Microscale Processing of Silk Protein

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Overview

• What is silk?
• How do we get it?
• What can we do with it?
Silkworms and Spiders
Silkworms and Spiders

Silkworm (B. mori)  Spider (A. diadematus)

[Diagram of internal structures of silkworm and spider with labels: protein coating, sericin, fibroin, lipid, glycoprotein, skin, spidroin]
Medical Uses

Sutures

Tissue Engineering

Altman et al, Biomaterials, 2002, 23, 4131
Silkworms and Spiders

Silkworm (B. mori)

Spider (A. diadematus)
Tensile Properties
Potential Spider Silk Uses

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Spider Silk Tapestry

- 11 x 4 ft, 2.6 lbs
- 4 years, $500,000
- 1,063,000 spiders
- “They never broke a single strand, yet the tapestry is as soft as cashmere.”
Natural Silk Spinning
and replicating this process

A. diadematus

i. Protein secretion

iv. Internal draw down

vi. Solvent removal

ii. Extensional flow

iii. Ionic gradients

v. Additional drawing
Fluid Flow in the Silk Gland

Converging gland wall = spatially accelerating flow

Secreted protein

Flow

Ion exchange

Aligned and folded protein
Laminar Flow of Silk
Laminar Flow of Silk
Microfluidic Funnels

$w(x)$
Other Microfluidic Funnels

Straight channel

Constant strain rate

Increasing strain rate

Constant acceleration

150 μm

150 μm

150 μm

150 μm
Simulation of Flow

To scale:

Natural Silk Spinning

i. Protein secretion

ii. Extensional flow

iii. Ionic gradients

iv. Internal draw down

v. Additional drawing

vi. Solvent removal

A. Diadematus

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Sources of Silk Protein

- Excised Silk Glands
- Dissolved fibers
- Cocoons or webs
- Recombinant proteins
Materials from Silk

Silk Microspheres

Srisuwan et al, J Mac Sci 2009
Monodisperse Silk Microspheres

Breslauer et al. Biomac 2009
Silk Micropatterns
Silk Nanopatterns

(a) Glass [original]  (b) hPDMS  (c) Silk

200 nm  200 nm  200 nm
Silk Microneedles
Silk Microneedles
Other Work

- Optics and Biosensors
- Dielectrics
- Medical Coatings

Kim et al. Nature Mat, 2010

Omenetto and Kaplan, Nature Photonics 2008

Wang et al. Adv Mat 2011
Refactored Materials

- Commercial scale production of native spider silk protein
- Artificial spider silk fibers
- www.refactored.com
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