# Polymer Coating Metrology by Indentation and Scratch

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# WELCOME!

Context of Coatings

Instrumented Indentation

Instrumented Scratch

Example Materials

Discussion & Questions

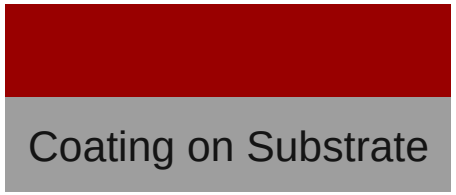
# COATING STRUCTURE

Today's Discussion

- Bulk Materials
- Single Layer Coating
- Ambient Conditions
- Brittle to Viscoelastic

Also Possible!

- Multilayer Coatings
- Composites
- Non-ambient conditions
- Viscous or Liquid-like?

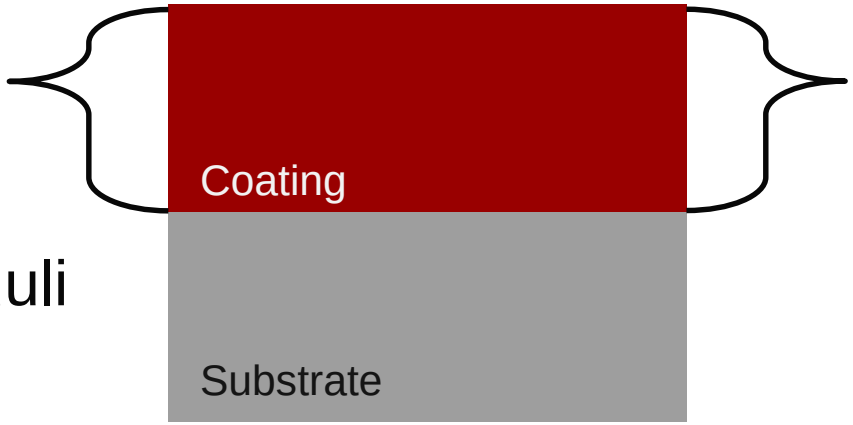





# QUANTIFICATION

## Indentation

- Hardness
- Elastic modulus
- Creep
- Storage/Loss Moduli




## Scratch

- Cohesion
- Adhesion
- Recovery
- Failure Mechanism(s)

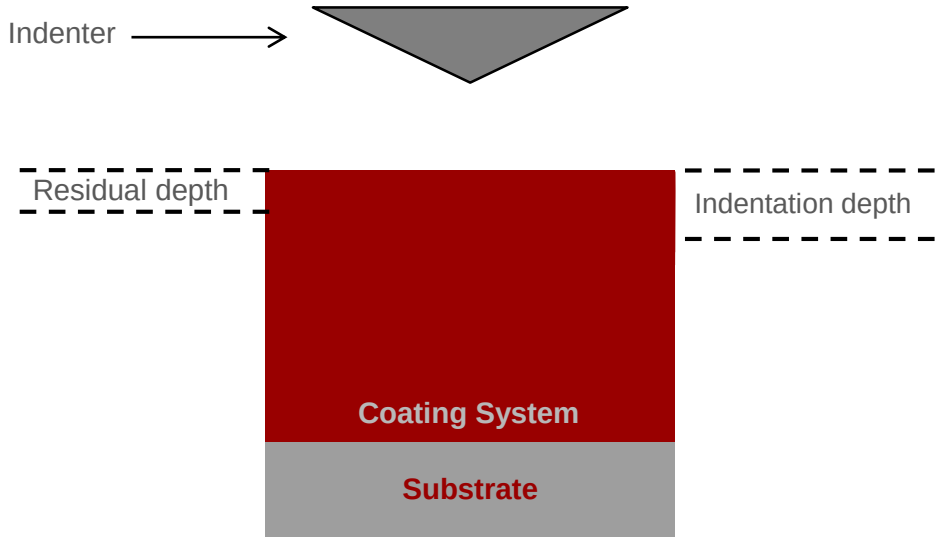
## Applications

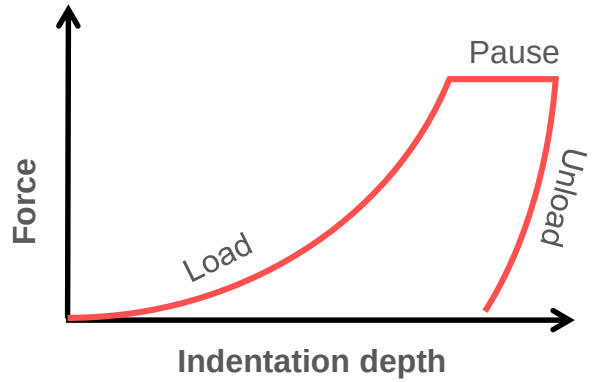
- Science! (basic research)
- Functional (components, packaging, active layers)
- Protective (lubrication, environmental damage, wear)
- Aesthetic (paint/primer, scratch resistance)

# Instrumented Indentation

# INSTRUMENTED INDENTATION

- Indenter of measured geometry contacts sample
- A progressive load to that indenter
- Remove the load and indenter
- ~~Image the residual indent~~
- Calculate Hardness, Modulus, Creep



# SINUS MEASUREMENTS

Overlay sine wave on Force

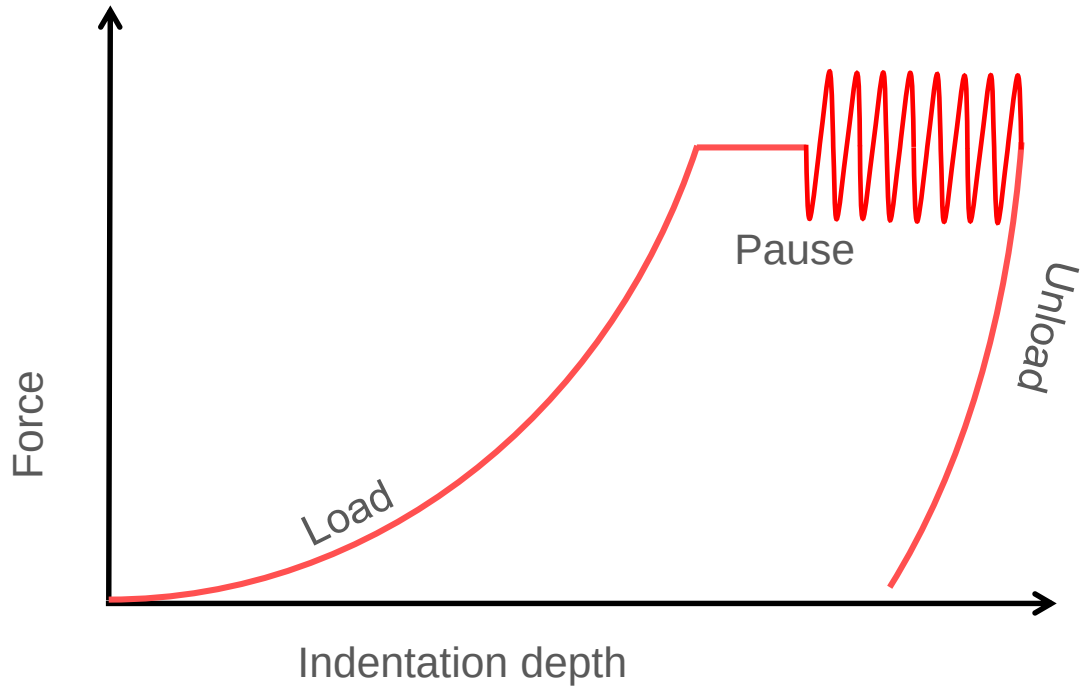
- In pause or in load
- Control frequency and amplitude

Time Dependent Properties

- Storage/Loss Moduli
- Rate dependence of properties

Properties vs Depth

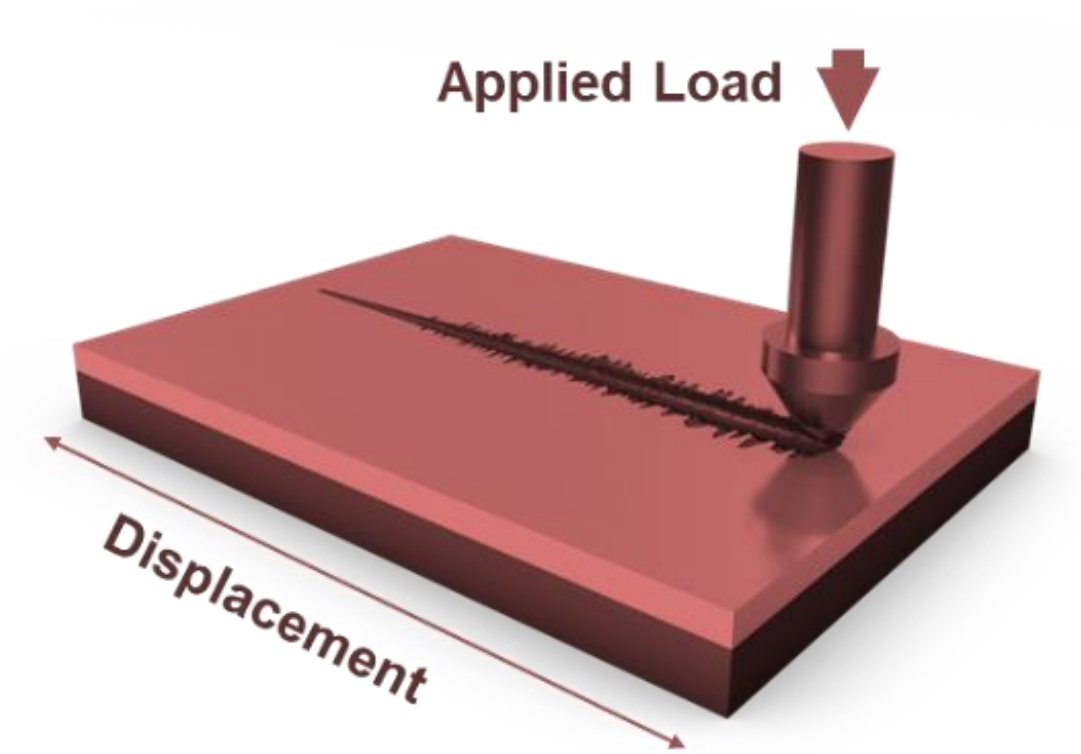
- Moduli, hardness, etc



# Instrumented Scratch

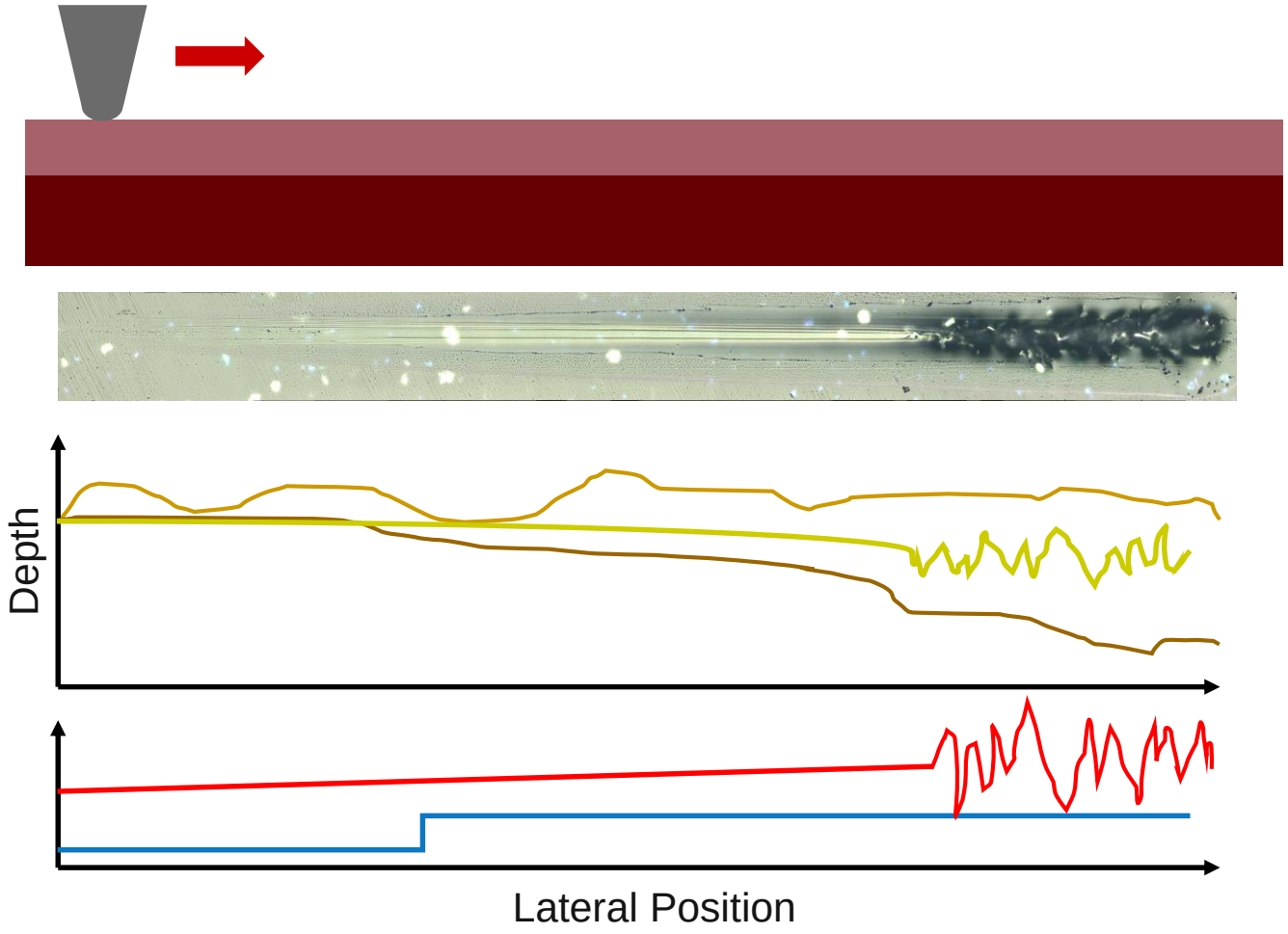
# INSTRUMENTED SCRATCH

- Indenter contacts sample
- Apply load to that indenter
  - Static or Progressive
- Apply Lateral movement under loading
- Measure and Image Scratch
- Quantify coating responses and failures



# ADVANCED SCRATCH

- Trace
- Scratch
  - Friction
  - Acoustic
- Retrace
- Panorama



# Example Measurements

# ELASTIC MODULUS

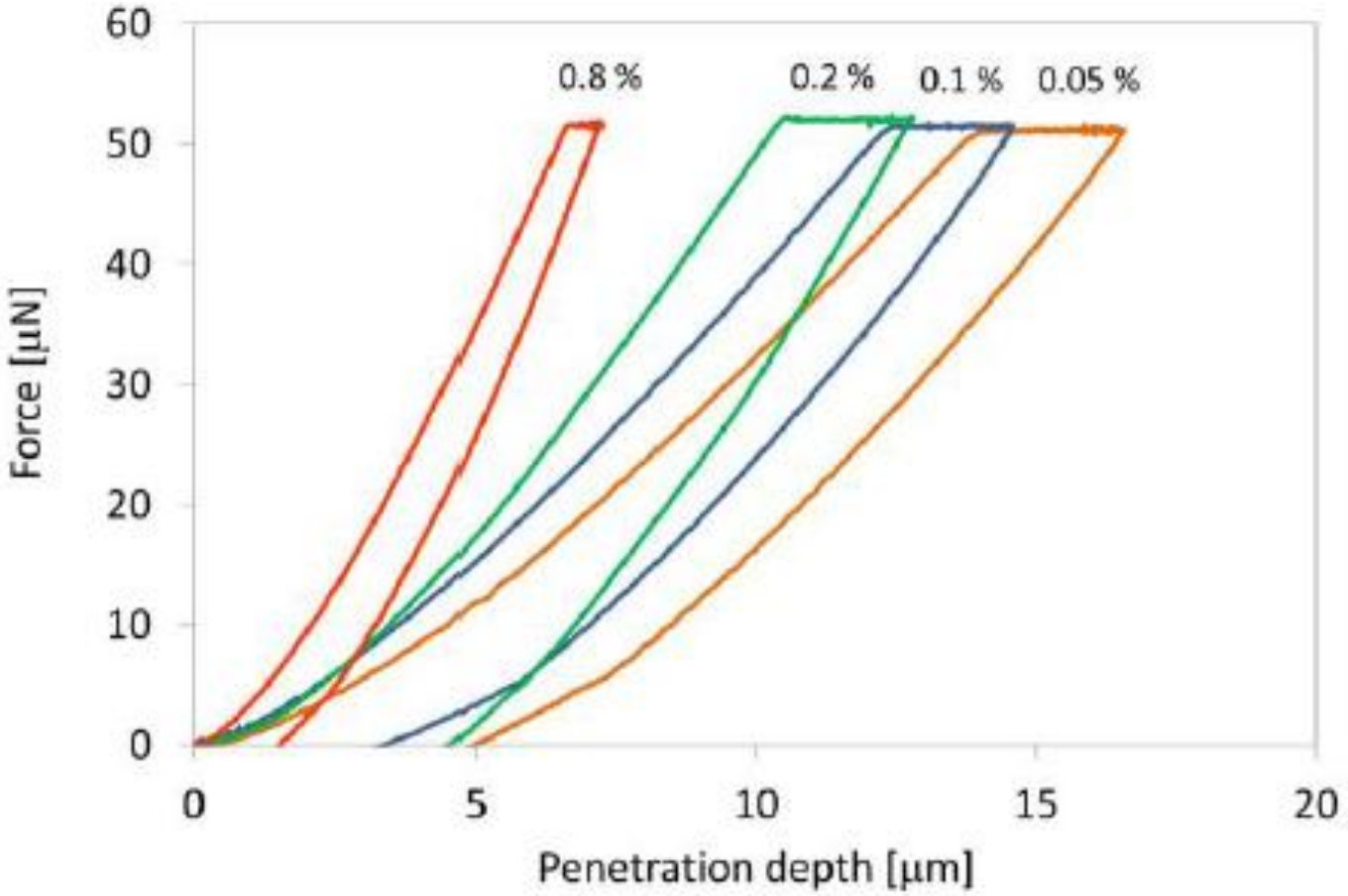
## Polyacrylimide Hydrogels

- Growth substrate in tissue labs
- Consistency of dessert gelatin

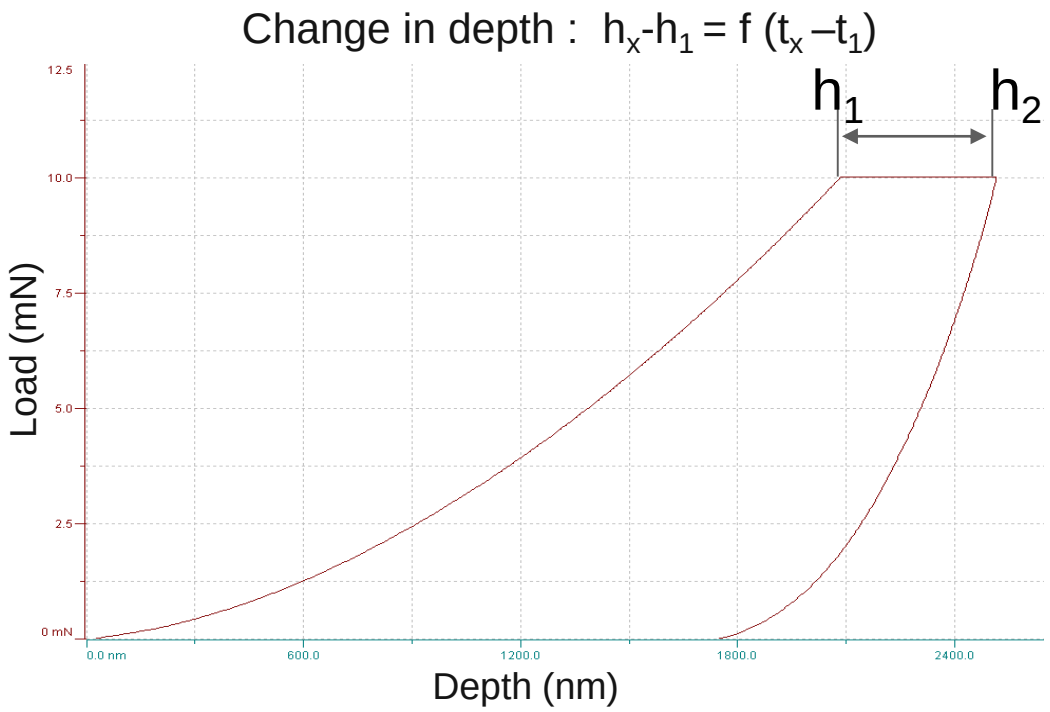
## Effect of Concentration on Modulus

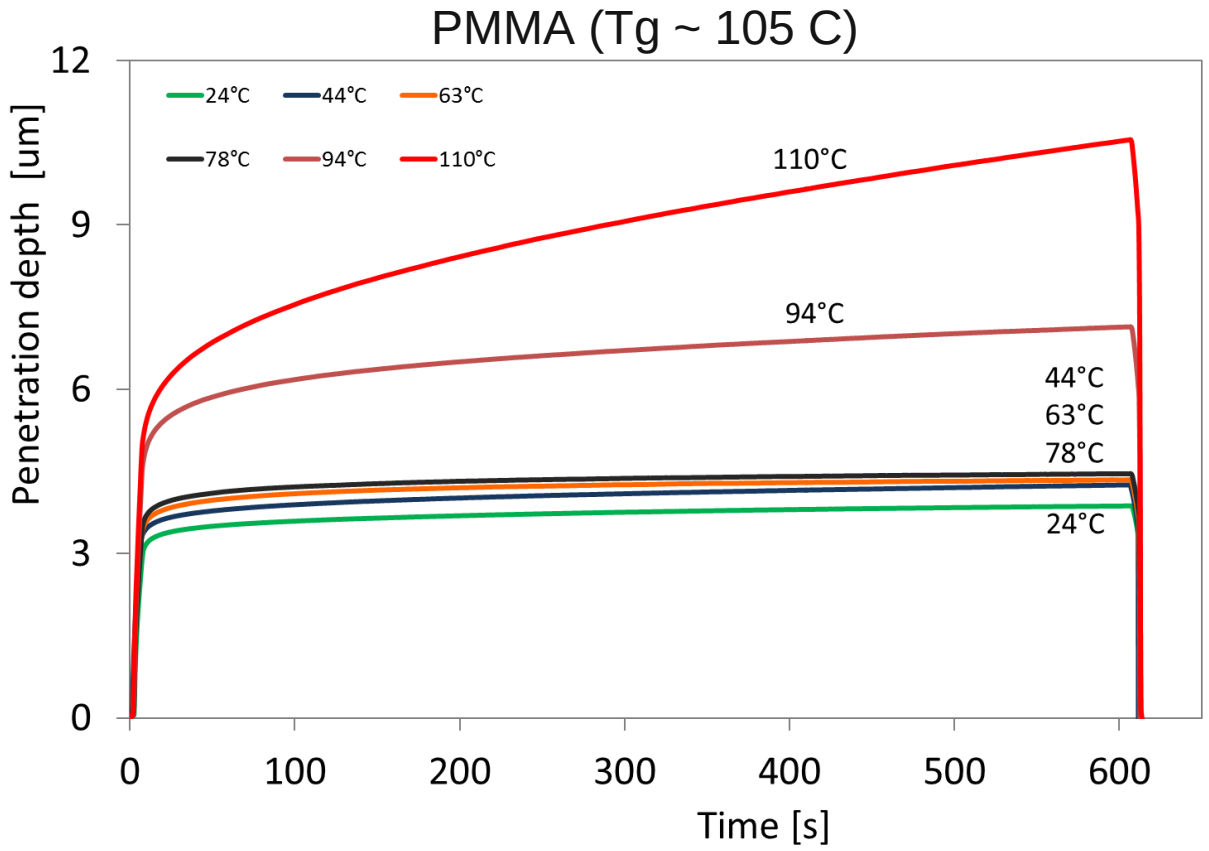
## Compare two Models

| Modulus (kPa) | | |
|---|---|---|
| **Sample** | **Hertz** | **Oliver and Pharr** |
| 0.05% | 37.1 (*0.9*) | 22.6 (*0.3*) |
| 0.1% | 43.9 (*0.7*) | 27.1 (*0.4*) |
| 0.2% | 55.5 (*2.4*) | 34.5 (*0.9*) |
| 0.8% | 111.0 (*3.1*) | 77.8 (*0.9*) |



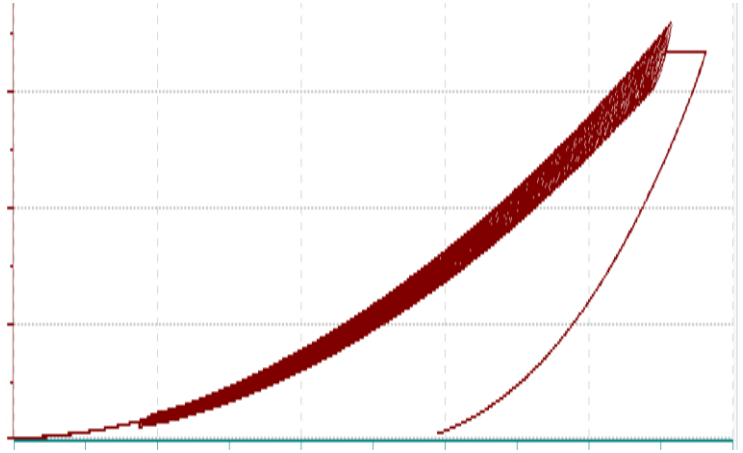
# CREEP & TEMPERATURE

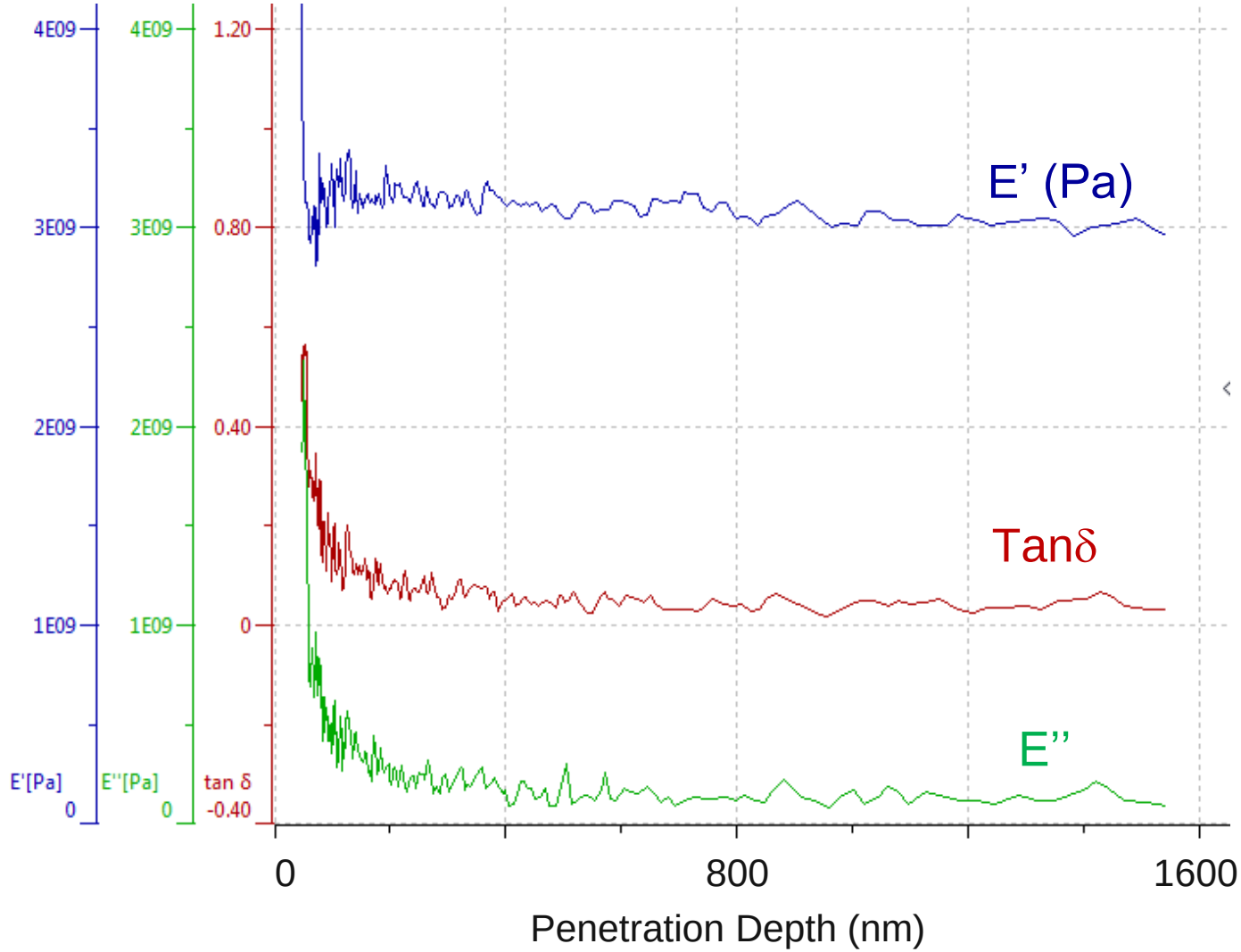


# STORAGE/LOSS VS DEPTH

- Polycarbonate Sample
- Sinus in Loading



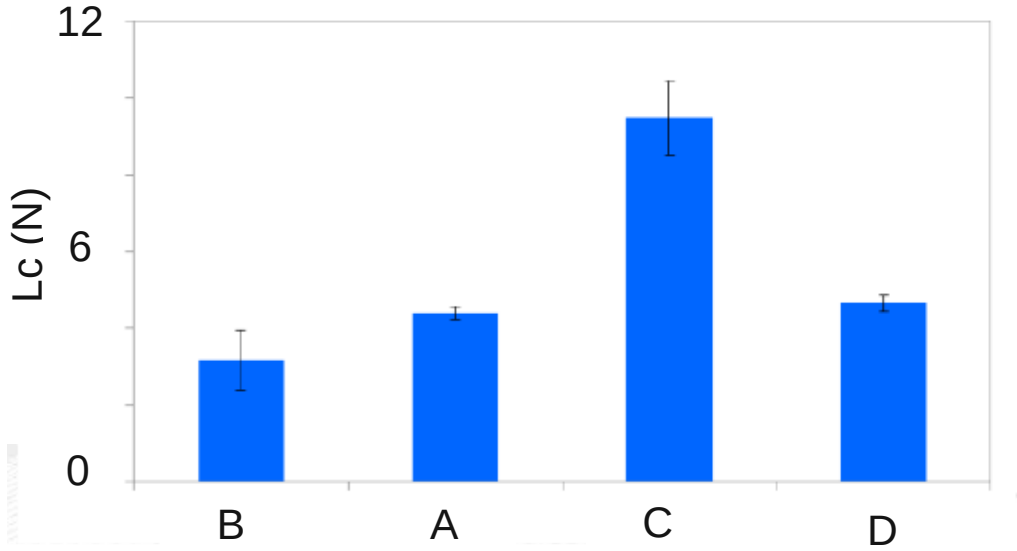


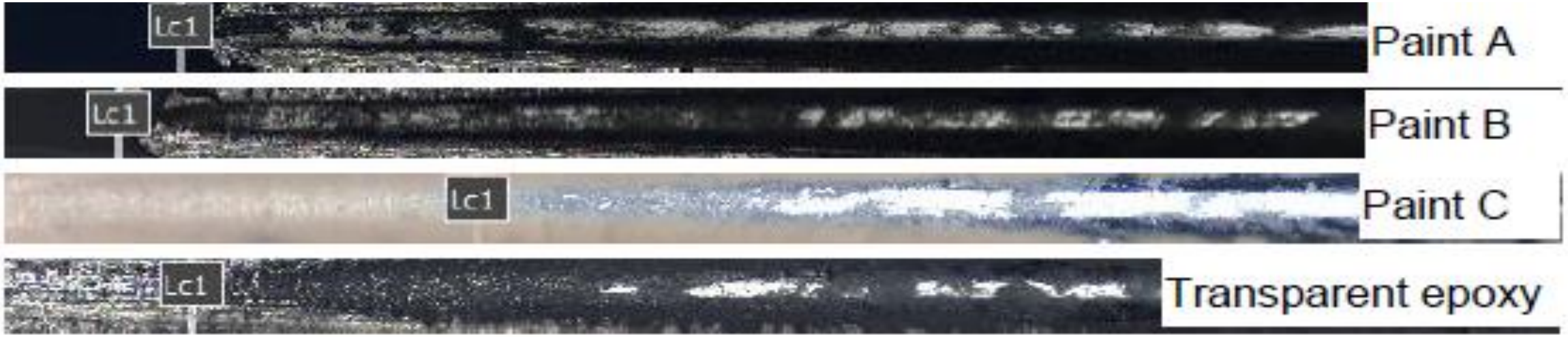
# PAINT ADHESION

Four paints with different bases

A. Polyurethane
B. Enamel
C. Acrylic
D. Epoxy

Compare Load at Delamination Failure



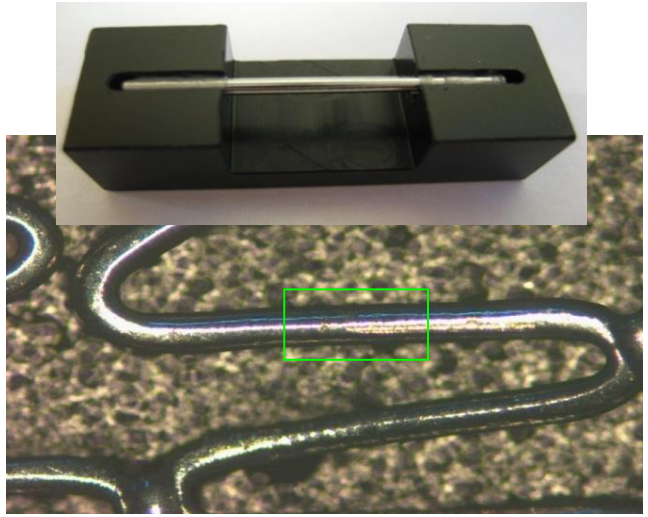



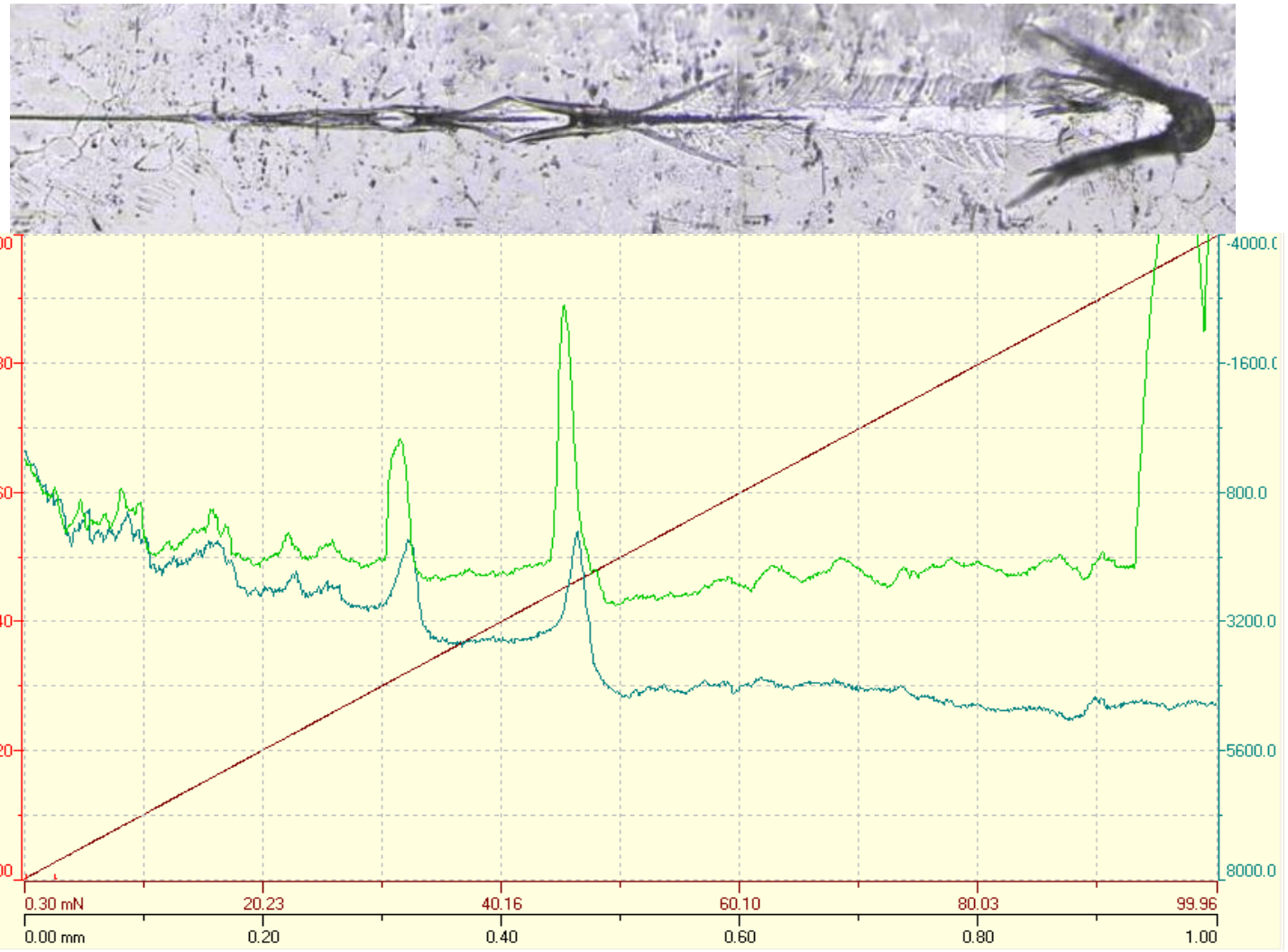
# FAILURE MECHANISMS

Coated Arterial Stent

- Protective Layer
- Drug Release Layer

Adhesion and Failure?

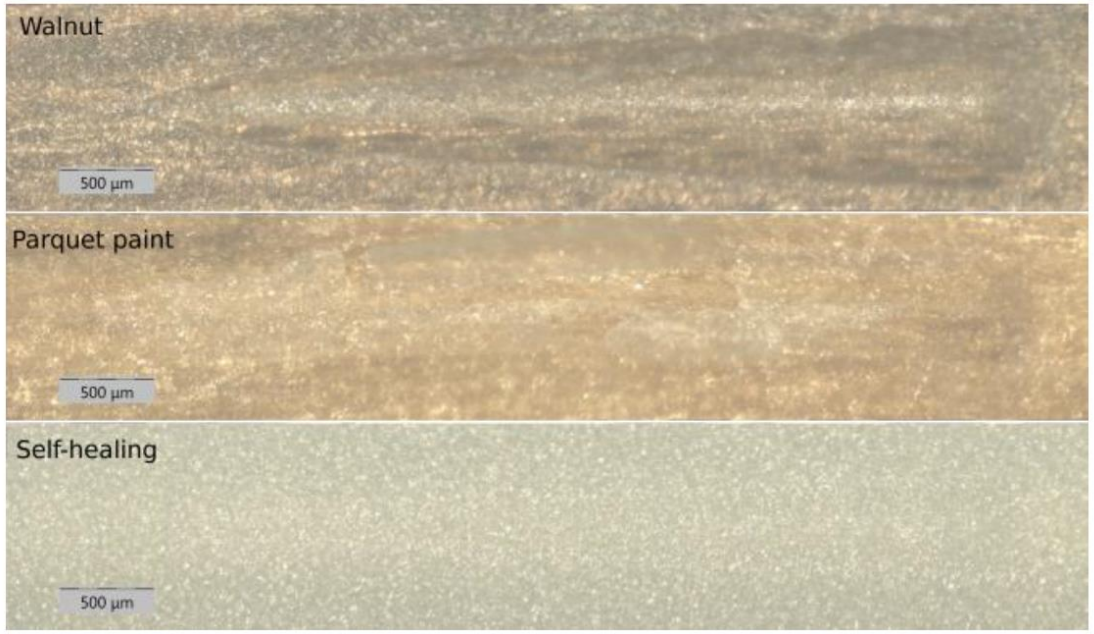


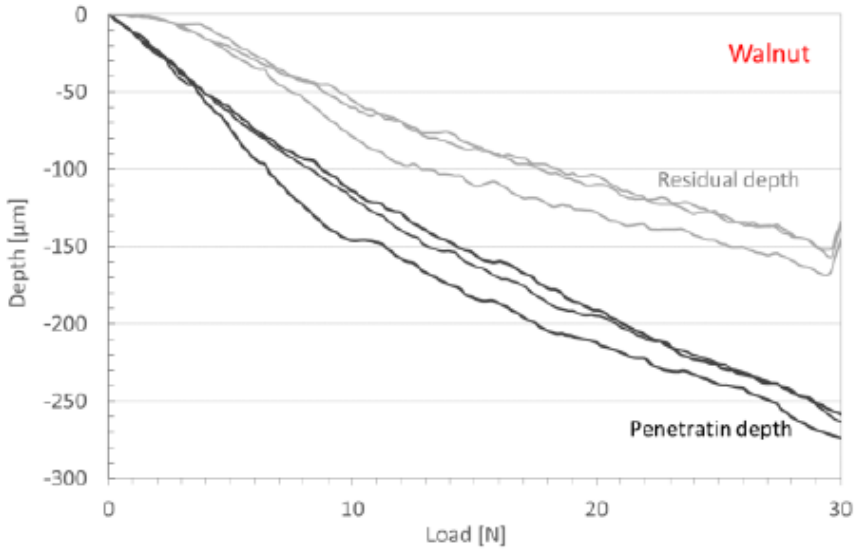


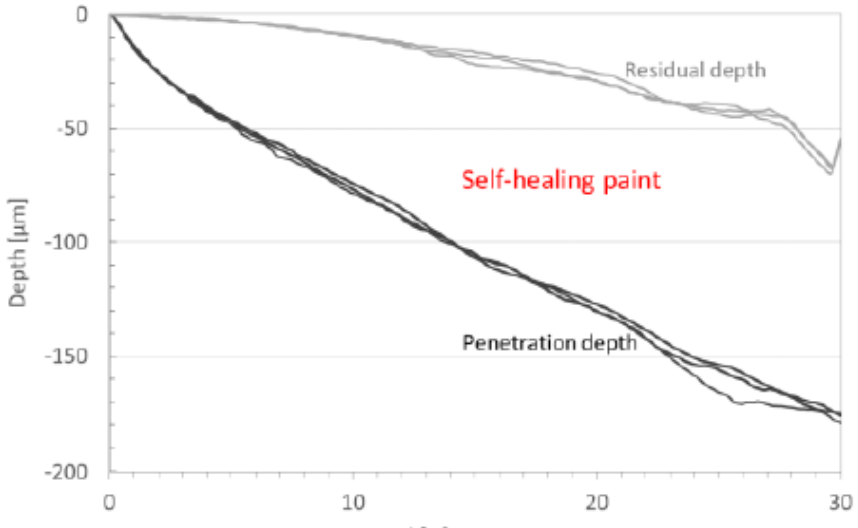
# RECOVERY OF PAINT

Compare Recovery of three Paints for MDF

Visual feedback is minimal



# CLOSING THOUGHTS

- Instrumented Scratch and Indentation are well suited to Polymer Materials
- Instrumented Scratch quantifies coating system behaviors
- Instrumented Indentation quantifies coating system properties
- They advance basic research, application development, and production needs

# THANK YOU!

Questions?

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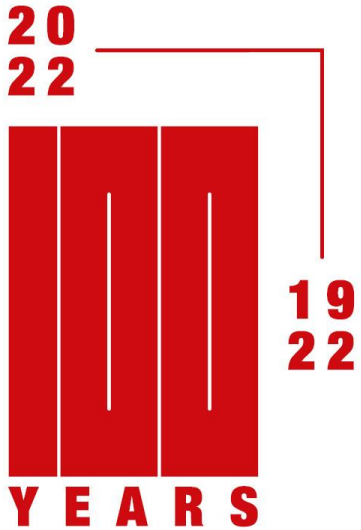


**Together we measure the world.**