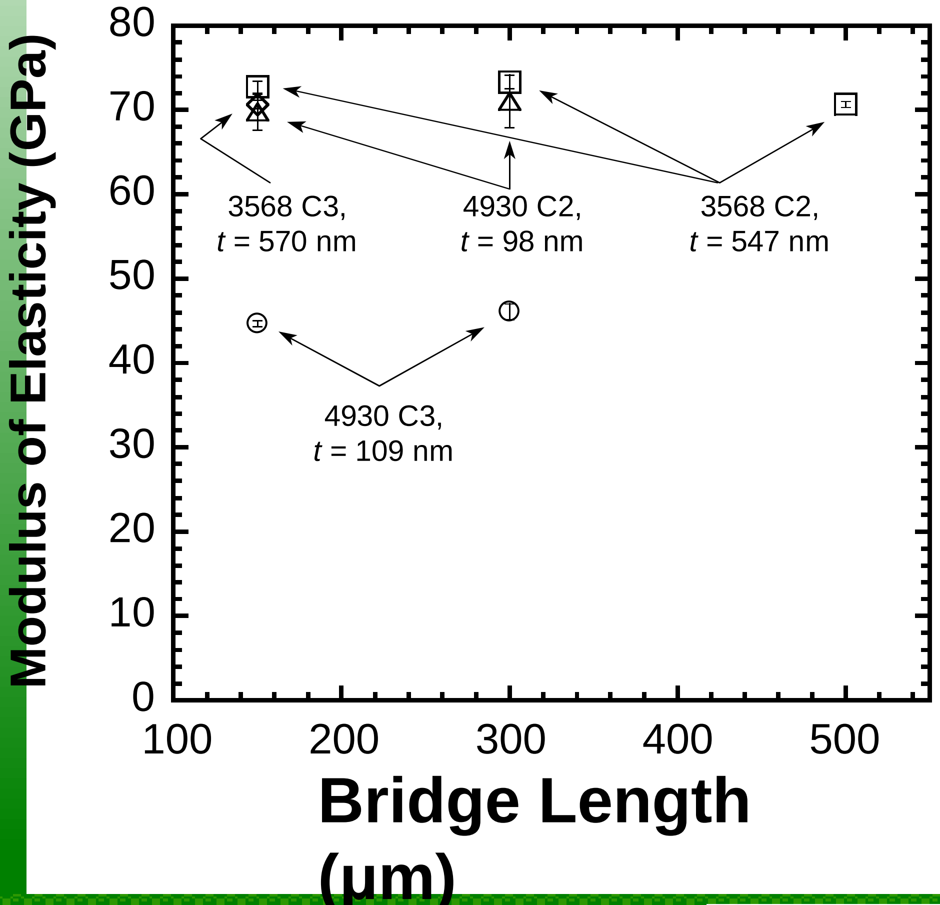
**Thickness:** 0.1 & 0.5μm

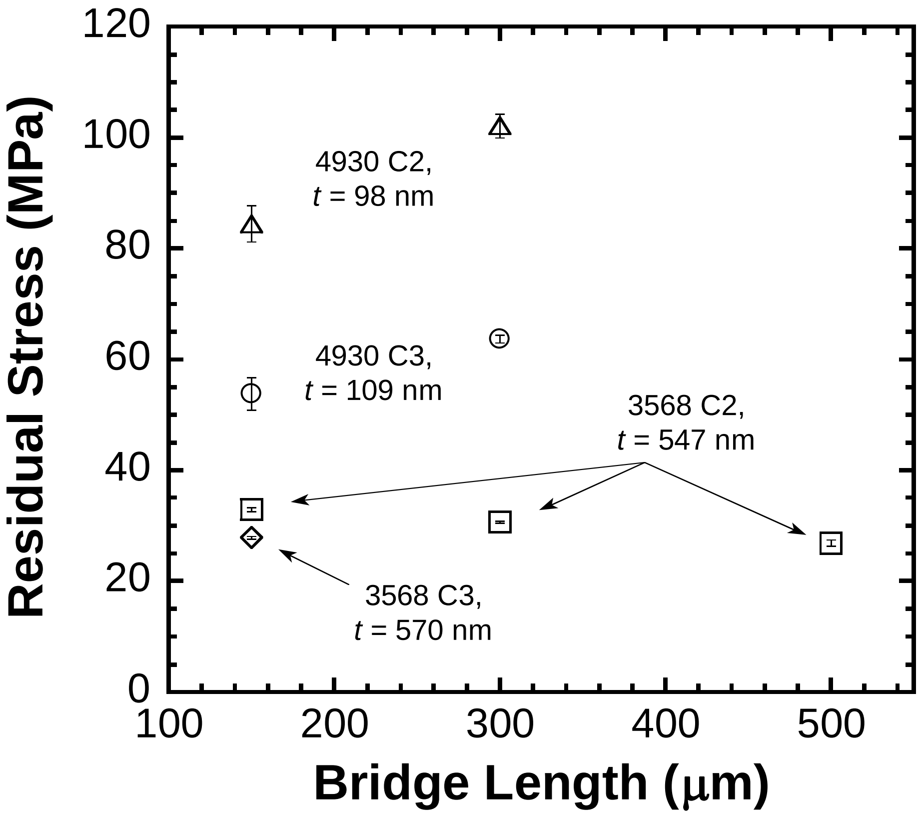
**Length:** 150, 300, & 500μm

**Number of Samples:** 9



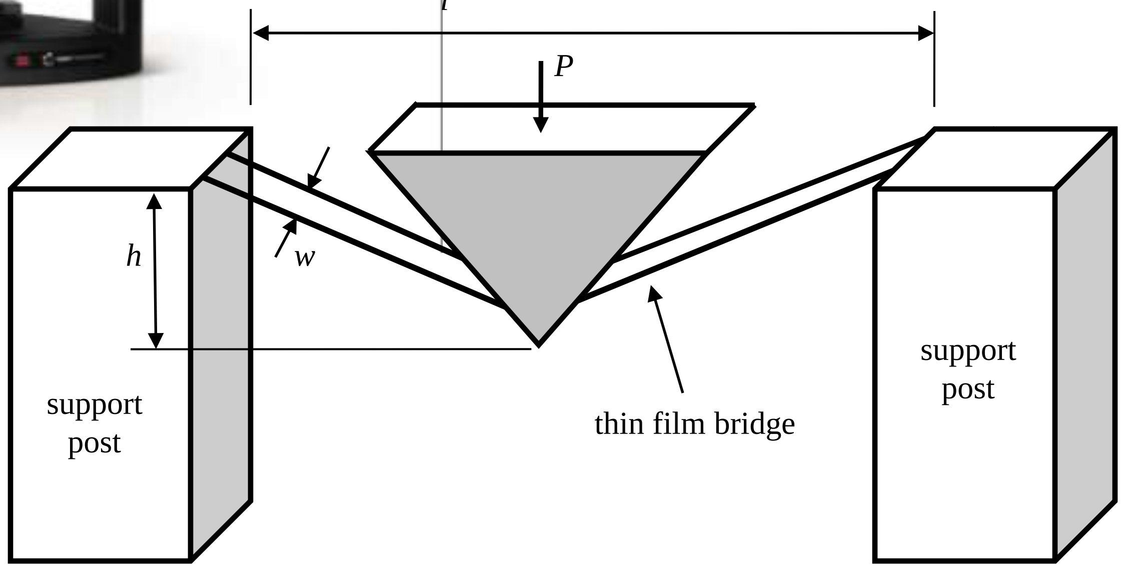
# Results: The new test protocol uses a simple membrane model to determine the elastic modulus and residual stress based on the bridge stiffness and deflection.




NANOMECHANICS, INC.

# Schematic of the Membrane Deflection Test

# Test Protocol:

1. Determination of the bridge thickness.

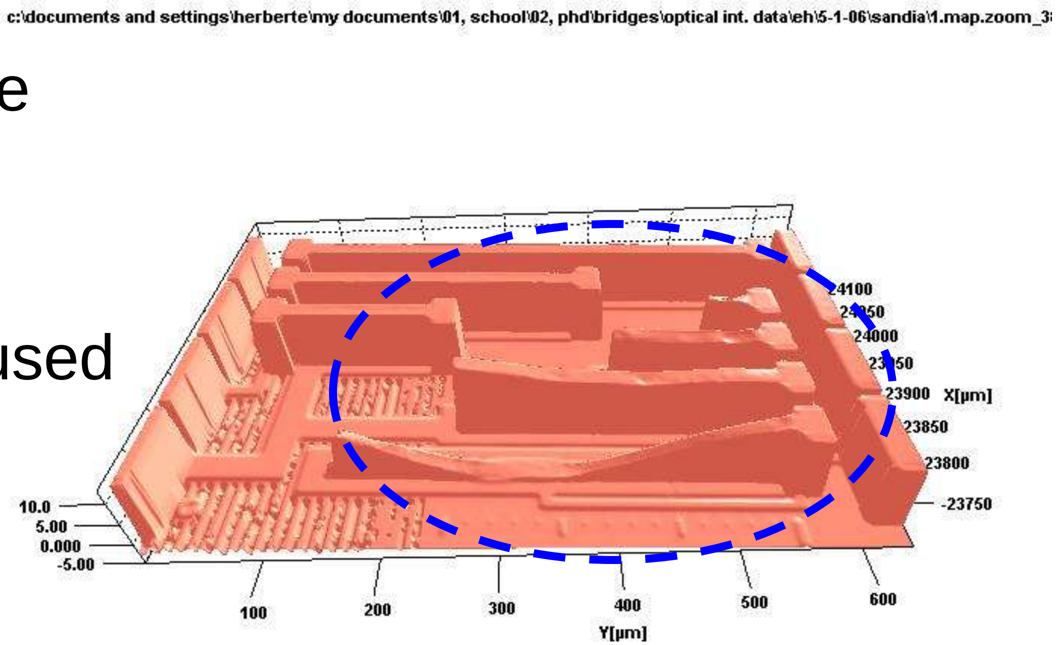
2. Measure the S-h response of the bridge.

3. Perform a linear regression of S vs. $h^2$.

# 1. Determination of the bridge thickness

Mechanical properties are highly dependent on the bridge thickness.

The Nano Indenter was used as a profilometer.

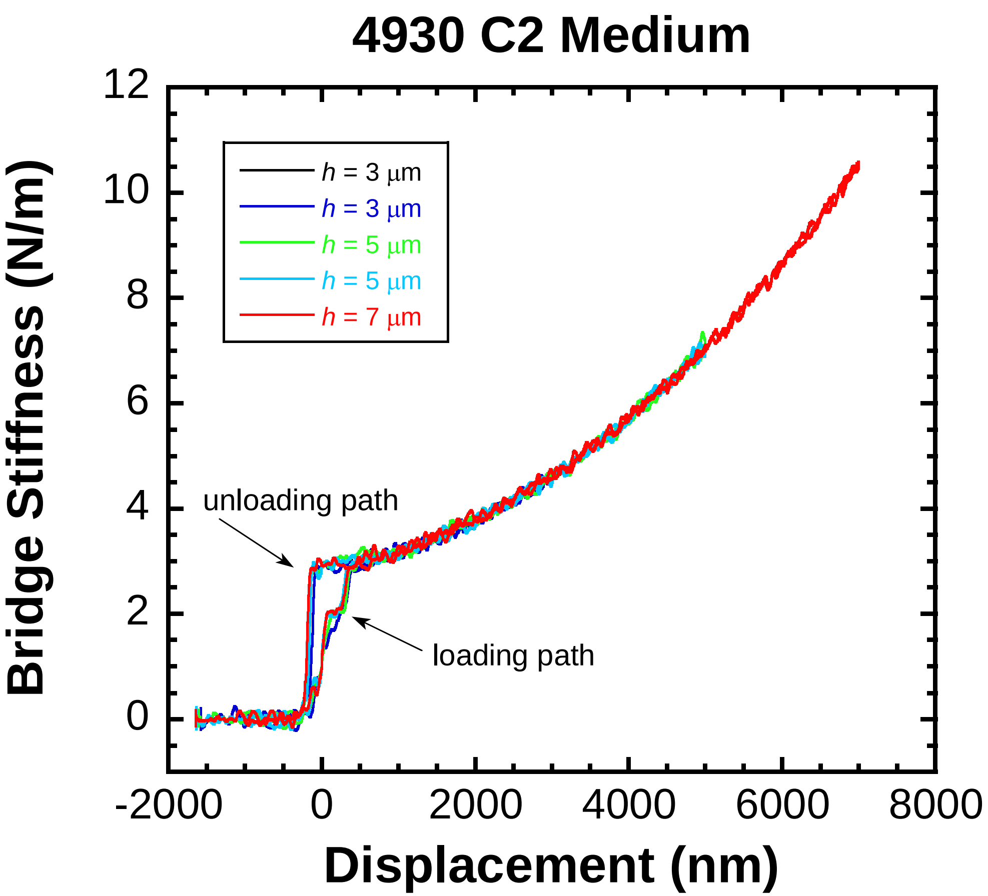



NANOMECHANICS, INC.

# 2. Measure the S-h response of the bridge.

5 tests were conducted to deflections of 3, 5, and 7μm.

Data were acquired using the Nano Indenter® DCM at 20Hz and 30nm oscillation amplitude.



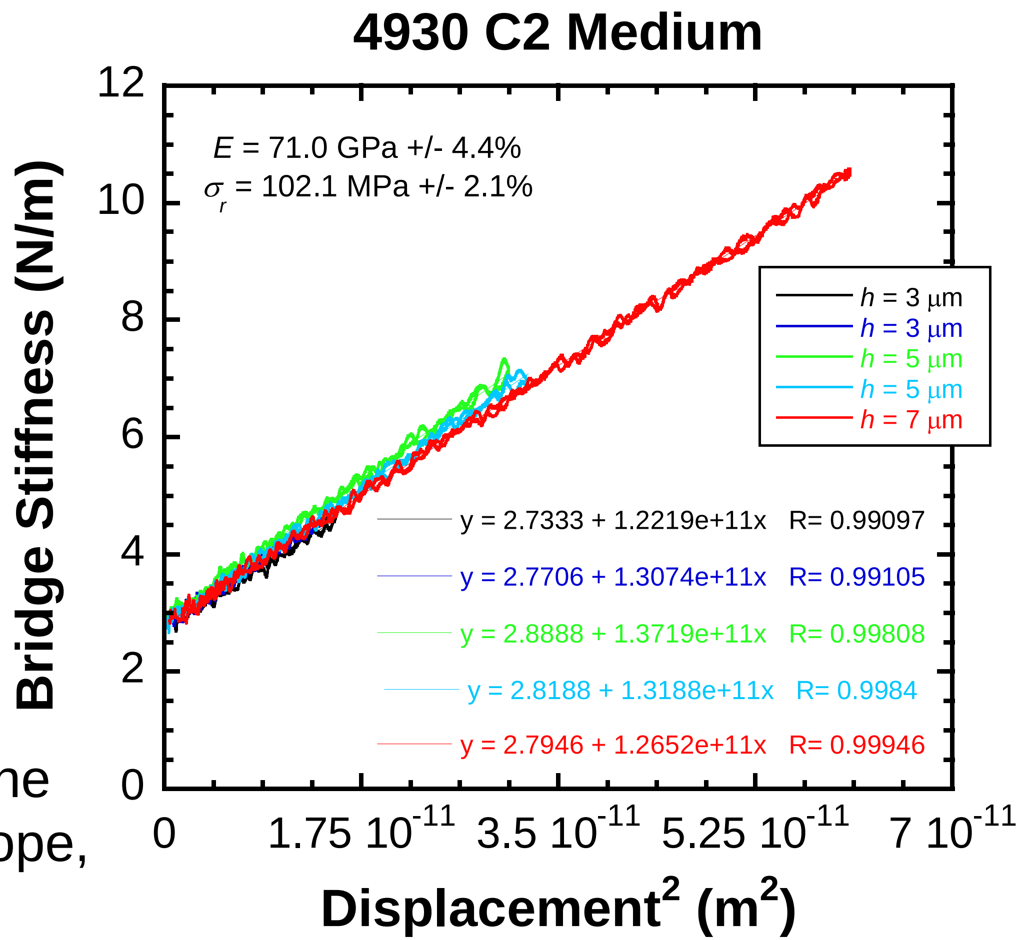
# 3. Perform a linear regression of S vs. h^2.

Equations for Residual Stress and Elastic Modulus:

$$\sigma_r = \frac{bl}{4A}$$

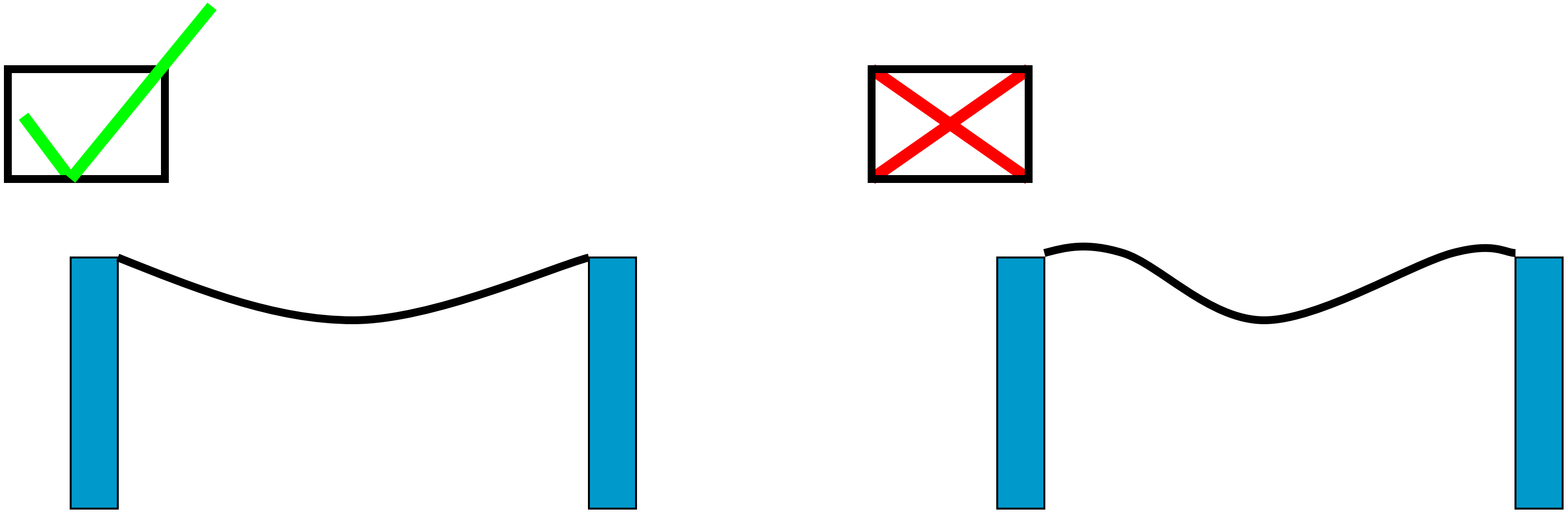
$$E = \frac{\left(m + \frac{6b}{l^2}\right) l^3}{24A}$$

Where b is the y-intercept, A is the cross sectional area, m is the slope, and l is the length of the bridge.




NANOMECHANICS, INC.

# Sample guidelines for the membrane deflection test:



$$\left(\frac{\sigma_r}{E}\right) >> \left(\frac{t}{L}\right)^2$$

# Conclusions

A novel technique for determining E and $\sigma_r$ on thin films has been proposed.

The primary advantages of this technique are:

- Improved signal-to-noise ratio
- Eliminates problems due to thermal drift

No external data analysis – the TestWorks software handles it for you.

Weakest link: Measurement of film thickness.

# Thank you!