ENGINEERED POLYMER SOLUTIONS

Science Simplified

Assessing Tack, Print and Block of New High-Gloss Architectural Binders using Rheological and Mechanical Measurements

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Challenges with Low-VOC High Gloss Paints

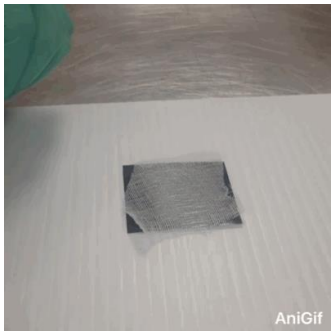
Poor Properties

Tackiness

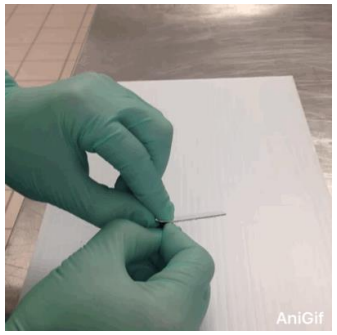
Poor Block Resistance

Low Hardness

Difficult to Differentiate Similar Samples with Current Test Methods



ASTM D 2064 – 91:
Print Resistance



ASTM D 4946 – 89:
Block resistance

Need for Better Test Methods

Ideal Test Method

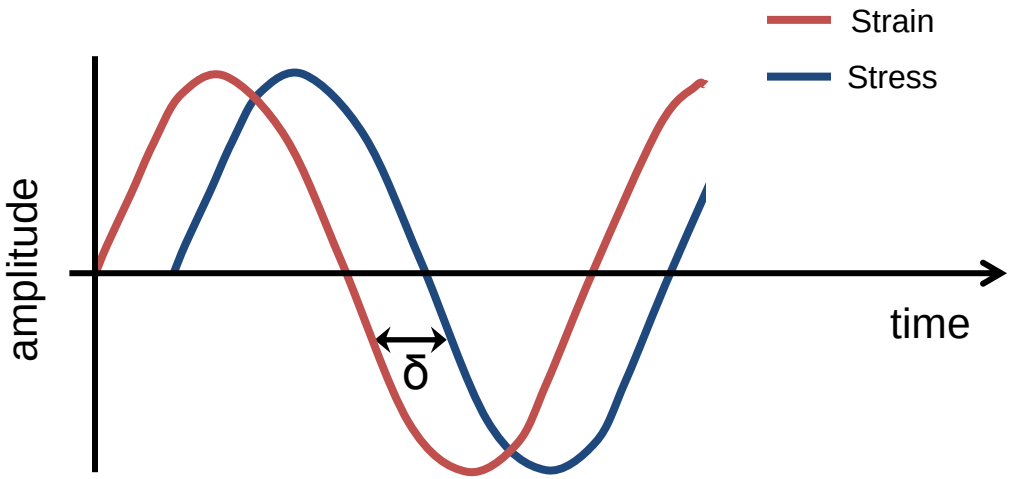
- Objective
- Quantitative
- Provides Insight into Structure-Property Information

Measuring Viscoelastic Properties using Rheology

Oscillatory rheology experiments measure

- ***E′*** **:** Storage (Elastic) Modulus (solid-like character)
- ***E″*****:** Loss Modulus (liquid-like character)
- **tan(δ) =** E''/E': Relative liquid-like/solid-like character

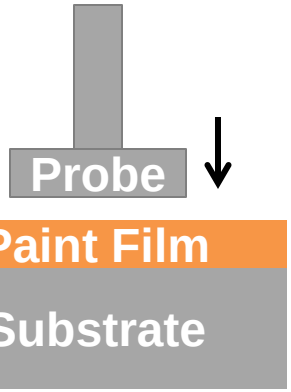
RSA-G2 Film Tension



How are Rheology and Tack Related?

***E'* : Elastic Modulus**
Solid-like character

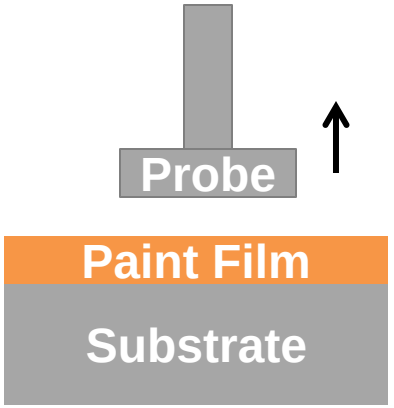
Step 1: Bonding



High E' : resists deformation and limits wetting of probe

***E" :* Loss Modulus**
Liquid-like character

Step 2: Debonding



High E": increases energy dissipation

Validating the Relationship between Viscoelasticity and Tack

- Tested 5 low VOC paints with differences in perceived tack
- Samples dried for 24 hours before testing
- Two parallel experiments

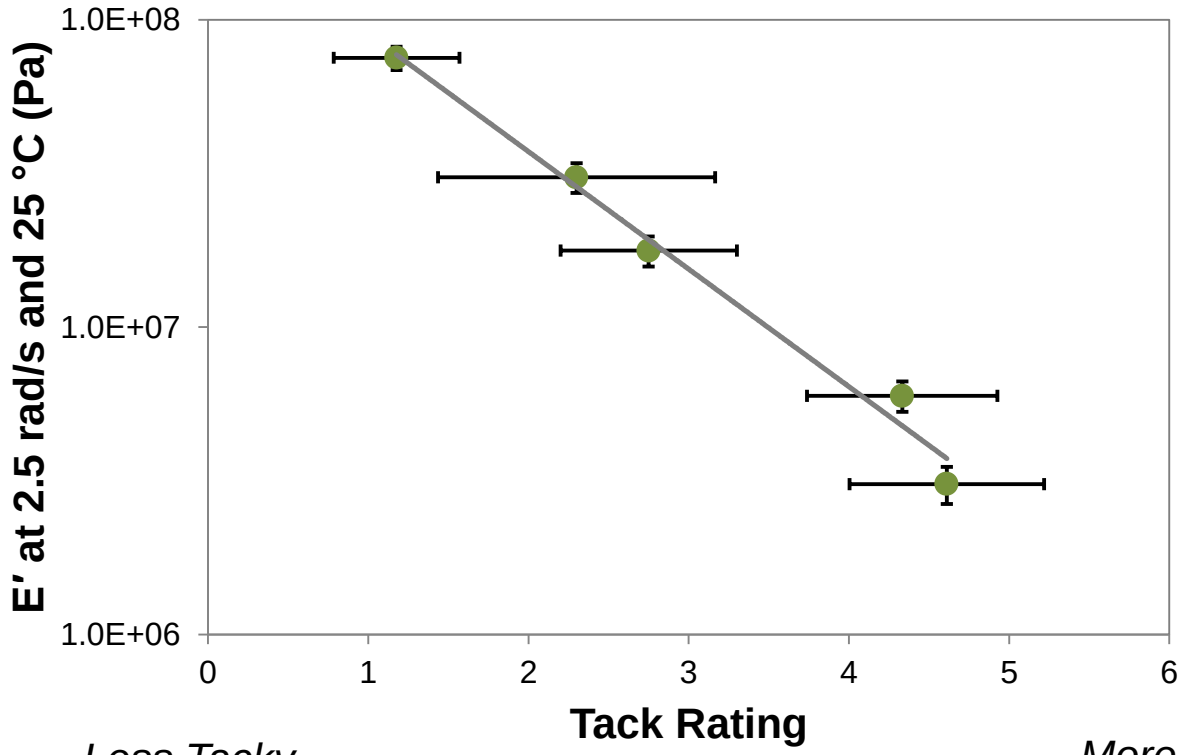
Tack Experiment

- 25 participants
- Each participants asked to
  - Contact paint films for 3 seconds with thumb
  - Rank paints from least to most tacky (1-5 scale)

Rheology Experiment

- Films run at 25 °C
- Measured E' and E"

Comparison of E' Measurements to Perceived Tack Survey



Rating

1 = Least Tacky

5 = Most Tacky

* 25 testers asked to rate samples 1-5 based upon 3 seconds of contact with thumb

Tack ratings correlate well with E′ measurements

Advantages of Rheological Measurements for Tack

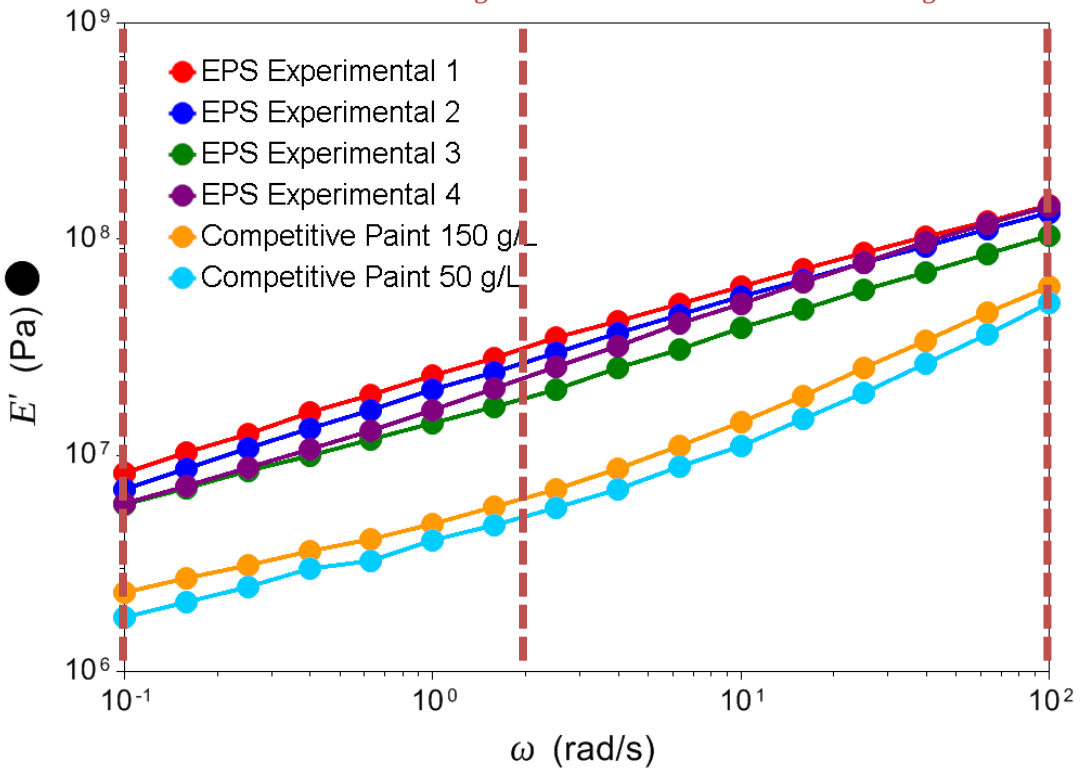
- Reproducible
- Repeatable
- Ability to relate tack to material properties
- Understand impact of bonding time

$$\omega_{bonding} \cong \frac{2\pi}{t_{bonding}}$$

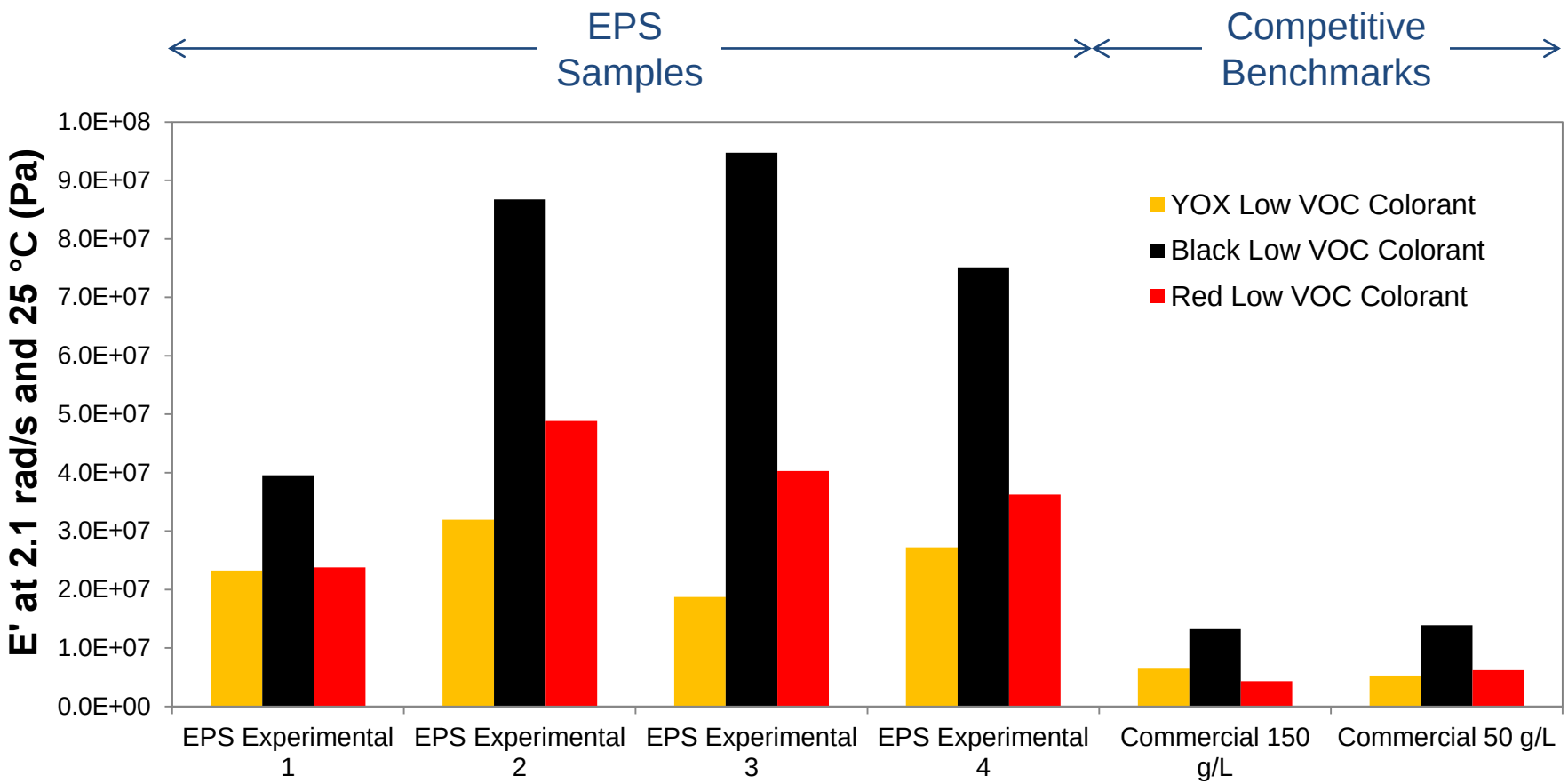
$t_{bonding} \cong 1$ hr

$t_{bonding} \cong 3$ sec

$t_{bonding} \cong 0.1$ sec



Viscoelastic Measurements for Quantitative Benchmarking and Screening Tool

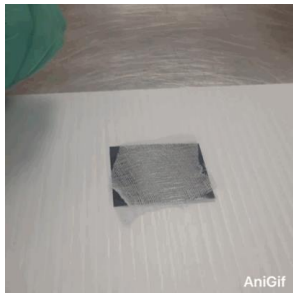


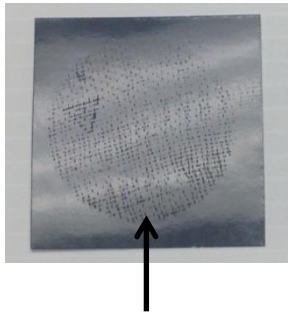
Viscoelastic measurements help rapidly screen formulas

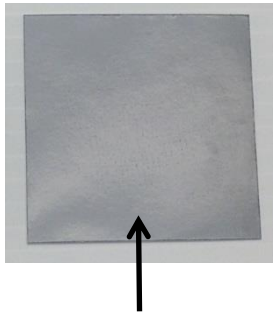
Rheology and Print Resistance

ASTM D4946

- 60 °C, 60 minutes
- Cheesecloth with 500 g weight on top of 1.25 inch stopper
- Visual evaluation of print

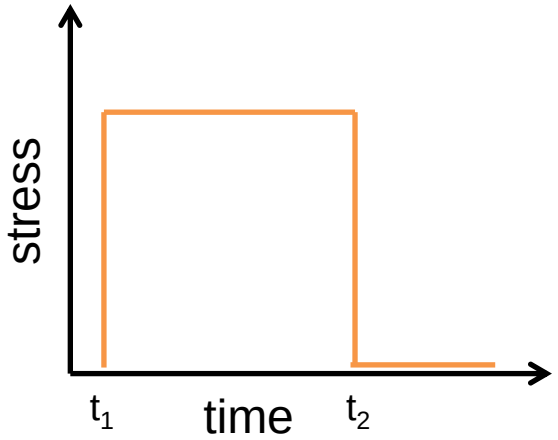




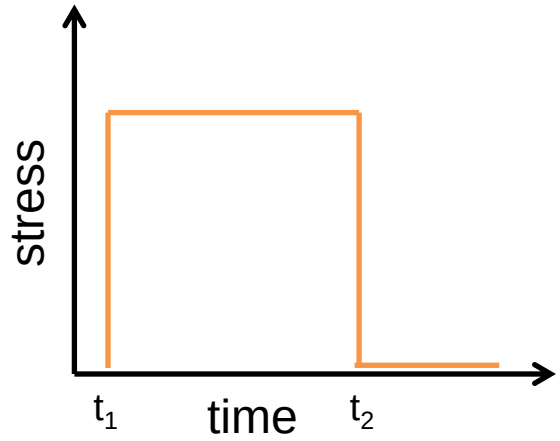


Creep and Recovery

- RSA-G2, 8 mm parallel plates 60 °C
- At t_1, apply compressive force applied
- At t_2, stress removed
- Strain measured during the experiment



Creep and Recovery Experiments



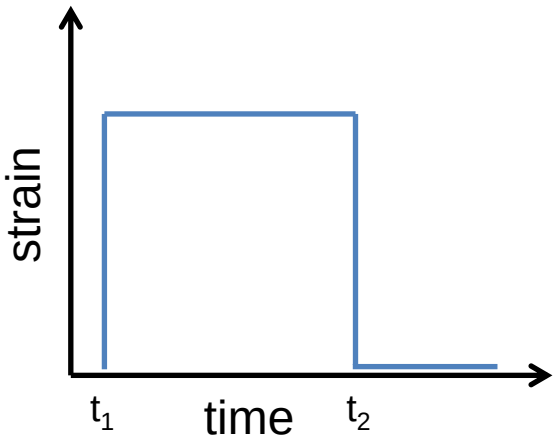
$t = t_1$: Step stress applied

$t > t_1$: Creep (strain measured)

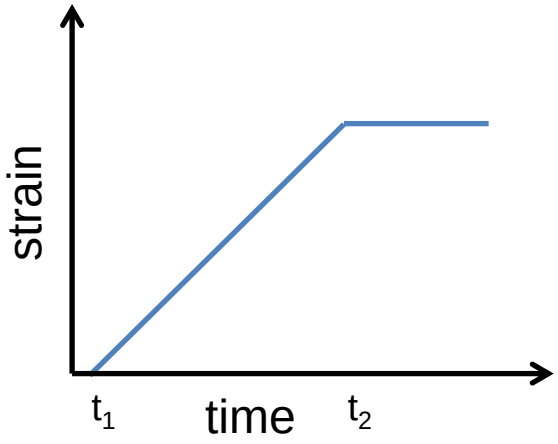
$t = t_2$: Step stress removed

$t > t_2$: Recovery (strain measured)

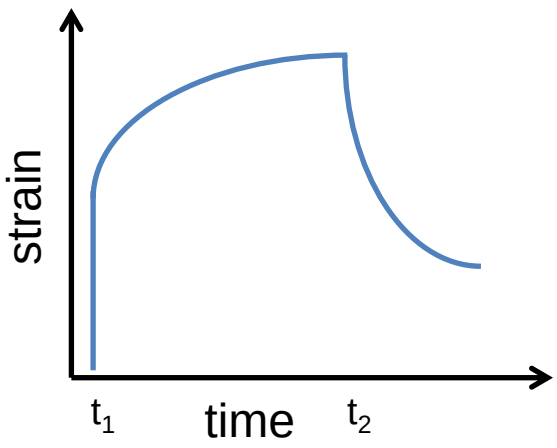
Elastic



Viscous

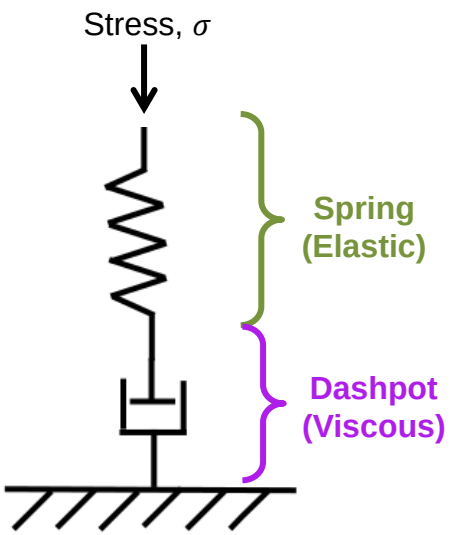


Viscoelastic

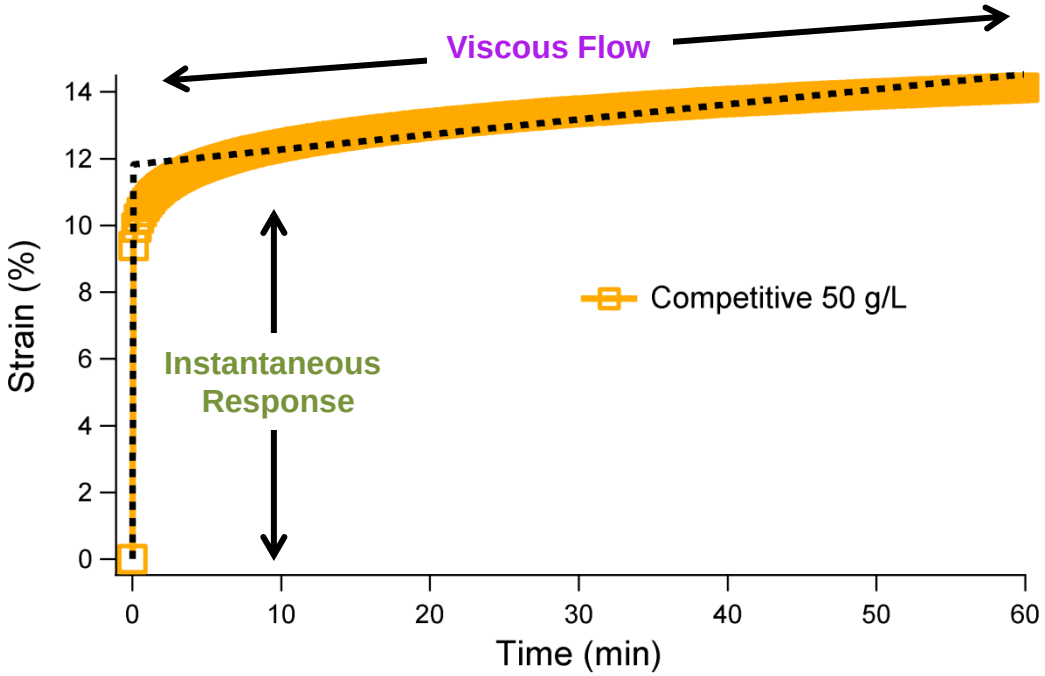


Modeling Creep Behavior

Maxwell Model

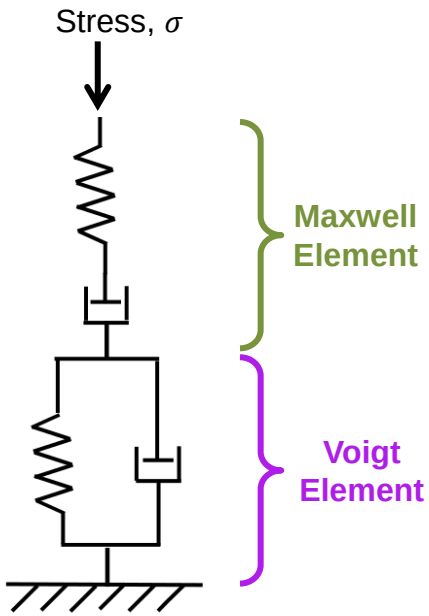


$$\varepsilon = \sigma\left(\frac{1}{E} + \frac{t}{\eta}\right)$$



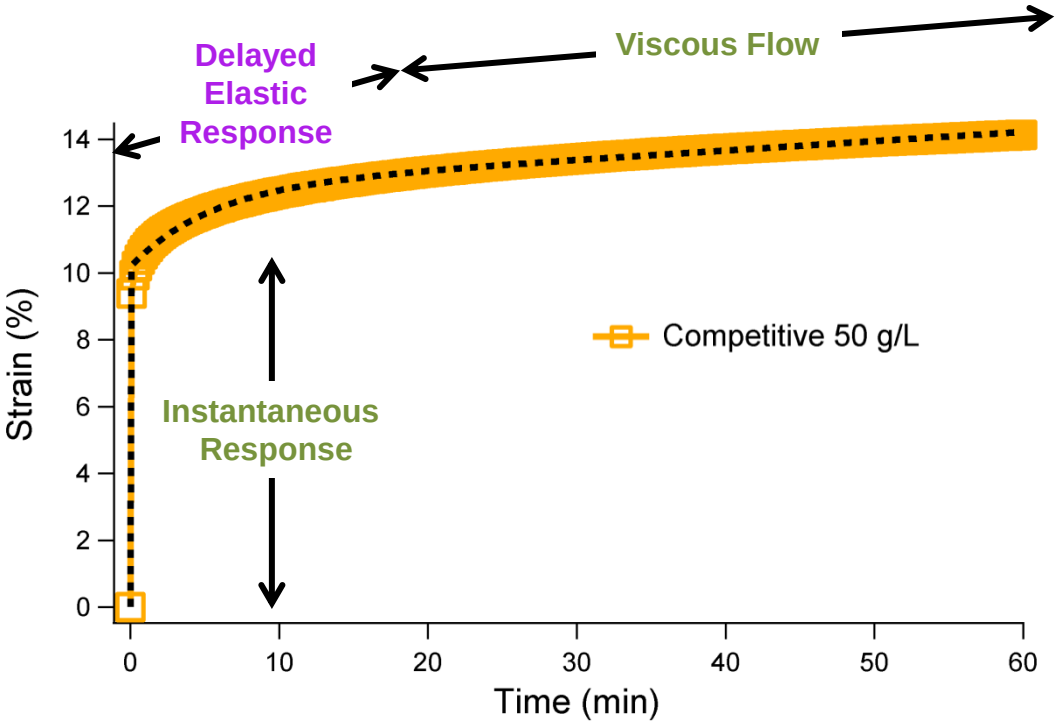
Modeling Creep Behavior

Burgers Model



$$\varepsilon = \sigma\left(\frac{1}{E_1} + \frac{t}{\eta_1} + \frac{1}{E_2}\left(1 - e^{-t/\tau}\right)\right)$$

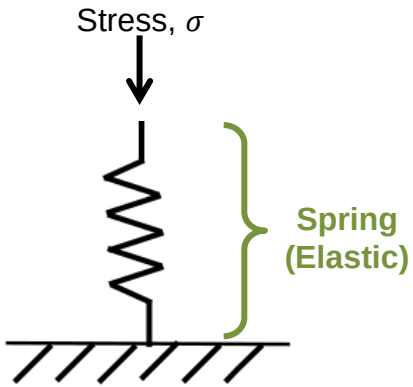
$$\tau = \frac{\eta_2}{E_2}$$



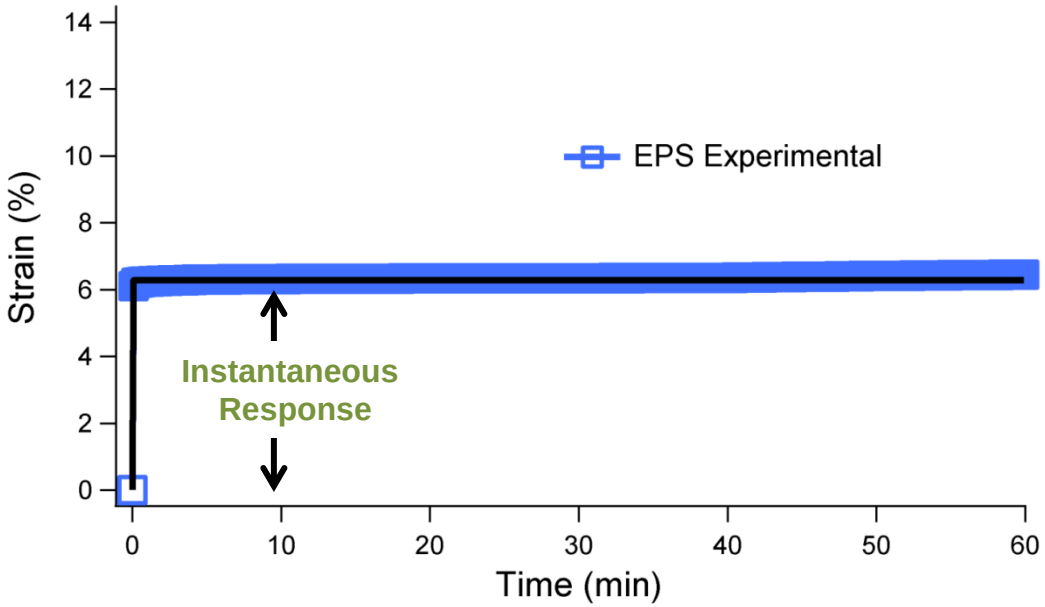
Behavior modeled well by multiple viscous and elastic elements

Modeling Creep Behavior

Linear Elastic Spring

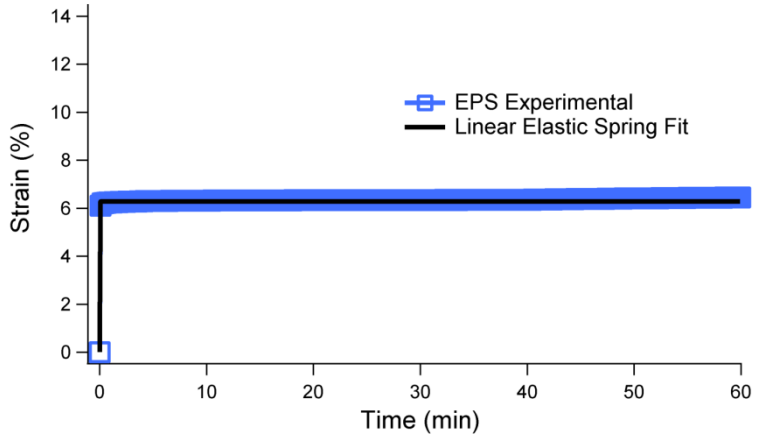


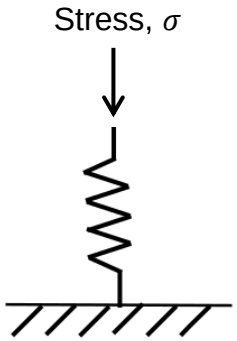
$$\varepsilon = \frac{\sigma}{E}$$



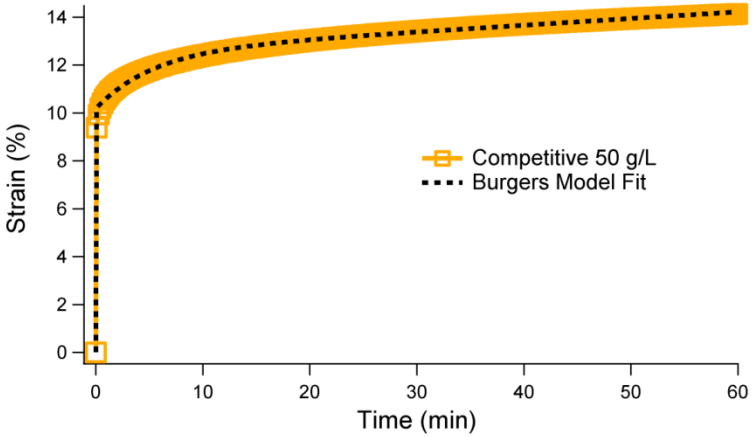
Behavior modeled well by single elastic element

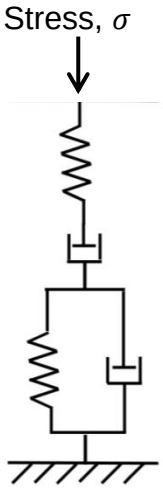
Creep Behavior and Print Resistance





- Only elastic deformation
- Recoverable deformation
- **Print Resistance = 9**





- Viscous and elastic response
- Non-recoverable deformation
- **Print Resistance = 6**

Creep experiment explains print resistance ratings

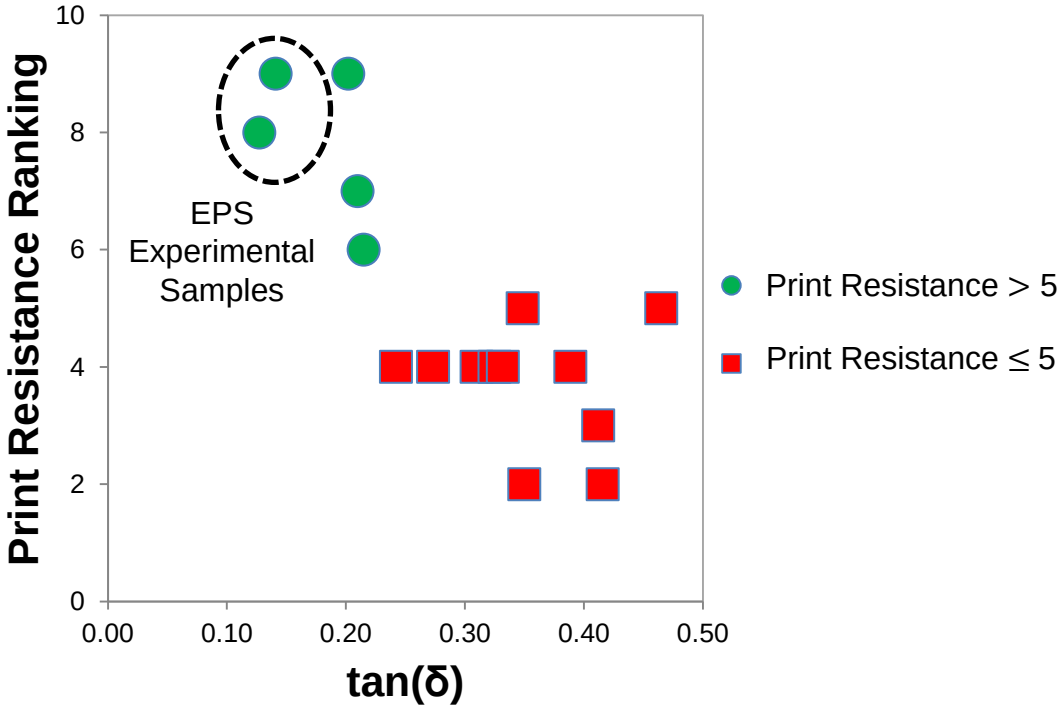
Tan(δ) and Print Resistance

- Viscous (non-recoverable)
- Predict lower print resistance

$$\tan(\delta) = \frac{E''}{E'} = \frac{Liquid - like}{Solid - like}$$

- Elastic (recoverable)
- Predict higher print resistance

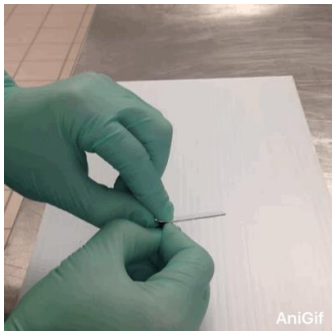
- Cheesecloth print resistance measured on
  - 15 commercial samples
  - 2 EPS experimental samples
- Print resistance ratings compared to measured tan(δ)



tan(δ) quickly differentiates samples with differences in print resistance rating

A More Quantitative Block Test

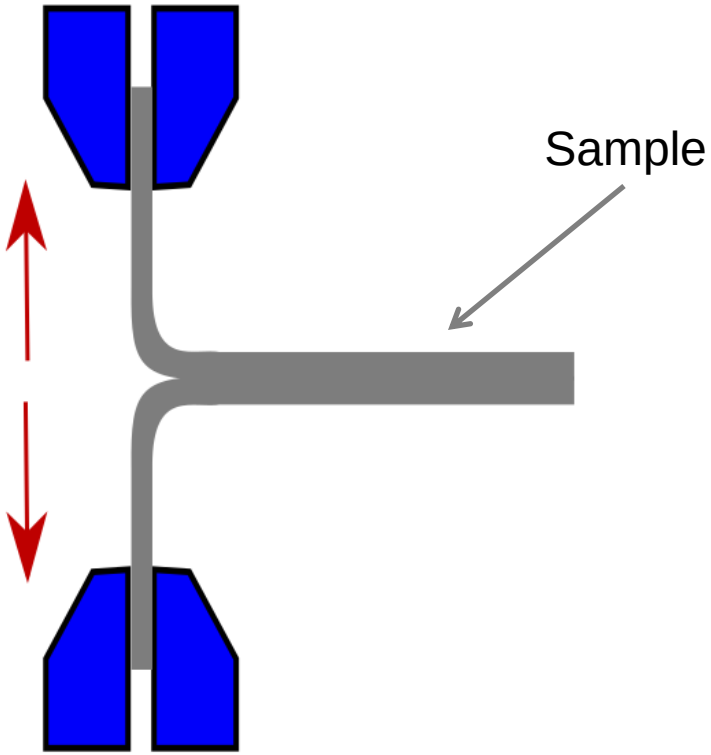
ASTM D 4946 – 89:
Block resistance



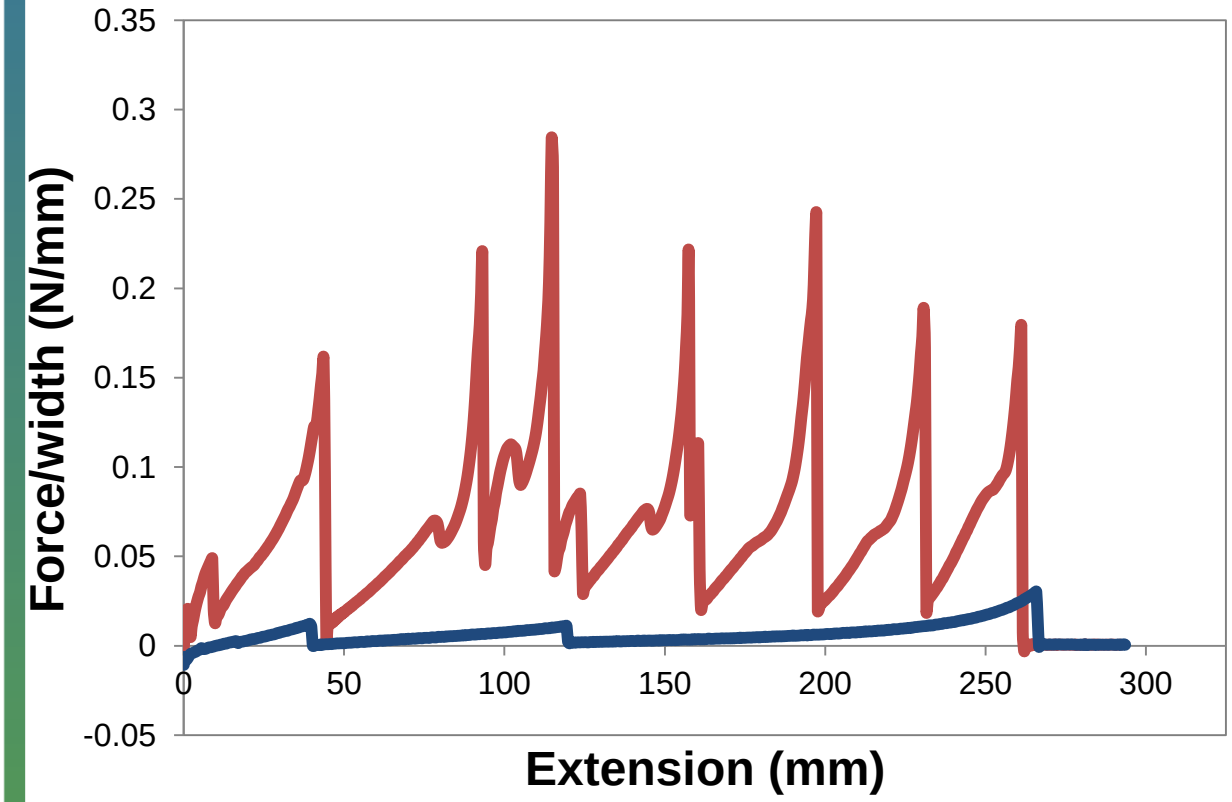
Block is influenced by:

- Viscoelastic properties
- T_g
- Molecular weight
- Surface-active additives

T-peel Tests

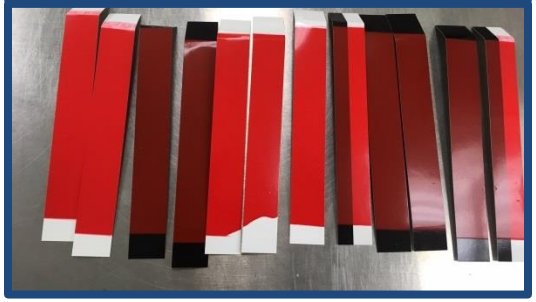


T-peel Tests and Block Resistance



Block Rating = 8

Block Rating = 8



T-peel tests differentiate samples which are indistinguishable by standard methods

Summary

- EPS has developed rheological and mechanical tests for
  - Tack
  - Print Resistance
  - Block
- EPS developed tests have many advantages compared to standard industry tests
- Tests are helpful development and benchmarking tools

	Rheology (Tack)	Rheology (Print Resistance)	T-Peel Block Tests
Quantitative?	✓	✓	✓
Objective?	✓	✓	✓
Structure Property Information?	✓	✓	