Silk “quality” revealed
Using dynamic mechanical analysis

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What silk am I interested in?
Qualities of silk:

- Cleanness
- Dyeability
- Reelability
- Shiny appearances
- Wearibility
- Good mechanical tolerances…

Structure-mechanical property relations

The tool: Dynamic Mechanical Thermal Analysis (DMTA)

Silk: a bio-polymer

Question: why do some silks have better mechanical properties than others?
Dynamic Mechanical Thermal Analysis (DMTA)

**Ball test (Mechanism)**

- Energy management
- Energy Stored (Elasticity)
- Energy Dissipated (molecular movement)

**The information**

- Energy storage/dissipation
- What structure cause the engineering properties

**Actual test**

- Temperature
- Humidity
- Mechanical stress

**Dynamic deformation**

- Phase angle $\delta$
- Response

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Typical DMA graph: Thermal analysis

- Water-Silk interaction
- Dry silk structure

Temperature (°C)

Storage Modulus (GPa)

Loss tangent
Density
Strength
Toughness
Extensibility
Thermal stability
Thermal conductivity
Light absorbance
…
Reeling
Degumming
Dyeing
Weaving
Functionalizing
…
SYNERGY
PROPERTY
FUNCTION
STRUCTURE
Mechanical, electronic, bio-compatibility, degradability, antibacterial…
Sequence, Composition, Helical structure, Random coil, β-sheet crystals, Hierarchical structure…
Case study: Silks of 3 grades

Mulberry field in Jiangsu Prov. China.  
Silk farmers working happily in yard.

Price depends on grades

Silk farming  
Silk manufacture  
Silk market
Morphology: cocoons and silks

Cocoons

Raw silks

G1

G2

G3

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J. Guan, D. Porter*, F. Vollrath. Thermally induced changes in dynamic mechanical properties of native silks. *Biomacromolecules*
Dynamic mechanical thermal analysis
Comparing “disorder”

Disordered structure disappeared after thermal annealing.

Dynamic mechanical thermal analysis
Hydrated or not?

Dynamic mechanical properties of silks under load

Loading history matters!

Silks increase their modulus at higher stress at the cost of losing extensibility.

Summary

• Dynamic Mechanical Thermal Analysis (DMTA) is sensitive to the structural differences between silk grade;

• Thermal-mechanical treatment could improve the dynamic mechanical properties of poor-grade silks;

• Hydration and loading history affect the mechanical properties of silks.
Thank you very much!