Review of Textile Chemistry and Manufacturing

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textiles

NC STATE UNIVERSITY COLLEGE OF TEXTILES

Overview

- Background
  - Introduction to the College of Textiles at NCSU
- Innovation in textile manufacturing
  - Technical trends
    - Now and in near future
  - Nonwoven technology
  - Bicomponent fibers

NCSU College of Textiles

- Largest Textile Institution in Western World
  - 50 faculty
  - 800 undergraduates
  - 150 graduate students
- Model Manufacturing Facilities
  - Spinning to Chemical Finishing
- The Nonwovens Institute
- Textile Protection and Comfort Center

NCSU College of Textiles

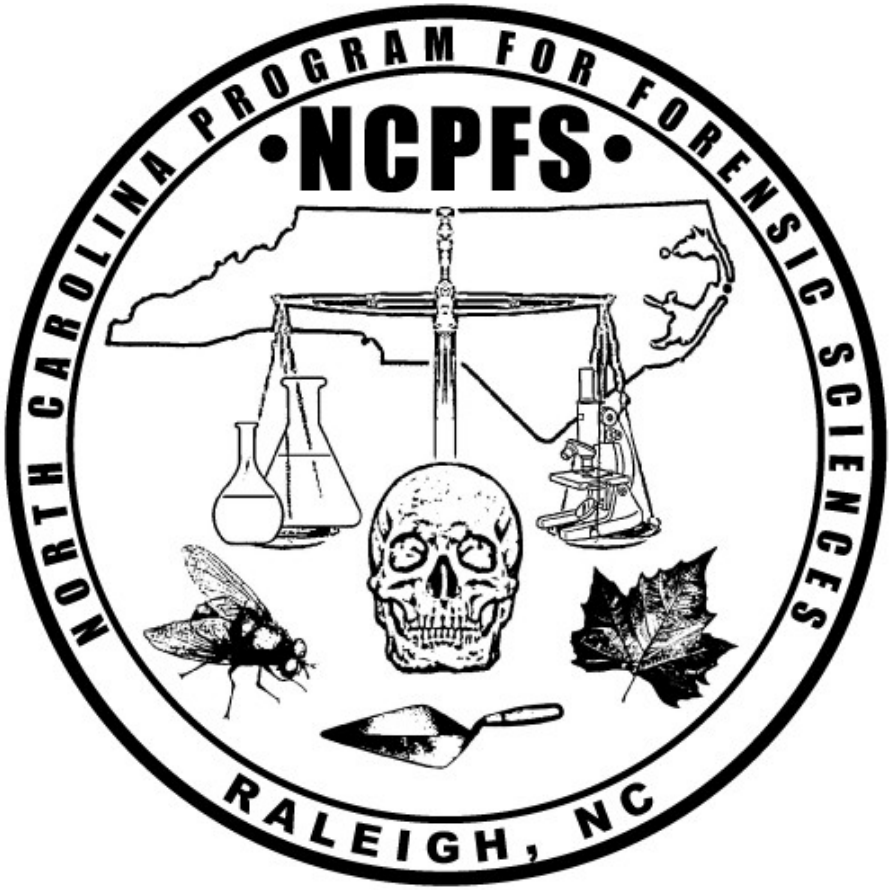
- Molecules to Markets
  - Chemistry
  - Engineering and Technology of Fibers
  - Marketing and Merchandizing
  - Fashion and Brand Management
- Maintain excellent relationships with
  - all major dyestuff and chemical suppliers
  - all major fiber producers
  - all major US retailers
    - Walmar, Target, Nike, Gap, JC Penneys, Victoria Secret
    - Many maintain sample library of almost all production batches

NCSU College of Textiles Research Areas

- Chemistry
  - Dye chemistry and molecular modeling
  - Design of functional chemical finishes
  - Polymer synthesis
  - Polymer extrusion (fibers)
  - Analytical chemistry
- Engineering
  - Spinning
  - Fabric construction
    - knitting, 2D and 3D weaving, nonwovens

Forensics at NCSU

- Faculty expertise:
  - Anthropology
  - Archeology
  - Chemistry
  - Fibers and Textiles
  - Entomology
  - Criminology
- NC Forensic Science Program - 2004



NCSU Professional Forensic Short-Courses

- Distance Education
- Textile fundamentals
- Forensic Textiles
  - August
- Discovery and Recovery.
  Death in Natural Environments
  - May
- Advanced Discovery and Recovery
  - August

On-going fiber/dye research

- Degradation of natural/synthetic fibers in soils found in South East
- Searchable database development
  - Dye characterization

Degradation of fibers. Soil burial

	Acid	Alkaline
	pH 4.4-6.5	*pH 7.5*
Rayon	1	2
Silk	15	7
Cotton (treated)	10	7
Wool	15	5
Nylon	>48	>48
Acrylic	>48	>48
Acetate	>48	>48
Plastic	>48	>48

Time for significant strength loss (months)

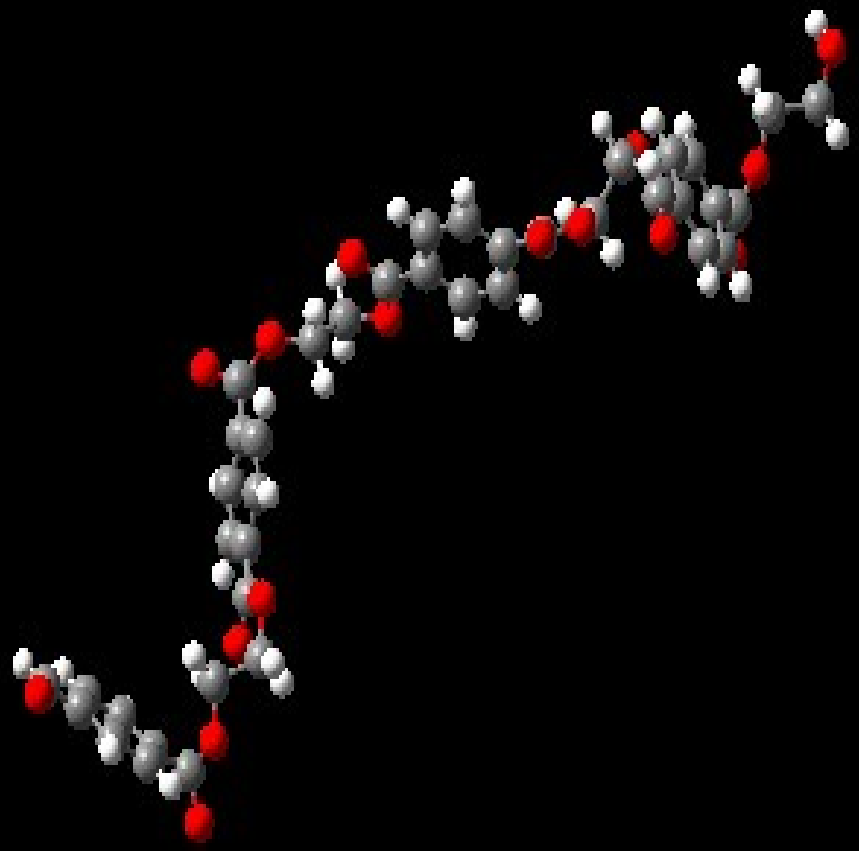
P.L. Turner, Biodeterioration of Materials, Vol. 2, 1972

Polymers: Building blocks of all fibers/plastics

- Polymers are very long chain of connected atoms

  poly = many mer = unit (latin)

- Examples:
  - DNA
  - Protein
  - Starch
  - All plastics
  - All fibres (almost)
  - All textiles



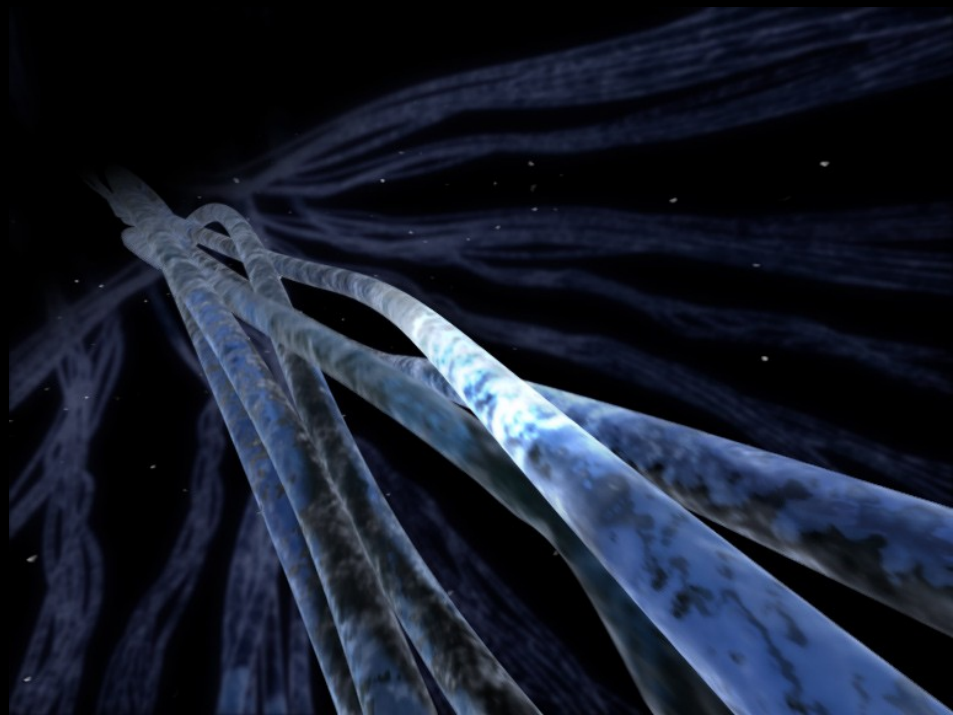
A fiber is….

- A class of materials that are long filaments, composed of oriented or semi-oriented polymers
- Fibers may be very long (continuous filament) – hundreds of feet in length

Or

- Relatively short (staple)

  (about 1 inch long)



Natural Fibers

- About 200 natural fibers
  - Vegetable
    - Cotton (21 million tons, $20 billion market)
    - Linen
    - Hemp
    - Jute, Flax, Soy….
  - Animal
    - Wool (1.3 million tons), cashmere (goat), angora (rabbit), camel, dog, cat, etc
    - Silk (from silk worm, spider…)
  - Mineral
    - Asbestos

Synthetic Fibers

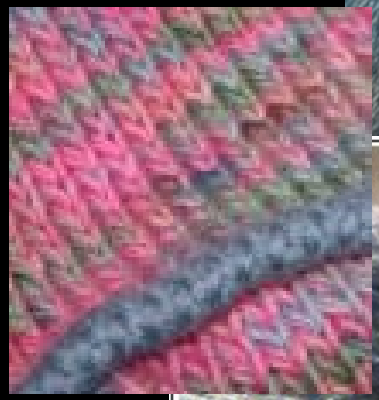
- Dozens of different types of synthetic fibers
- Polyester — regular, basic dyeable
- Poly(propylene)
- Poly(amide) — nylon 6.6, nylon 6, kevlar, nomex
- Poly(acrylonitrile) — acrylic
- Poly(urethane) — Elastomeric (Spandex)

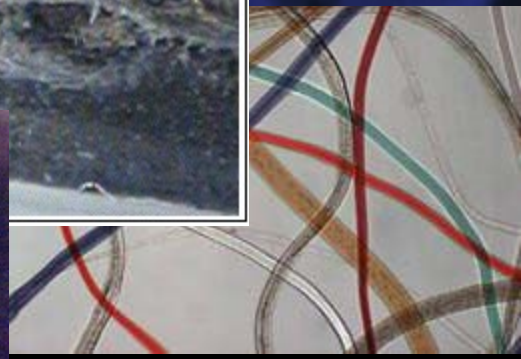
- Chemically modified natural fibers
  - Viscose,
    - Lyocell (environmentally benign spinning process)
  - Cellulose diacetate / triacetate
  - Cellulose nitrate, others

Textiles are….

- any material made mainly from fibers
  - Yarn
  - Woven fabric
  - Knitted fabric
  - Carpet
  - Nonwoven
  - Composite material with fibers (e.g. Formica, carbon fiber reinforced plastic



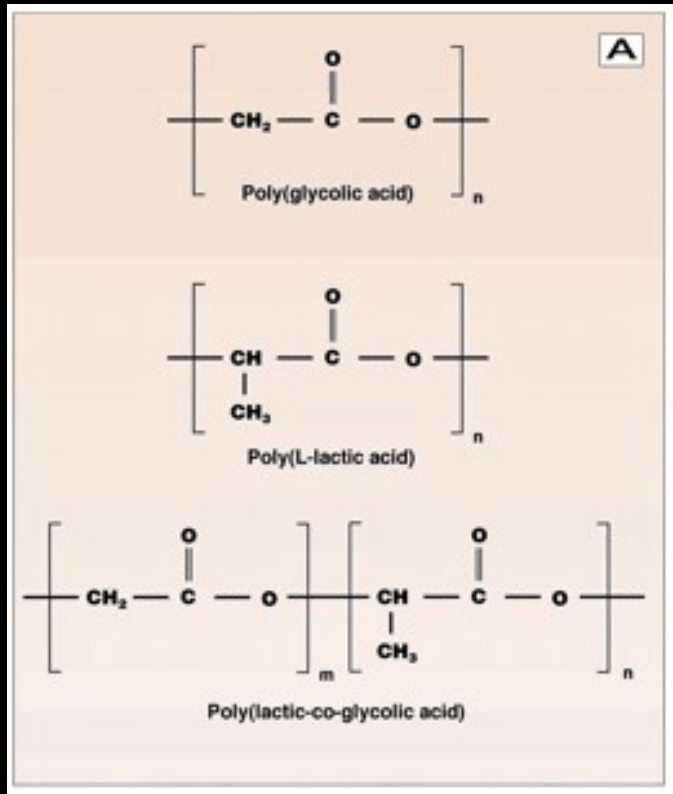



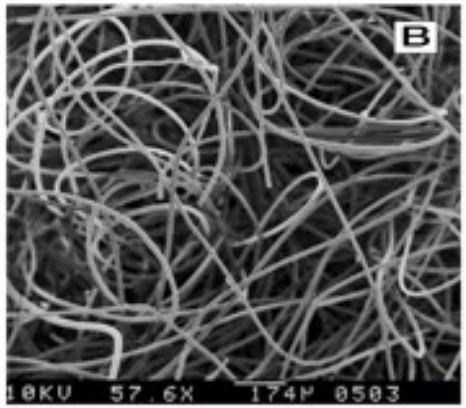
Technology trends
What's happening now

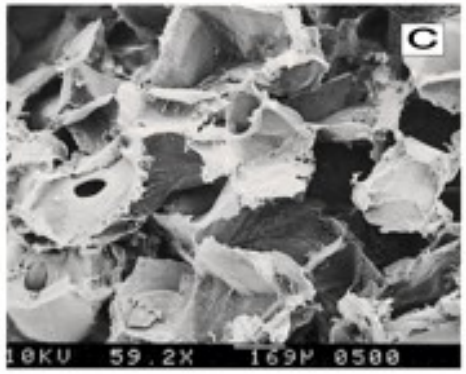
- Polyester now higher volume than cotton
  - Average US teenager still owns 19 denim garments, though!
- Far more stretch garments
  - Spandex
    - Jeans, T-shirts,
- Performance sports wear (wicking sweat away from body)
  - Increasing use of microfibers
  - Bicomponent fibers

New Fiber: Poly(Lactic acid)

- Environmentally benign process
- Large projected market growth
- Manufactured from corn starch
  - D- and L-Lactic acid
- Biodegradeable
- Made by Cargill-Dow







Technology trends
The near future…

- Dye Chemistry
- Mature industry
  - Few new high volume dyes
  - Unlikely to change much
    - Replacement of toxic dyes
- New Functional Dyes
  - Porphyrins as self cleaning textiles
    - Light activated
    - Antimicrobial (filters, masks)
    - Bioterrorism (chemical and biological agents)

Technology trends
The near future….

- Surface (finishing) chemistry
  - Plasma treatment
    - forms carboxylic acids on surface of nonpolar fibers
    - fluorocarbons
    - other functional groups
  - New flame retardant chemistry
    - All household textiles may require flame retardant finish

Technology trends
The near future….

- Security tagging of garments by retailers may lead to easily traceable garments
- New polymer systems
  - Fibers that swell when wet (reversible)
    - Water proof
      - No surface chemistry applied
    - Highly breathable dry

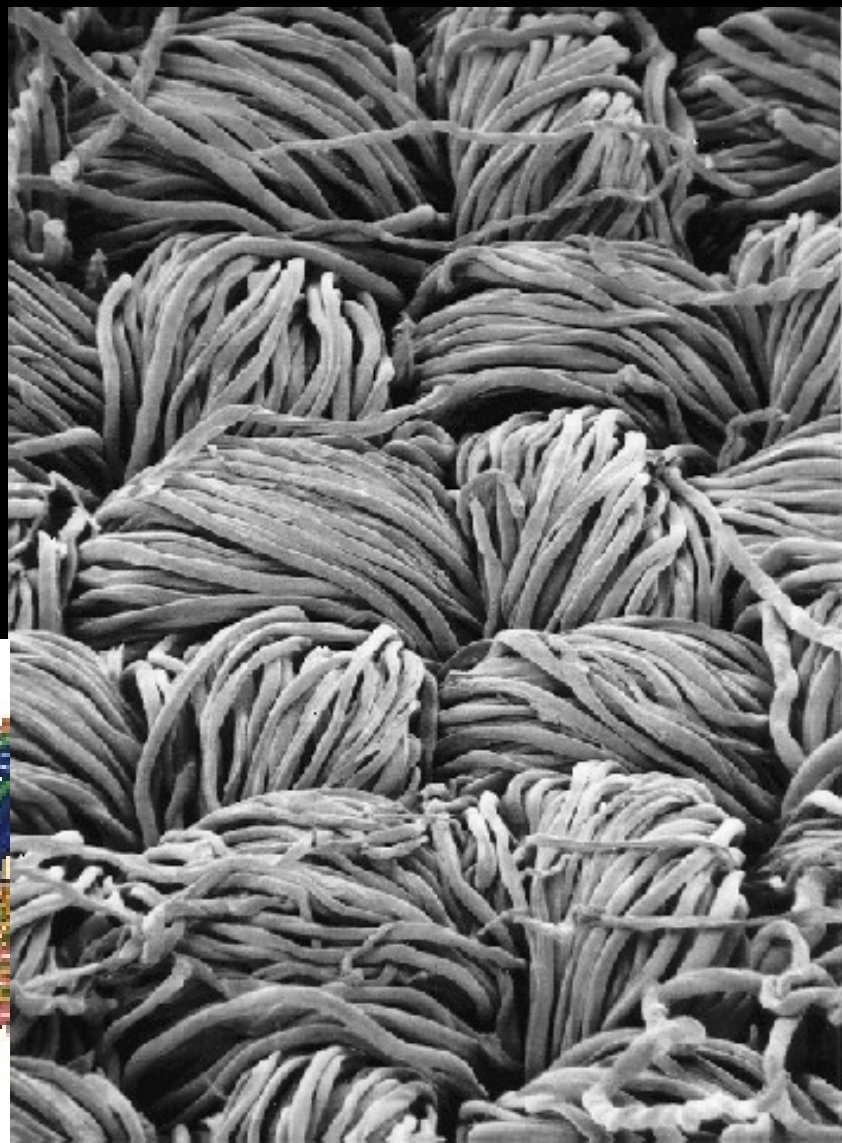
What can we analyze?

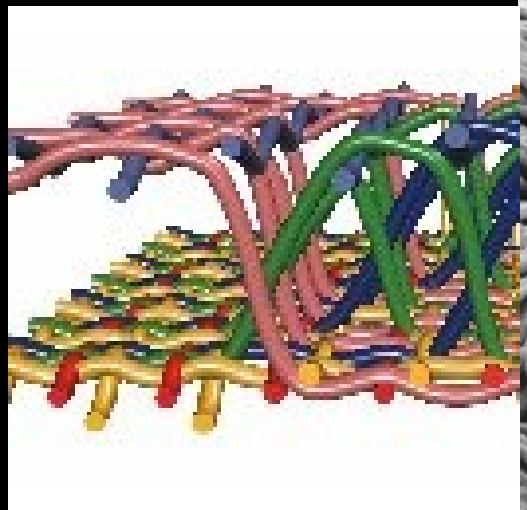
Textile, Fiber and Chemical Analysis. Visual and Instrumental Assessment

- Macroscopic
  - Color
  - Texture
  - Weave/knit properties
- Micro-analytical
  - Microscopy
  - Transmission/Reflectance measurement
- Chemical analysis
  - IR, NMR, MS, GC, High Performance Liquid Chromatography, Atomic Absorption, ICP, UV/vis, DSC, elemental, x-ray crystallography.

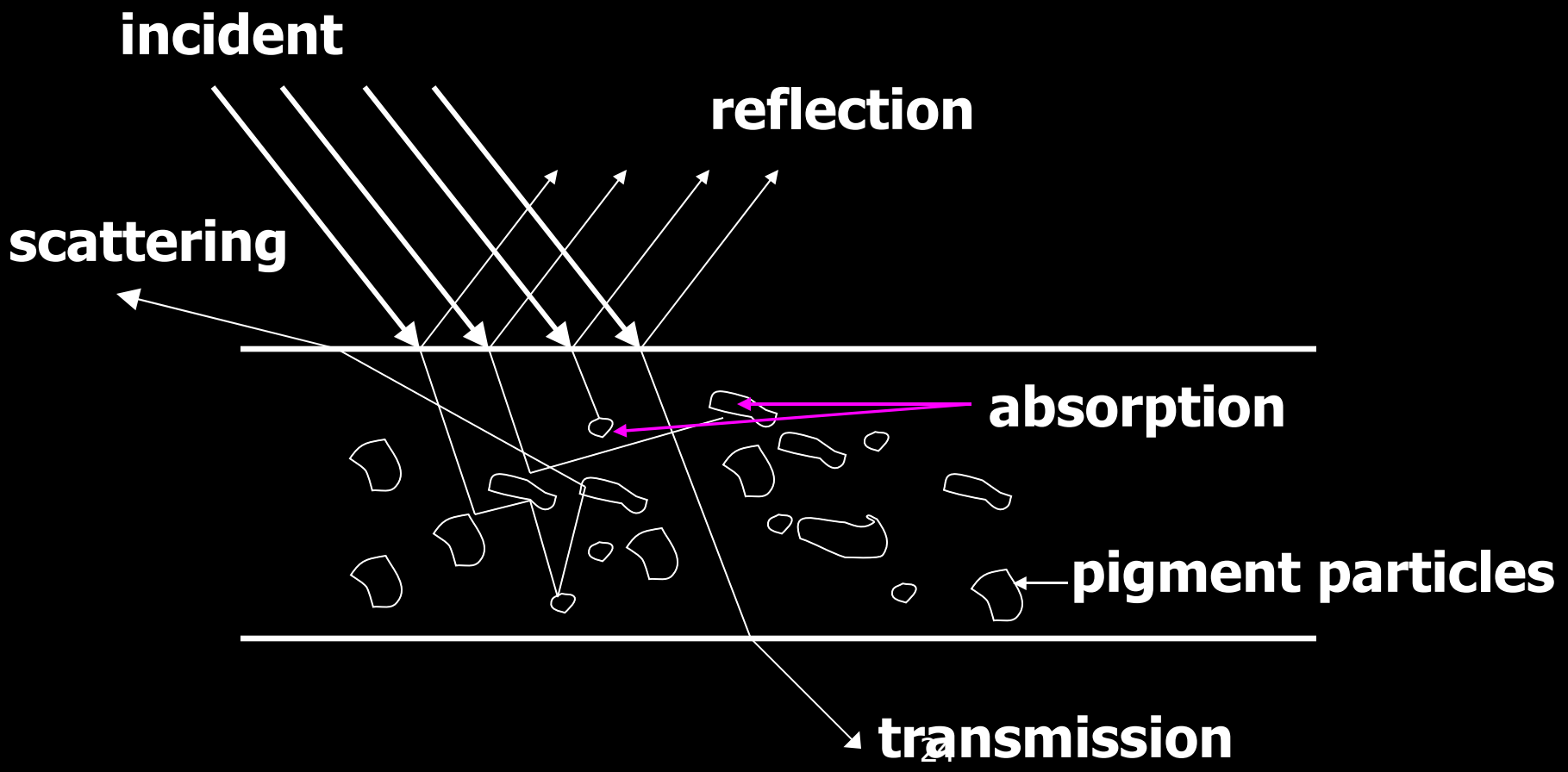
Cotton – Weave (or Knit) Analysis

- Yarn properties
  - Twist, type of spinning
- Fabric density
- Weave or knit type





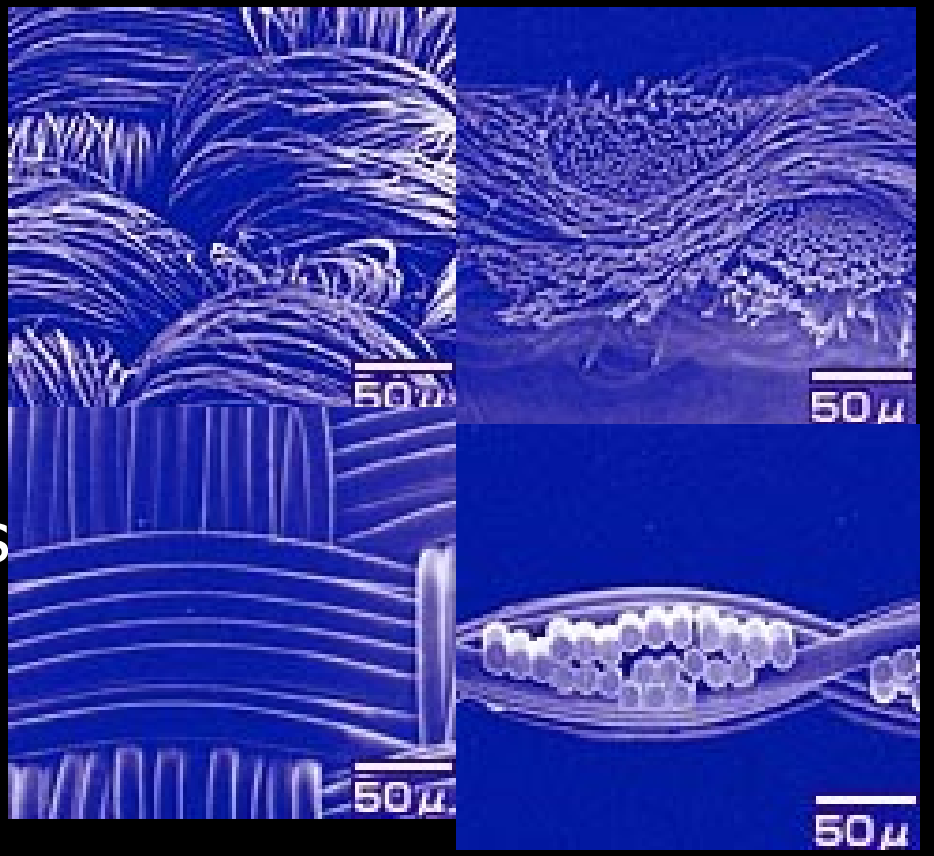
Absorption and scattering with a colored surface



Microfibers

- Very small fiber diameter
- Often polyester or nylon
- Shape is often indicative of manufacturers process

micro

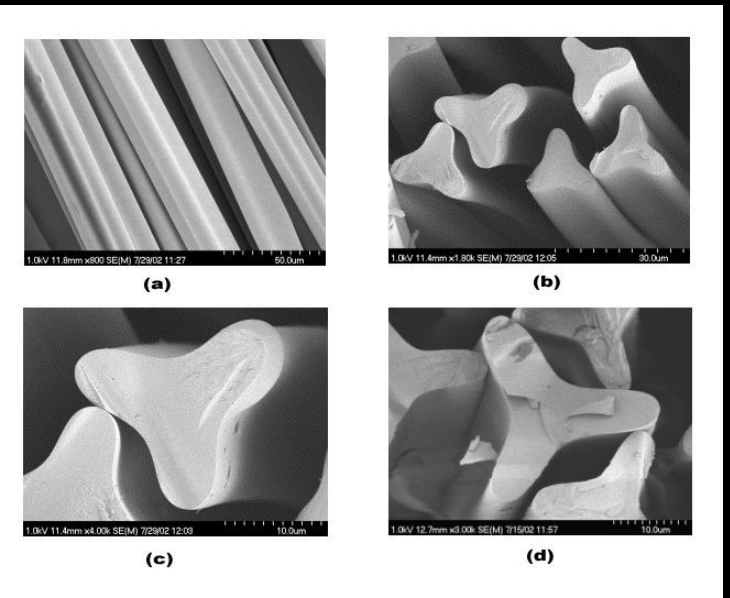


standard

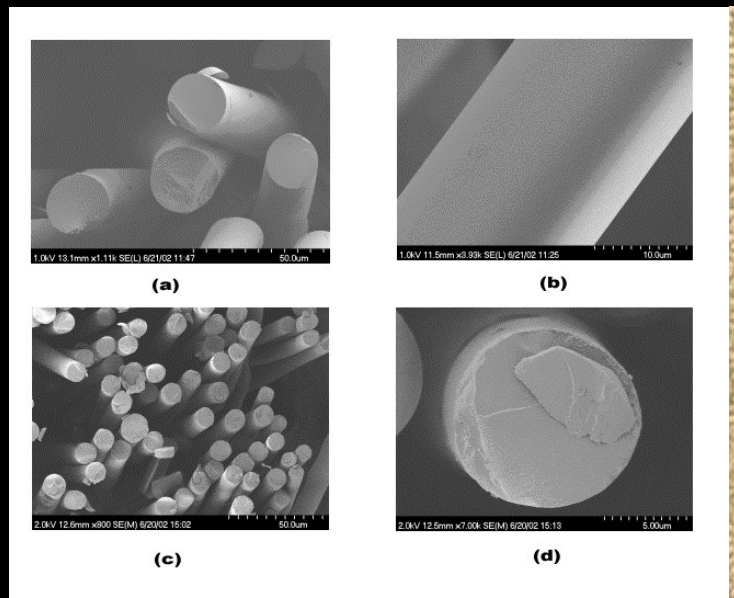
Synthetic fiber cross-sections

- May be circular, Y-shaped, X-shaped, or other

Trilobal



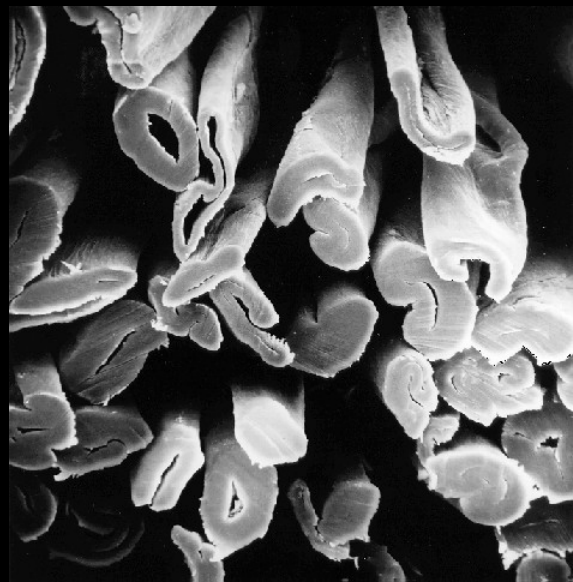
Circular



Hollow

Chemical analysis of fibers

- Example: Cotton
  - Physical and chemical properties of cotton depend on where it was grown (Texas, California, Egypt…..)
  - Chemical properties vary from season to season
    - Cotton fields irrigated in the field due to drought in Texas have much higher levels of metals (Iron, Magnesium…) than 'non drought' cotton
  - Common traceable chemical treatments



Chemicals applied to textiles

- Potentially traceable levels of a number of chemicals may be present on fibers
  - During manufacture
  - During consumer use

Potentially traceable chemical finishes applied to textiles

- During Manufacture
  - Softeners (flexible polymeric materials)
    - Silicones, Quaternary ammonium surfactants
  - Flame retardants
    - all childrens' nightware
    - Likely to be required in all upholstery/drapes, etc.
  - Water repellent materials
    - Silicone, fluorocarbon

Traceable chemical finishes applied to textiles

- During Manufacture (cont.)
  - Stain repellent finishes ('Teflon®'-based polymers)
    - Fluorocarbon-alkoxylated block copolymers
  - Crease resistant finishes
    - Dimethyloldihydroxyurea (DMDHEU), others
  - Antimicrobial finishes
    - Ag based, quaternary ammonium
  - Fluorescent brightening agents
    - Stilbenes, others
  - UV blocking finishes (new)

Traceable chemical finishes applied to textiles

- Consumer use
  - Laundry detergent formulations
    - Surfactants
    - Fluorescent brightening agents
    - Softeners
  - Antistatic agents (Bounce®)

Nonwovens

- Nonwovens are Engineered Fabrics
- Nonwovens are manufactured by high-speed, low-cost processes – Large Volume, Lower Cost than traditional processes
- Nonwovens are in many applications already, but most are hidden and you do not see them

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Nonwovens Markets and Applications

A $50 Billion Market!

- **Disposables** (55-65%)
  - **Baby Diapers**
  - **Adult Incontinence**
  - **Feminine Hygiene**
  - **Medical**
  - **Wipes**
- **Durables** (35-45%)
  - **Filtration**
  - **Protective Garments**
  - **Interlinings**
  - **Home Furnishing**
  - **Geotextiles**
  - **Agricultural**
  - **Automotive**
  - **Carpet Backing**

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute









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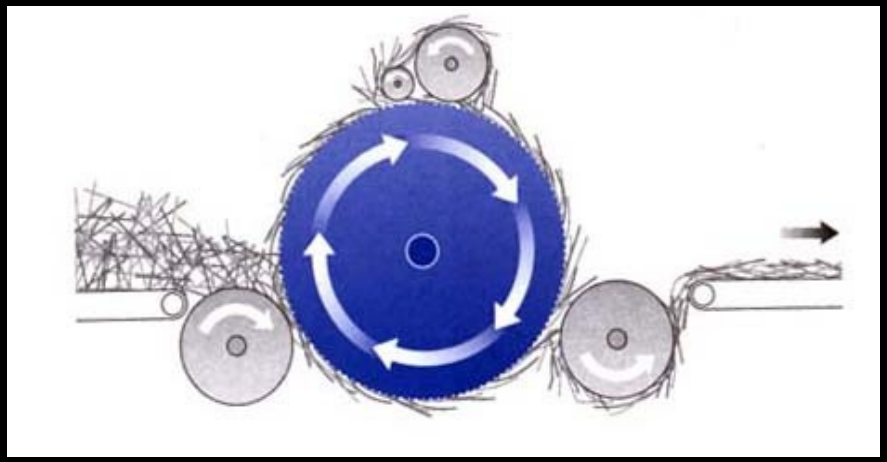
Basic methods of manufacture of nonwovens

- **From Fibers**
  - Web Forming
    - Dry-lay (Carding)
    - Air-lay
    - Wet-lay
  - Bonding
    - Mechanical
      - Needling
      - Hydroentangling
    - Thermal
      - Calendering
      - Thru-air
    - Chemical
    - Adhesive
- **From Polymers**
  - Extrusion & Web Forming
    - Spunbond
    - Meltblown
  - Bonding
    - Mechanical
      - Hydroentangling
    - Thermal
      - Calendering
      - Thru-air

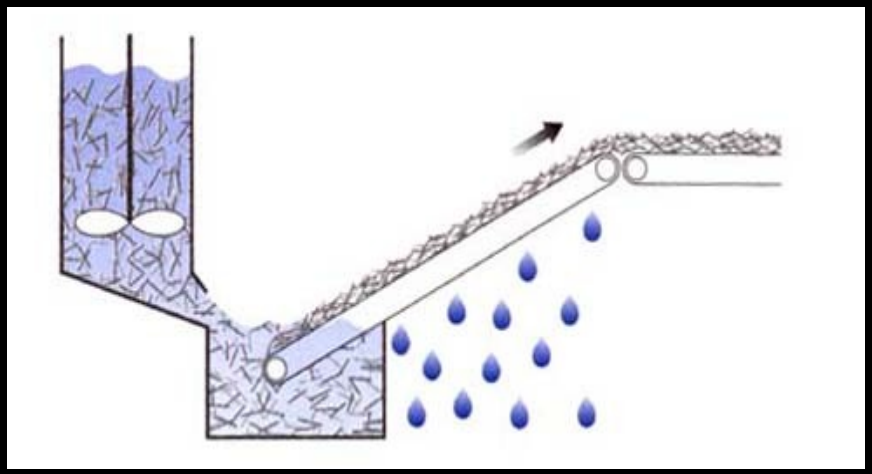
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Web Formation

The dry-laid process
Web is produced from staple fibers Production takes place in a carding machine fitted with rotating rollers.



The wet-laid process
The fibers are separated by water and laid on a circulating screen belt on which the water is drained off.



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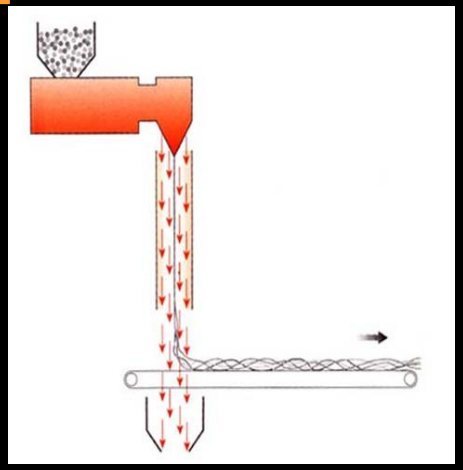
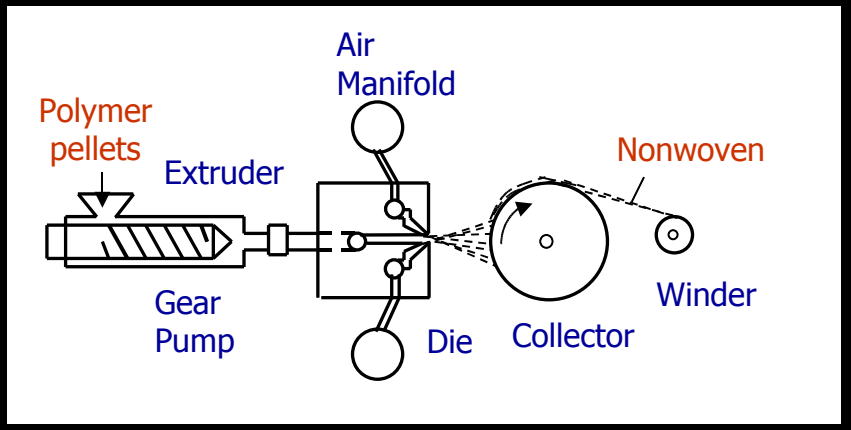
Web Formation

The spunbonding process
This is a continuous production process, from raw material (polymer granulate) to web. The web requires bonding.



The meltblowing process
This is a continuous production process, from raw material (granulate) to web. The web Requires no bonding.



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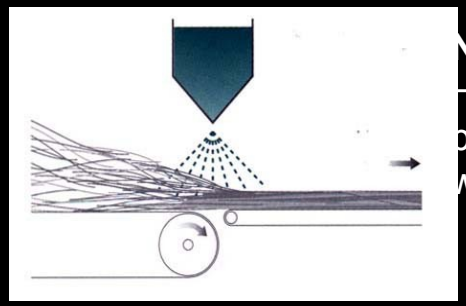
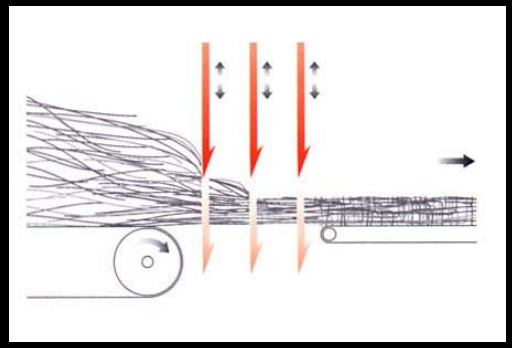
Web Bonding

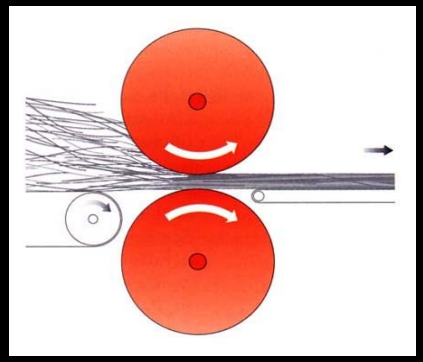
Adhesive bonding
Here the fibers are bonded by means of an adhesive.



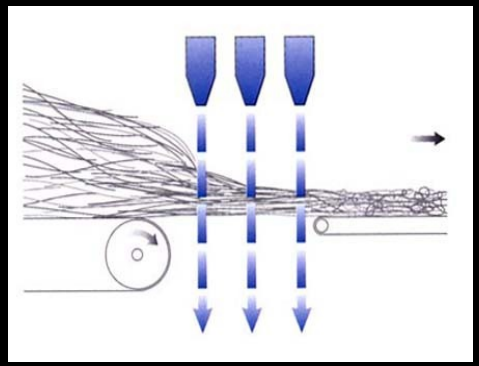
Needling
Here the fibers are bonded using needles with barbs.



Thermal bonding
This is homogenous bonding of the fibers between hot, rotating cylinders.



Hydroentangling
This is mechanical bonding by means of ultrafine, powerful jets of water.



Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Nonwoven manufacture is high speed

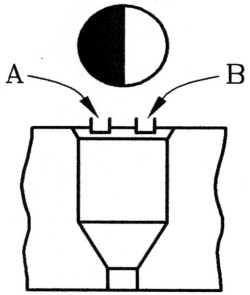
- SpunMelt
  - > 300-1000 meters per minute – 5 to 6 meters wide
- High Speed Cards
  - > 300-400 meters per minute – 5 to 6 meters wide

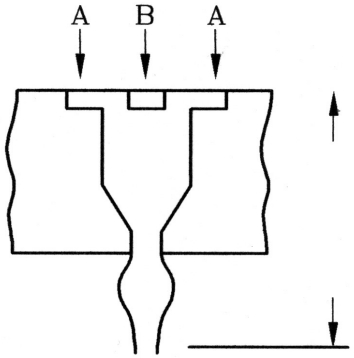
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Bicomponent fibers

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

BICOMPONENT SPINNING



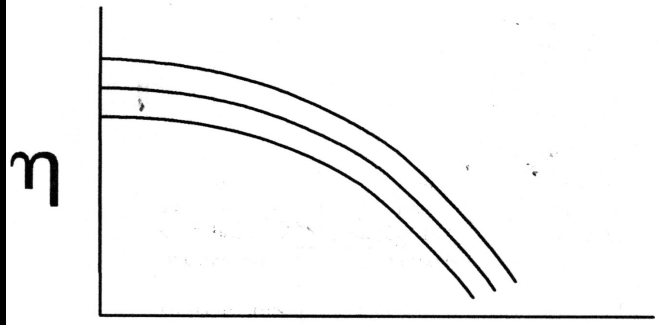


POLYMERS TOGETHER

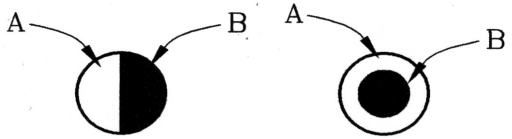
FREEZE LINE

Internal X−section= f ($\Delta\eta_{AB}$, Placement of polymers, $\Delta\dot{M}_{AB}$)

$\Delta\eta_{AB}=f$ (Temp, shear, MW, Type of Molecule)

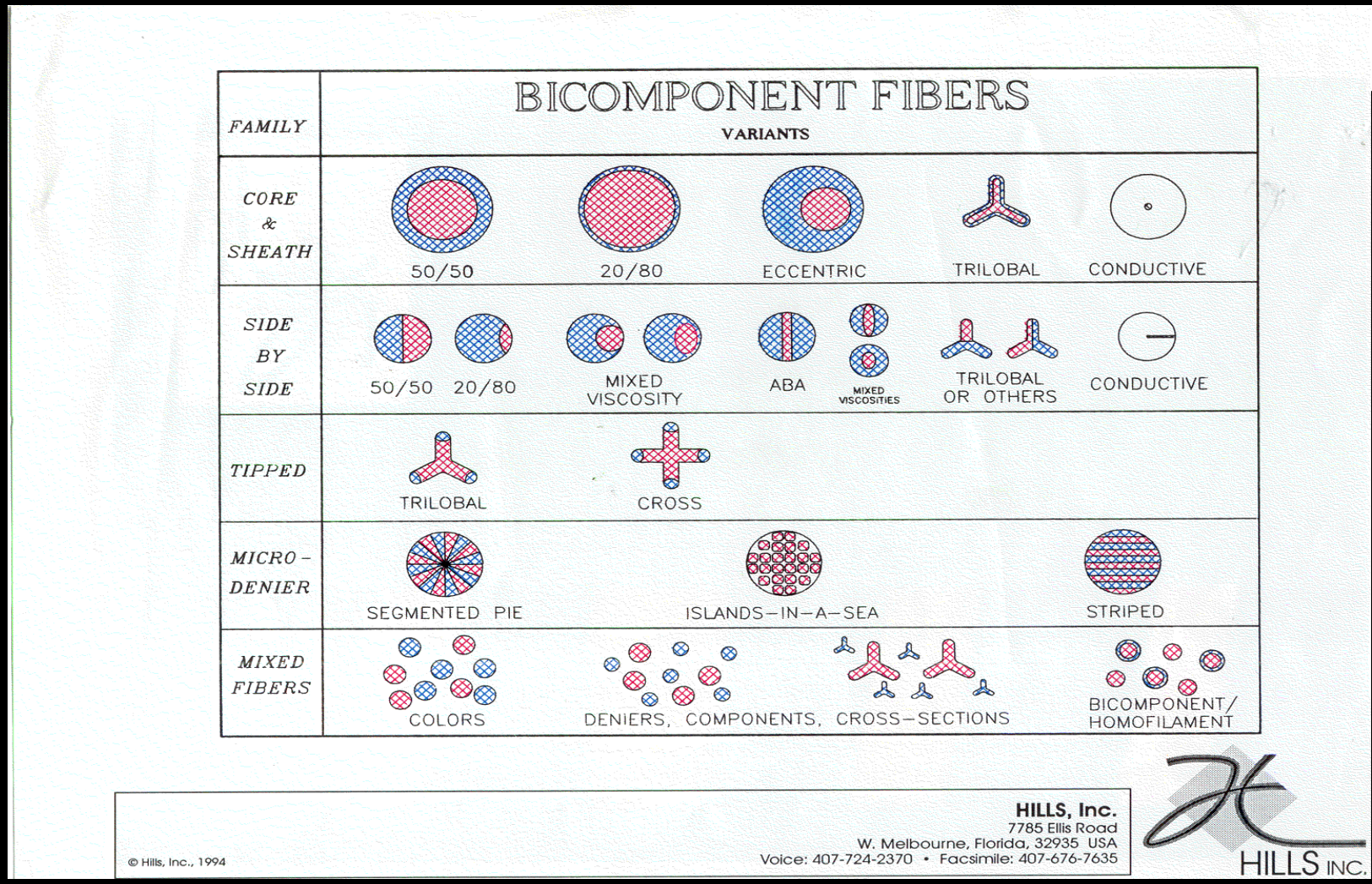


Lower Temp



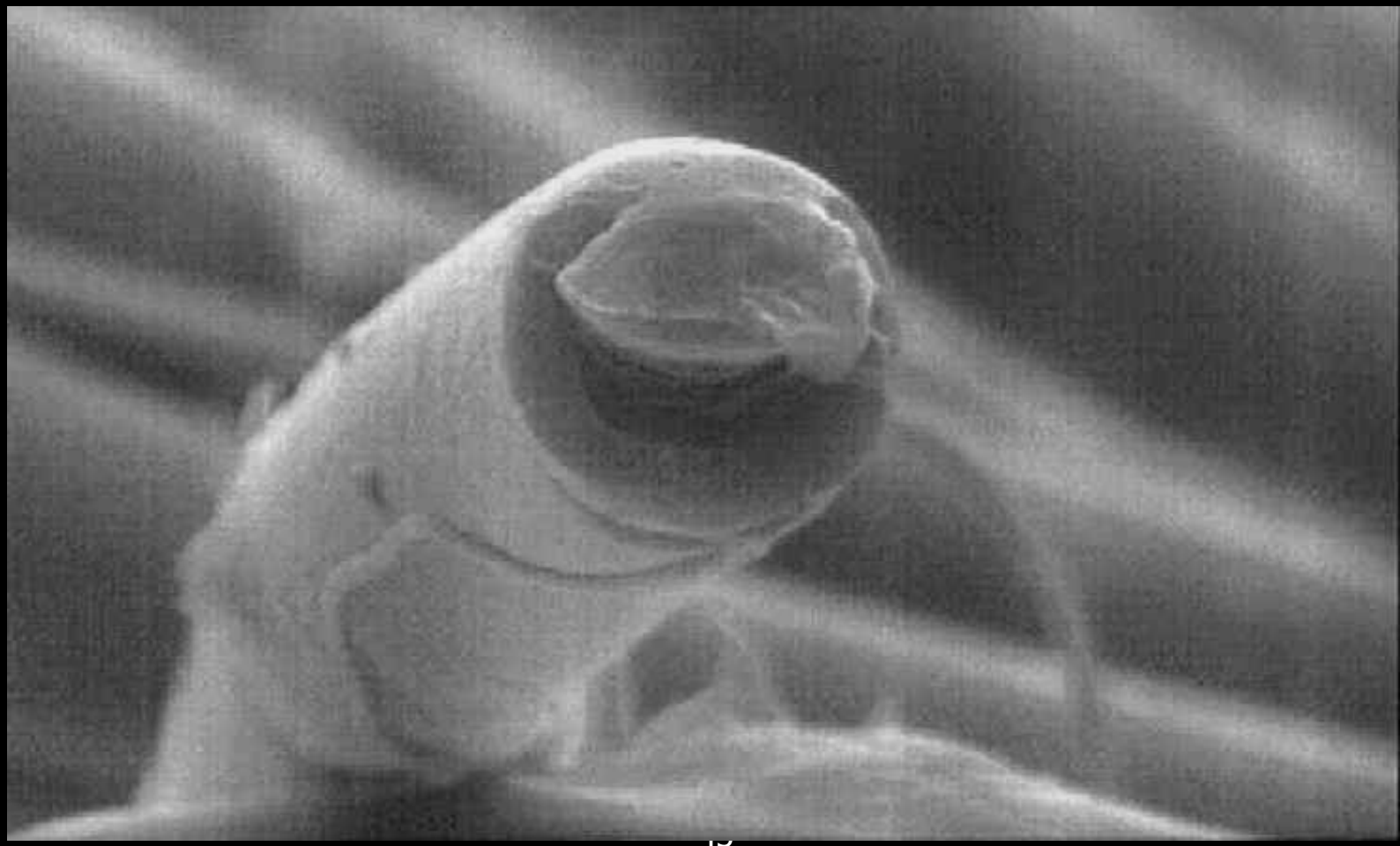
$\Delta\eta_{AB}=0$	$\eta_{A<<}\eta_B$

Bicomponent Variants



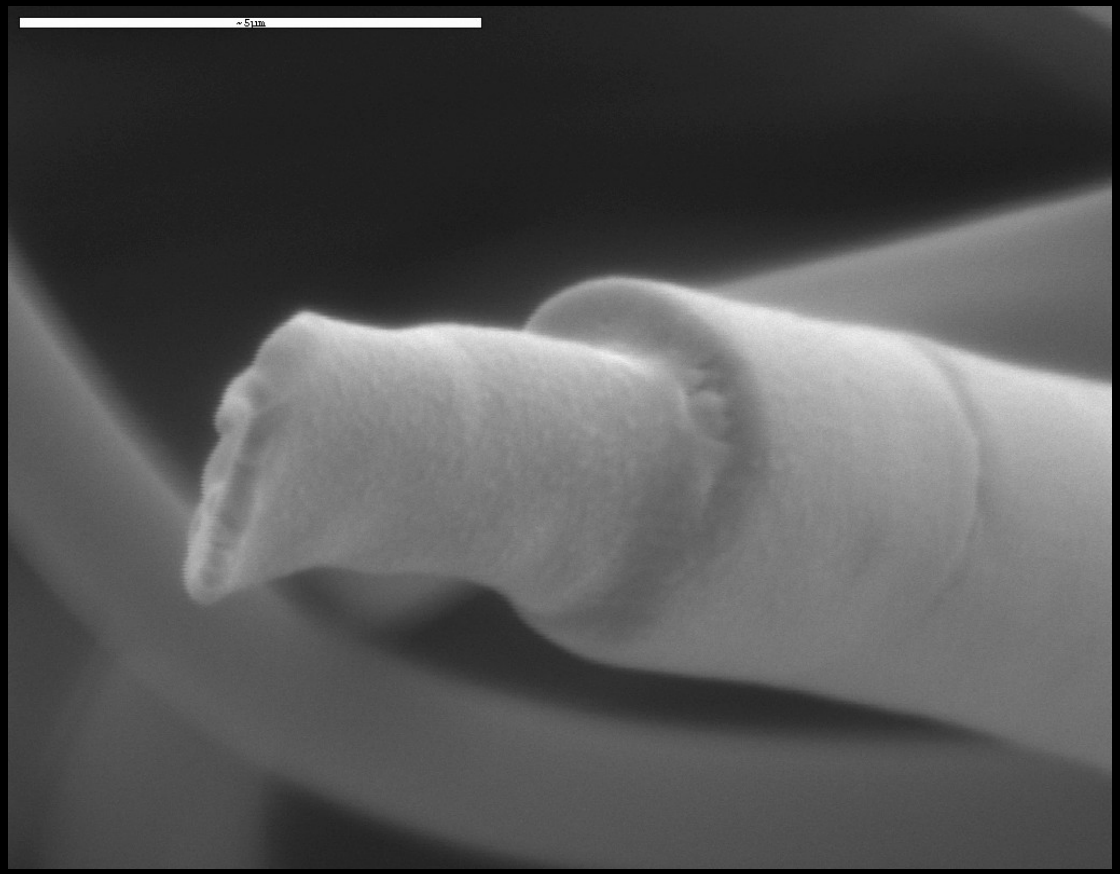
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Melt Blown, Sheath/Core 50/50 PE/PP



Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

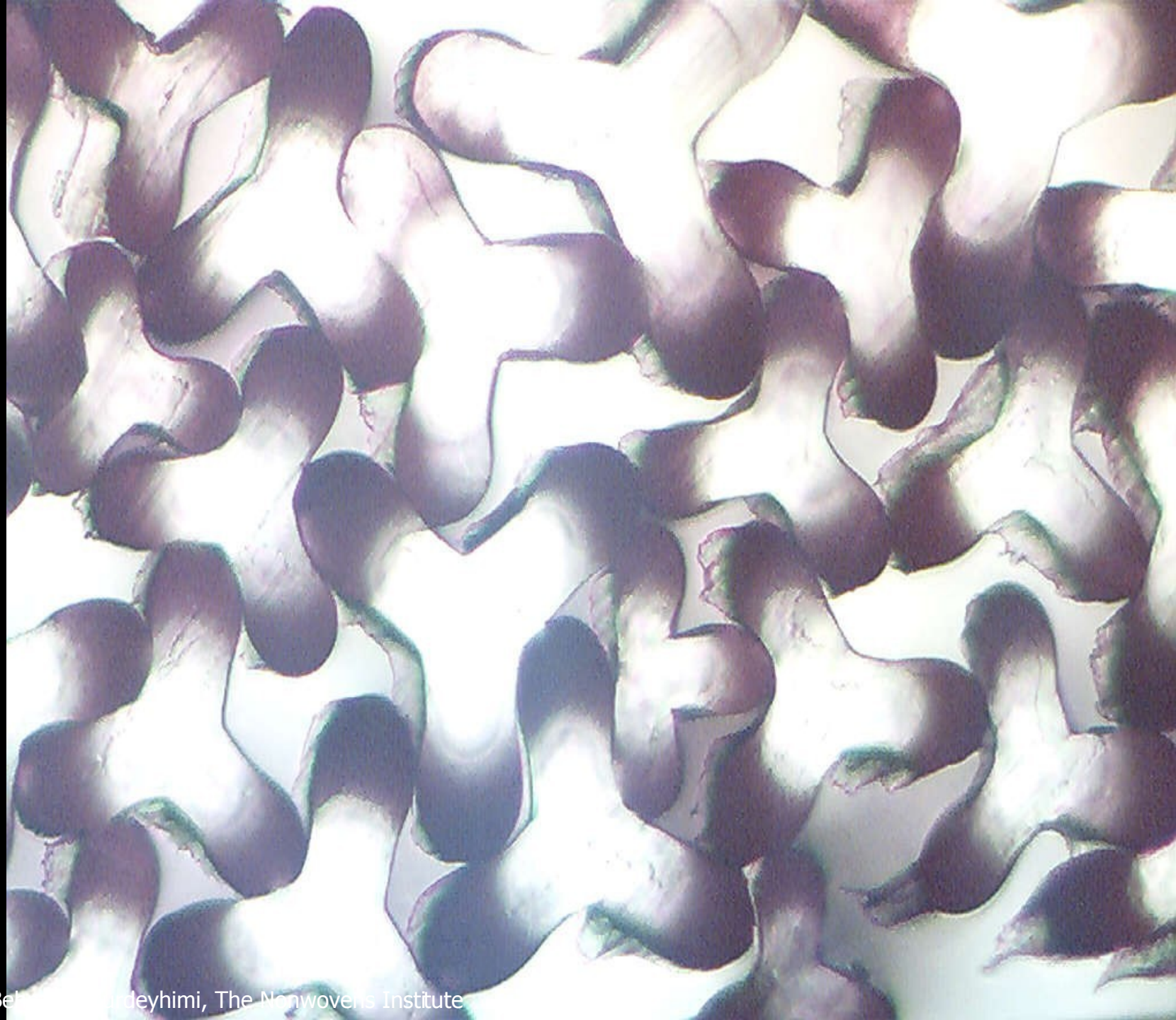
Cross-section of S/C PP Meltblown



Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

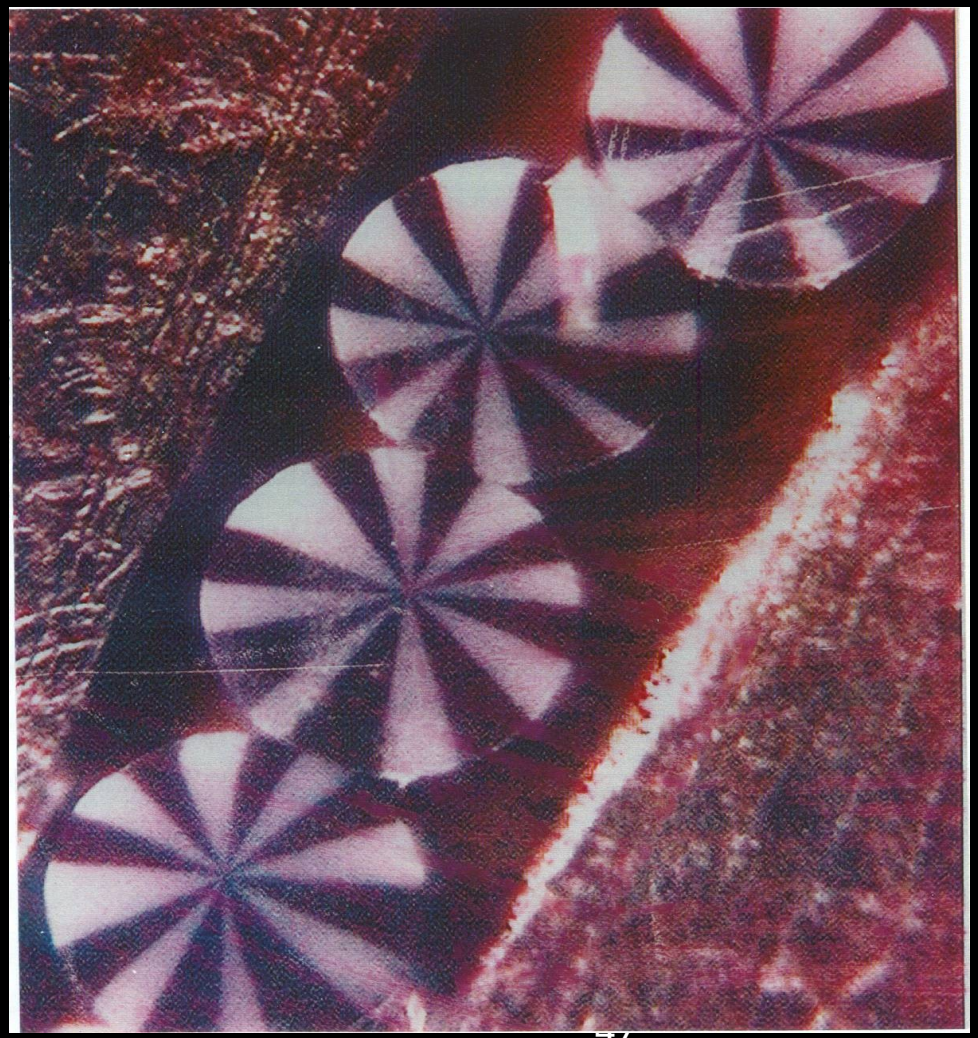
Side by Side Trilobal Cross Section

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute



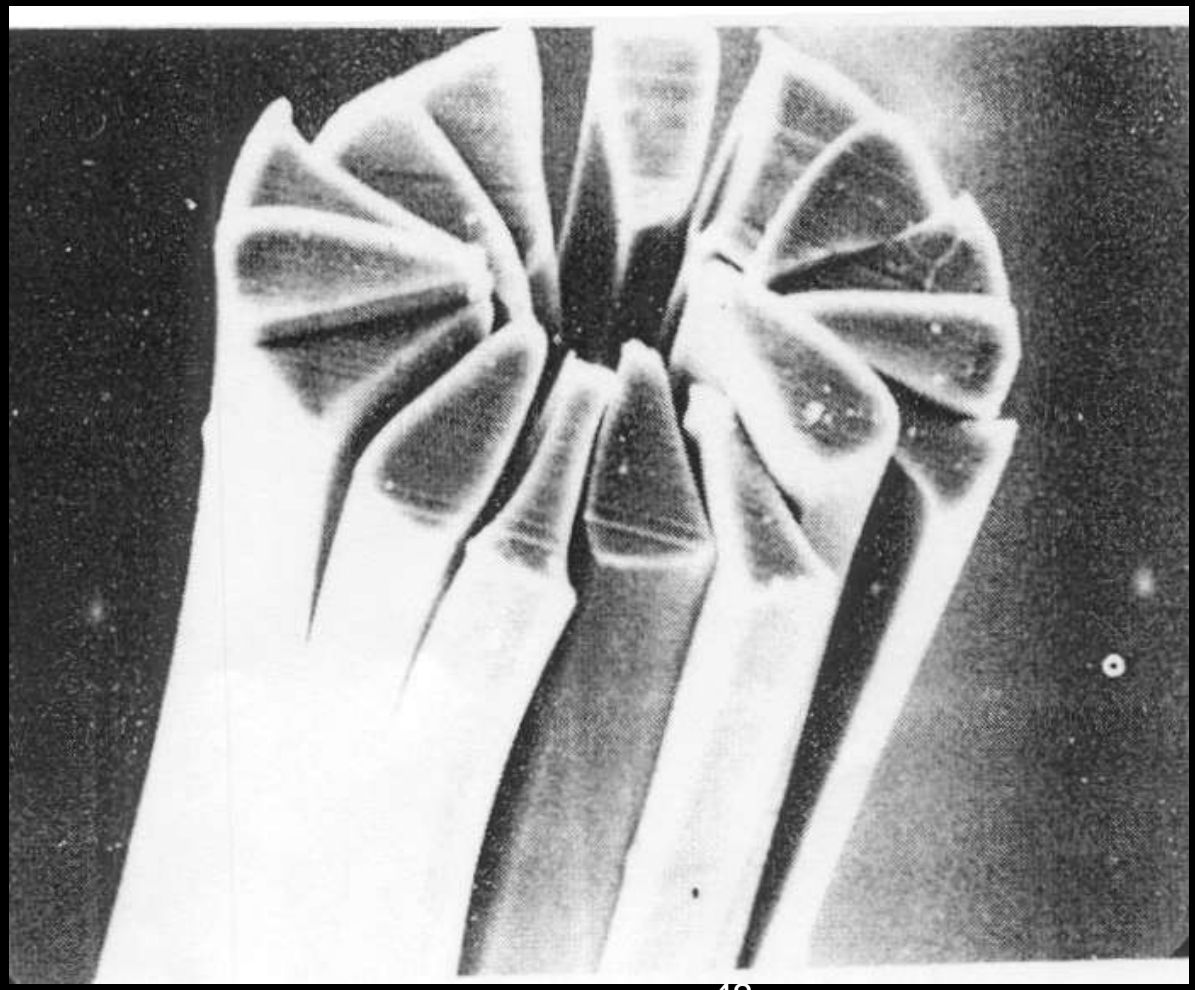
Courtesy: prof. Be[illegible]deyhimi, The Nonwovens Institute

Sixteen Segment Pie



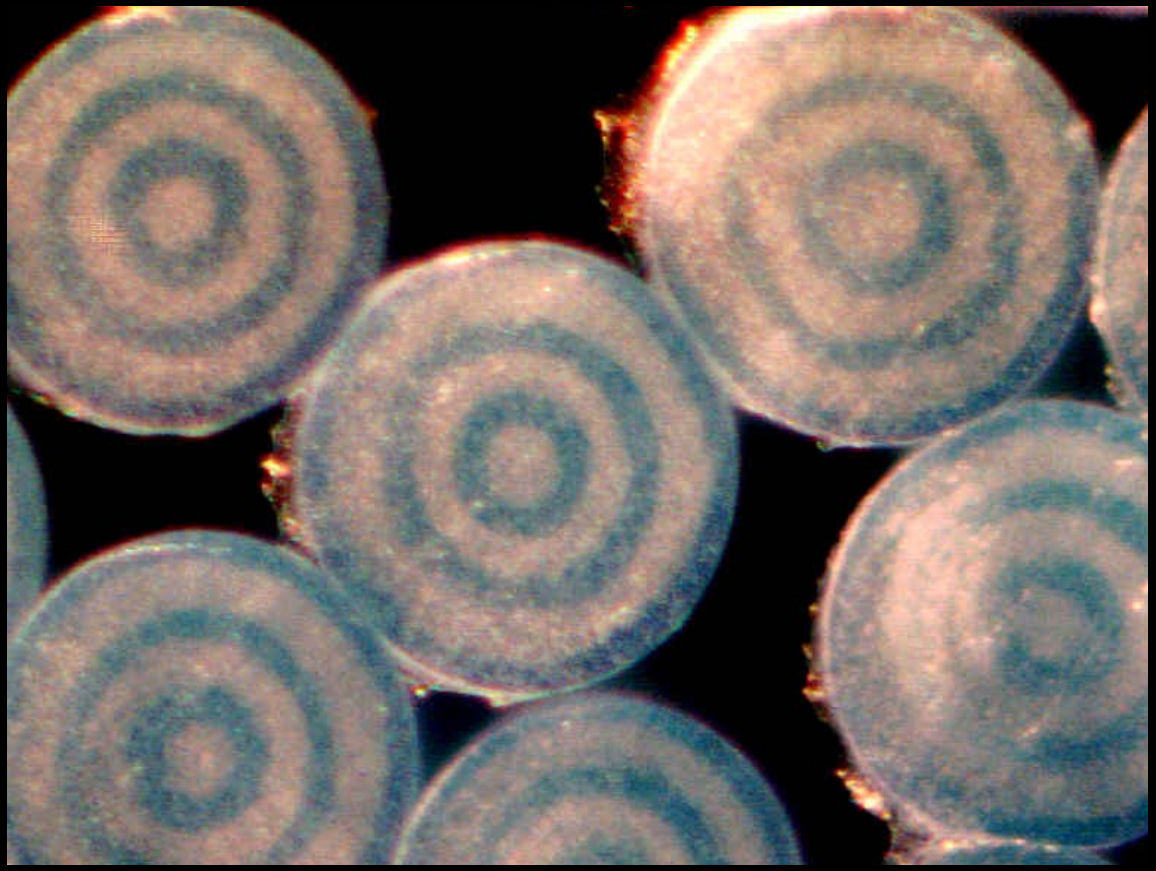
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

16 Segment Split, Pie



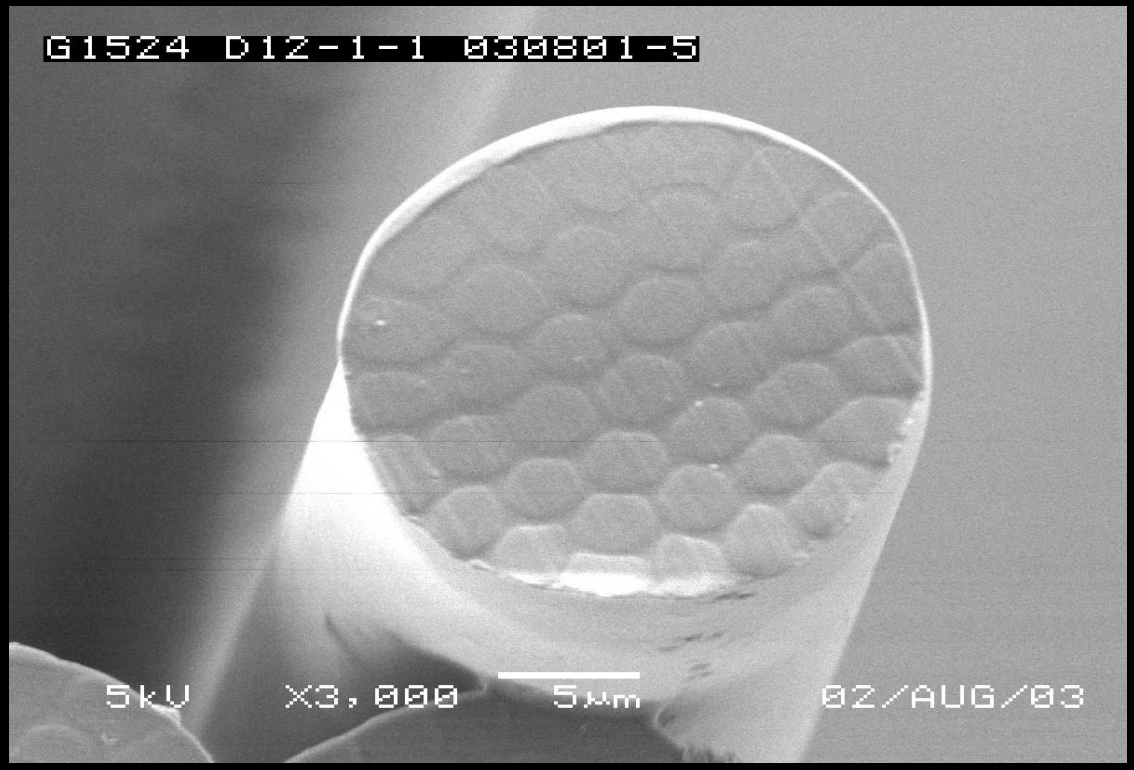
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Concentric Ring



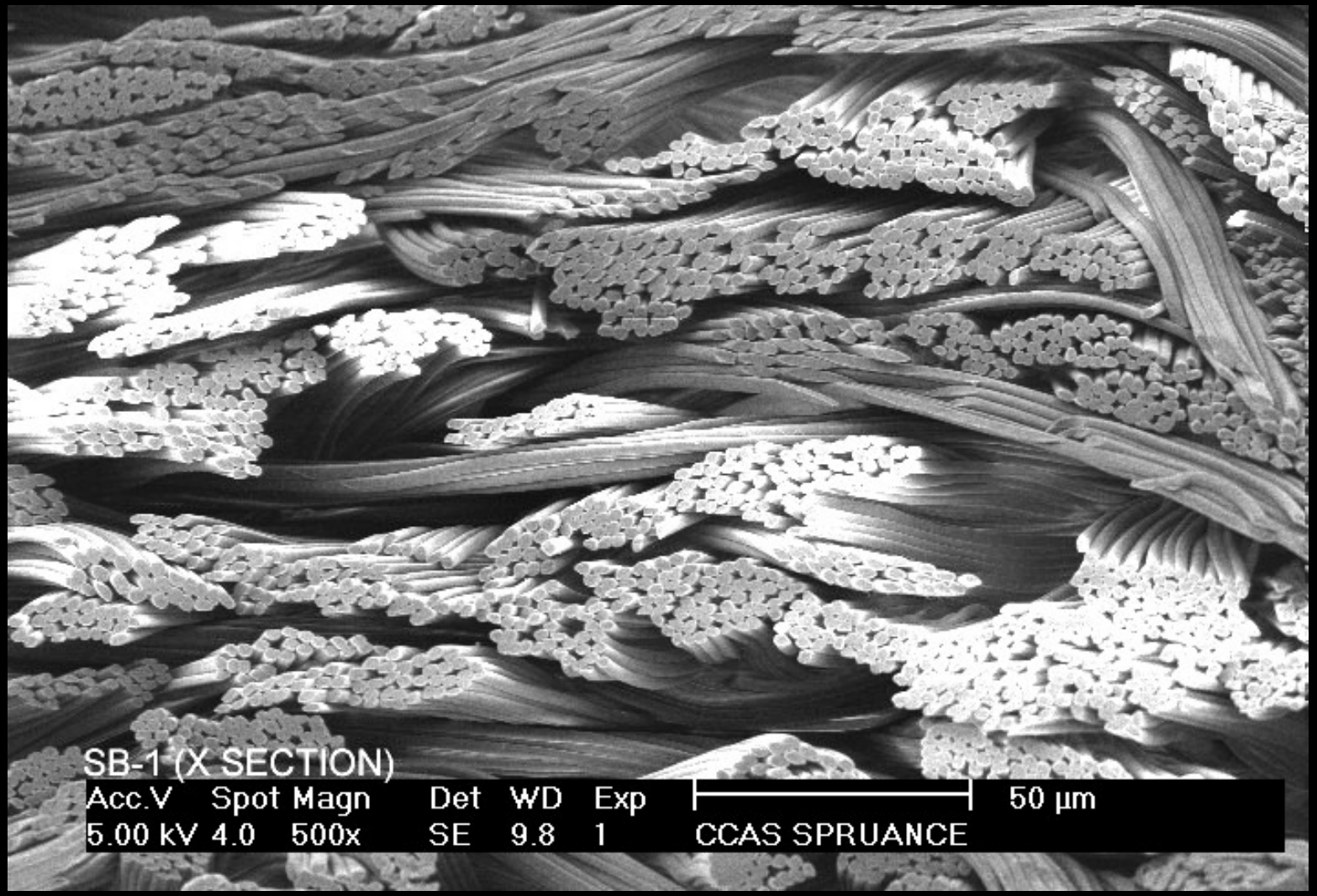
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

37 Islands-in-the-Sea



Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

25 Islands-in-the-sea Spunbond



Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

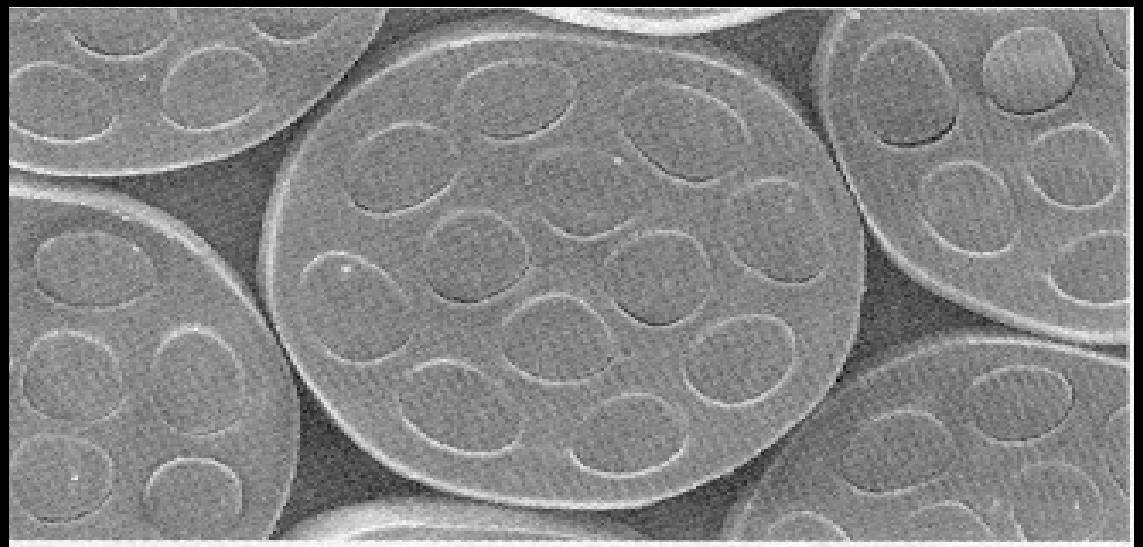
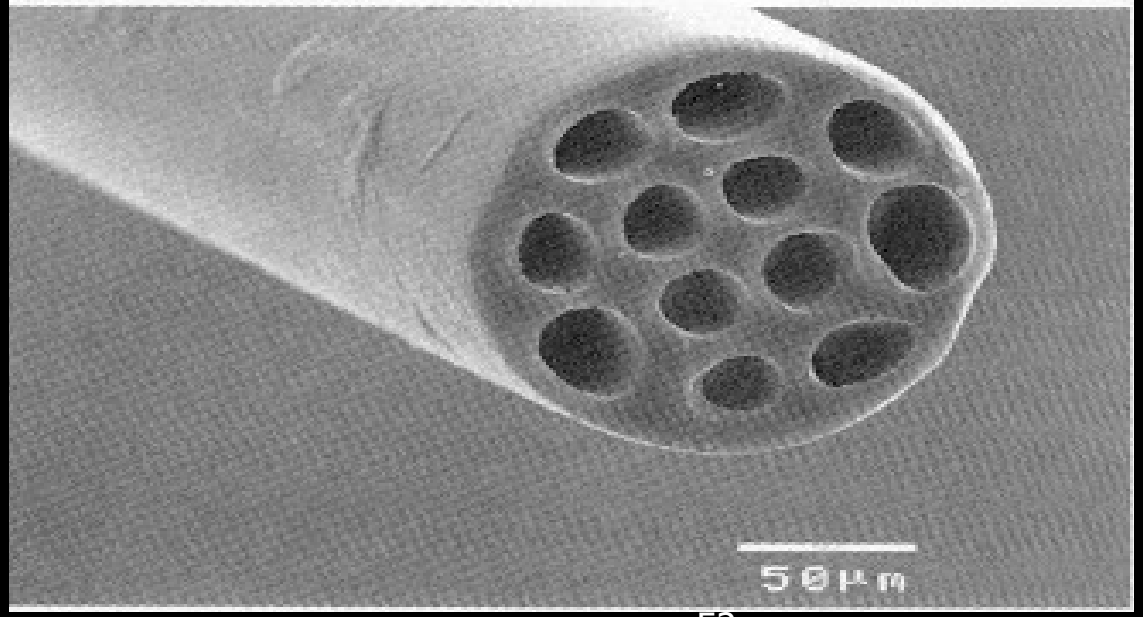
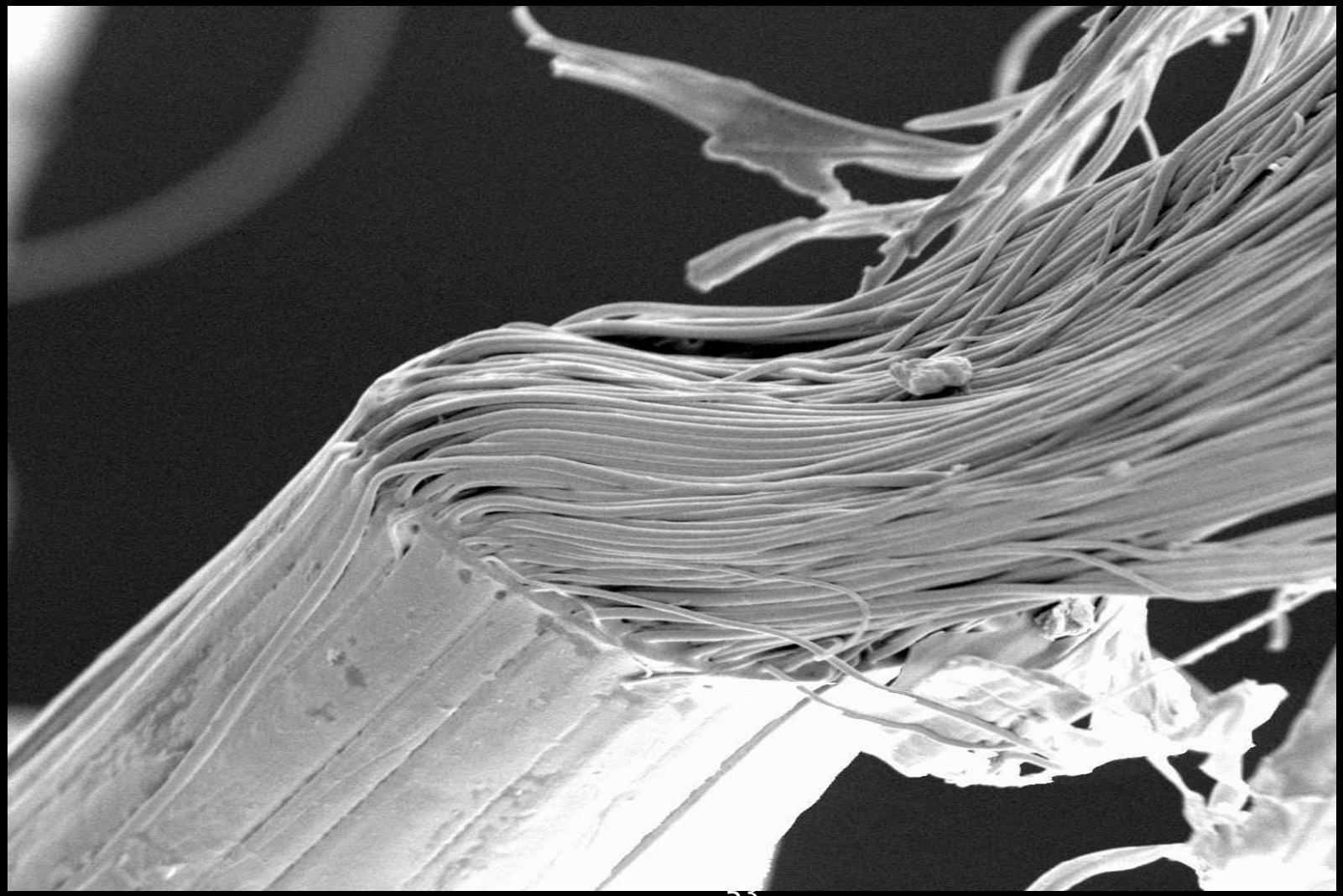


Fig. 5



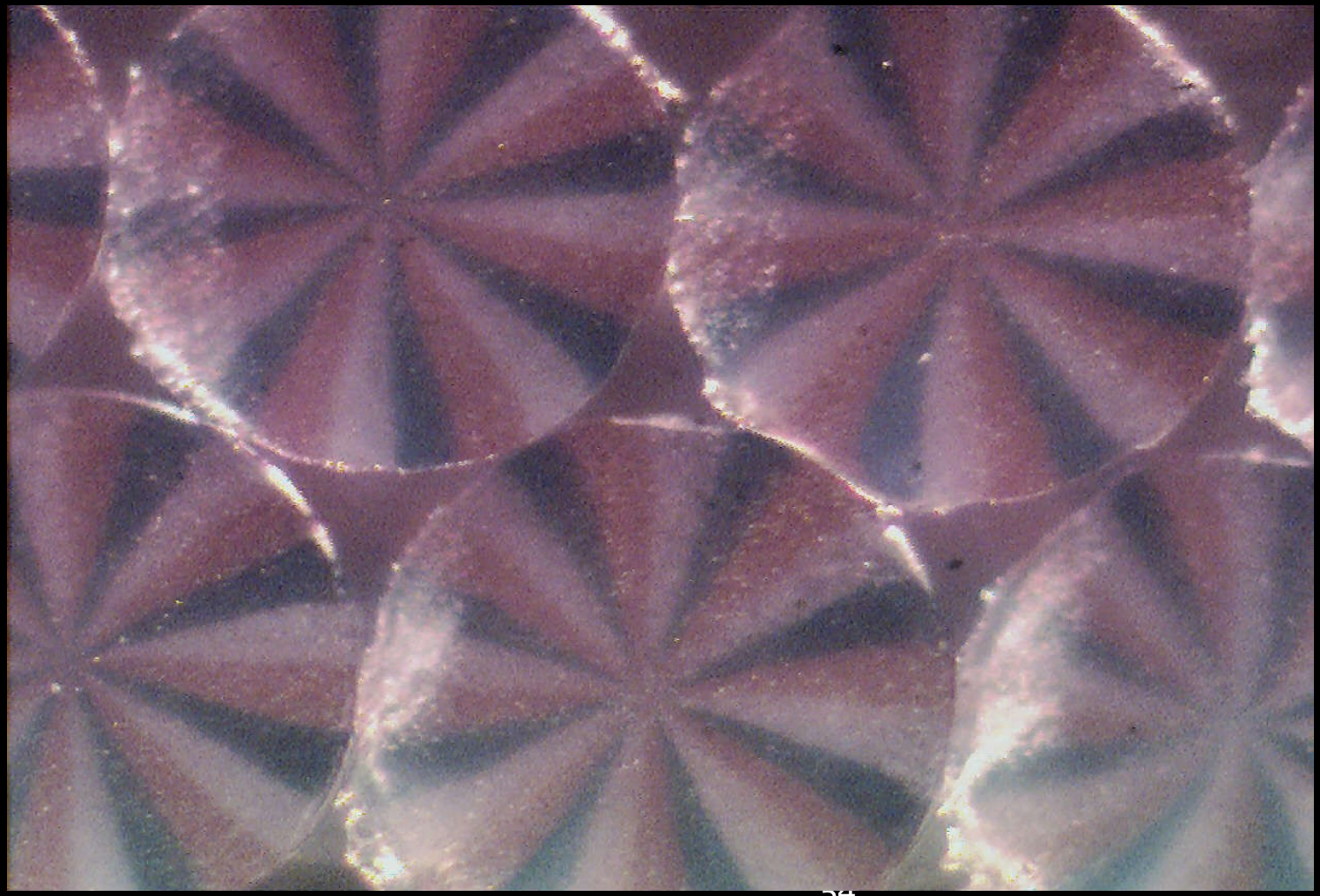
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

600 Islands-in-the-Sea

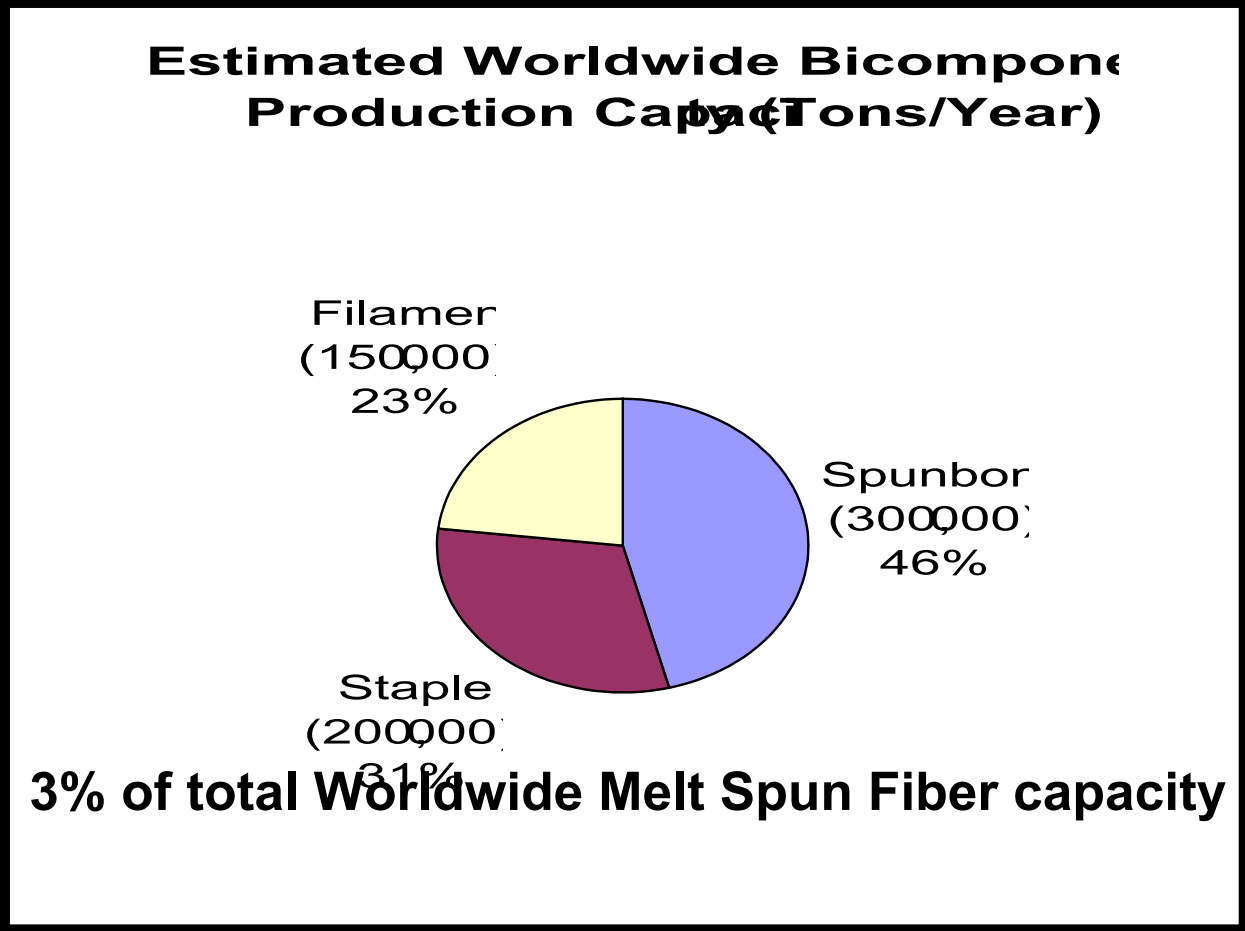


Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Tri – Segmented Pie



Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute



3% of total Worldwide Melt Spun Fiber capacity

Approximately 75% of all bicomponent fibers go to a nonwoven end use

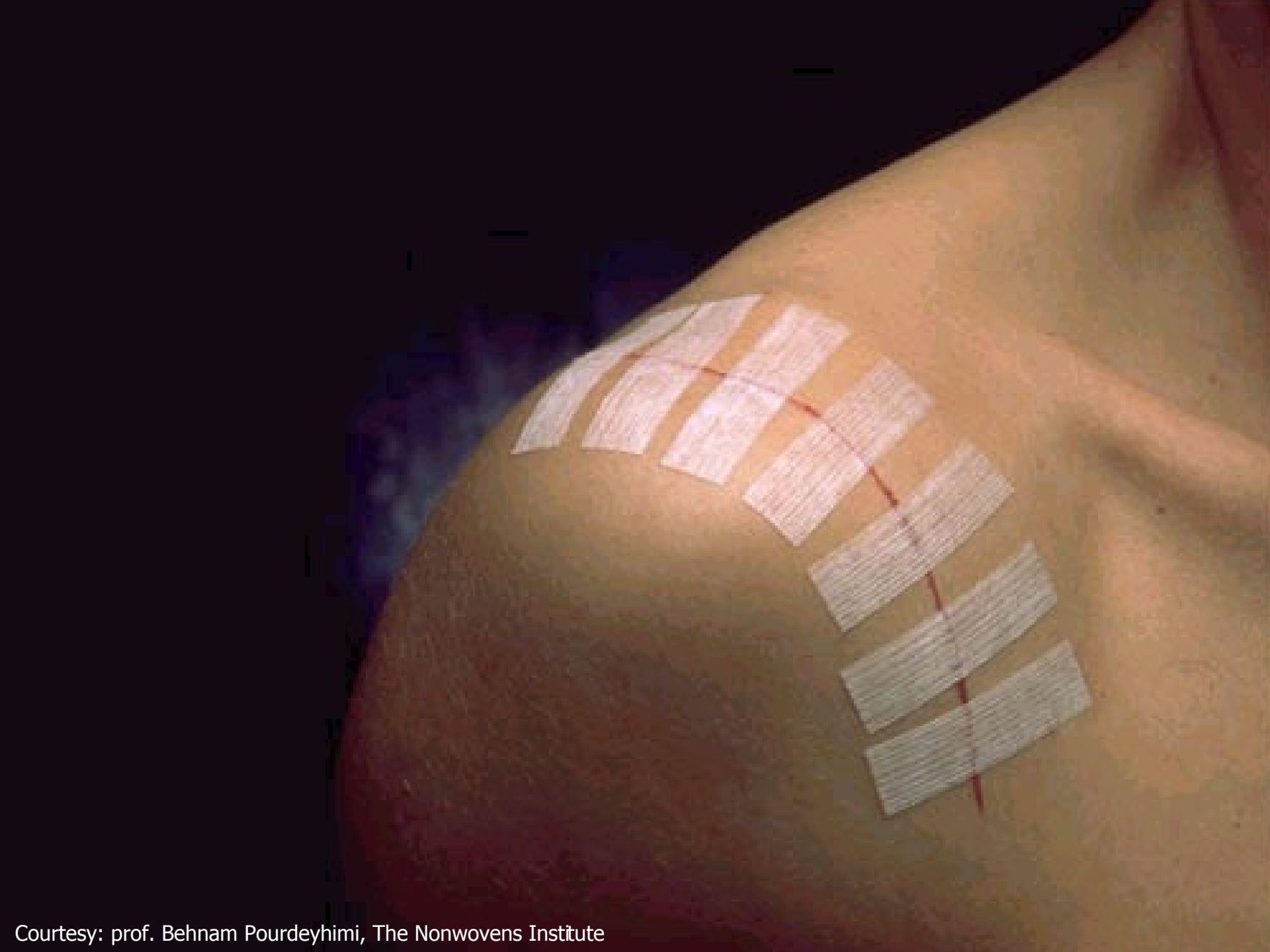
Most bicomponent capacity is extruder fed.

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Medical applications

- In medical applications, nonwovens offer maximized levels of safety and hygiene. They are used in adhesive plasters, wound pads and compresses, orthopedic waddings and stoma products.
- The nonwovens used here must, for example, be particularly absorbent and air-permeable, must not stick to the wound, and also have to ensure a skin-friendly micro-climate.

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute



Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Thinsulate™ Acoustic
INSULATION

Explore Thinsulate™ Acoustic Insulation, it's lightweight, flexible and easy-to-install, it offers excellent sound absorption in a variety of applications.

Thinsulate™
INSULATION

It's warm. It's comfortable. And it's high quality. Look for outerwear, footwear and accessories that carry the Thinsulate™ Insulation hang tag and you'll be warm and comfortable.

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Thinsulate™ Insulation

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Sorbents

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

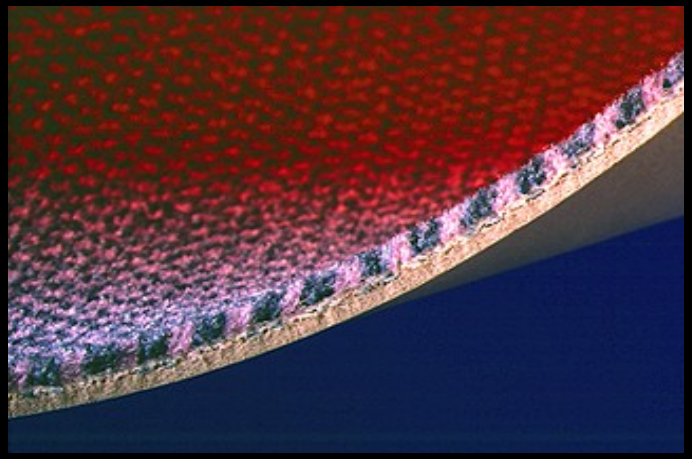
Furniture/Textile Applications

- In furniture/textile applications, nonwovens satisfy even the most disparate functional requirements for producing upholstered furniture, bedware and quilted products, and protective clothing.
- Nonwovens here excel in terms of their textile look, their air-permeable breathability, and high abrasion resistance values.

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Tufted Carpets

- In Carpets, nonwovens constitute the invisible supporting inside layer of tufted carpets and carpet tiles.
- In automotive carpets, nonwovens are used as first and second backings mainly for making molded automobile carpets.



Source: Freudenberg Nonwovens

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

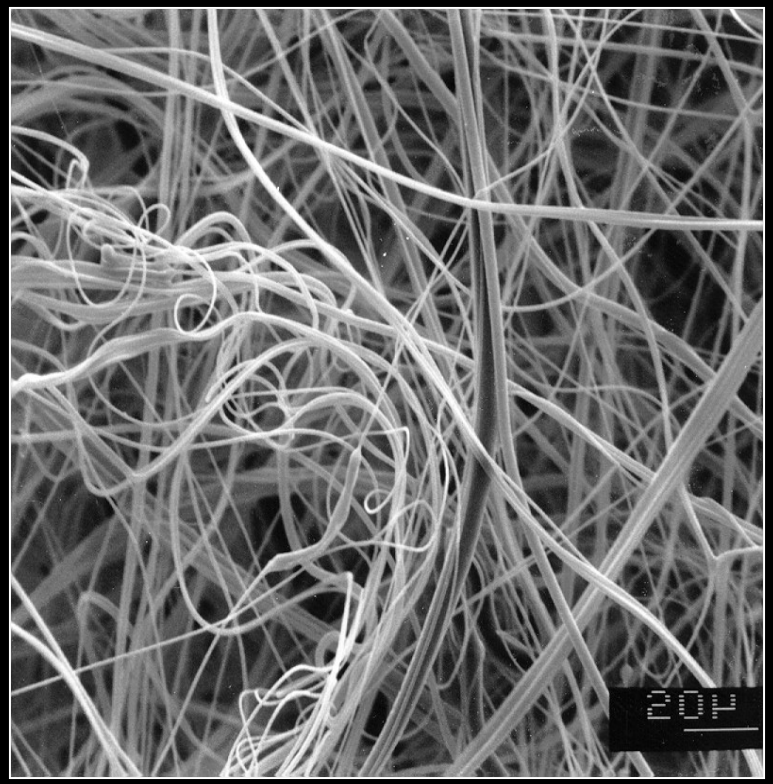
In Shoes…

- A broad spectrum of applications including:
  - liners,
  - counterliners,
  - interliners and
  - reinforcing materials
- Membranes and insoles ensure a healthy foot climate and a high degree of foot comfort.

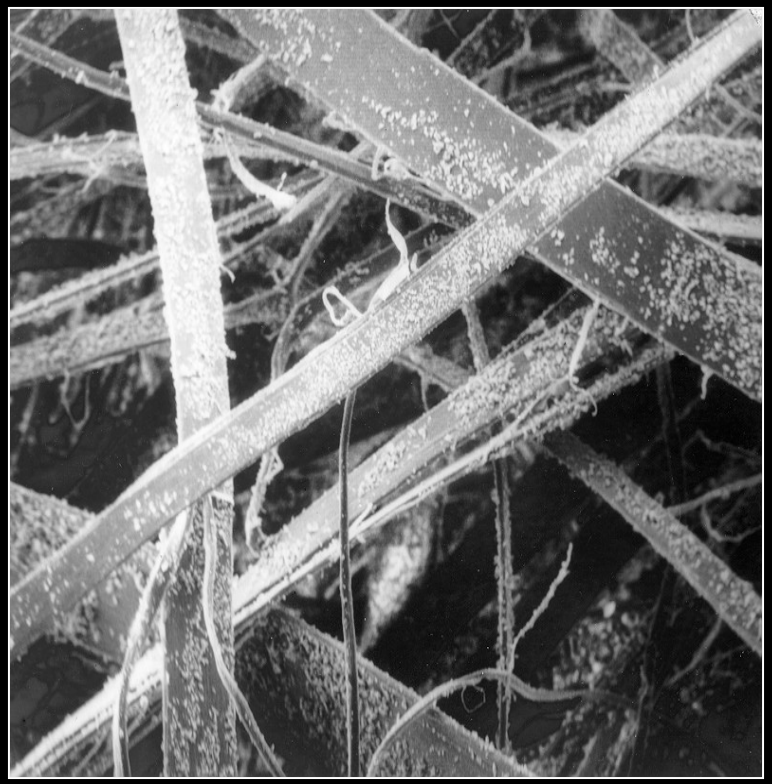
Source: Freudenberg Nonwovens

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Filtration Media Technology



Meltblown



Split Film

Source: 3M

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

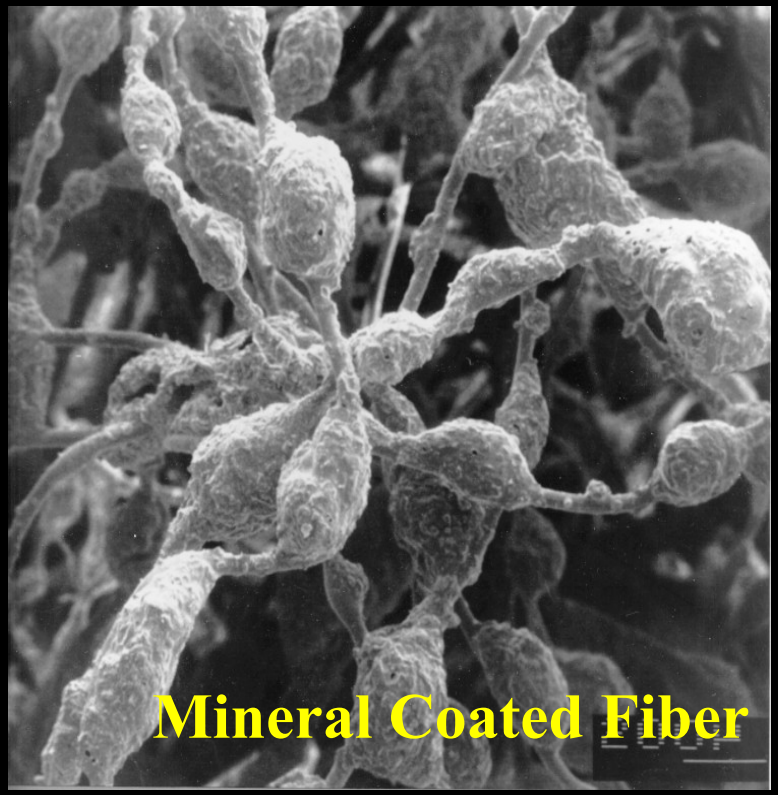
Automotive Interiors

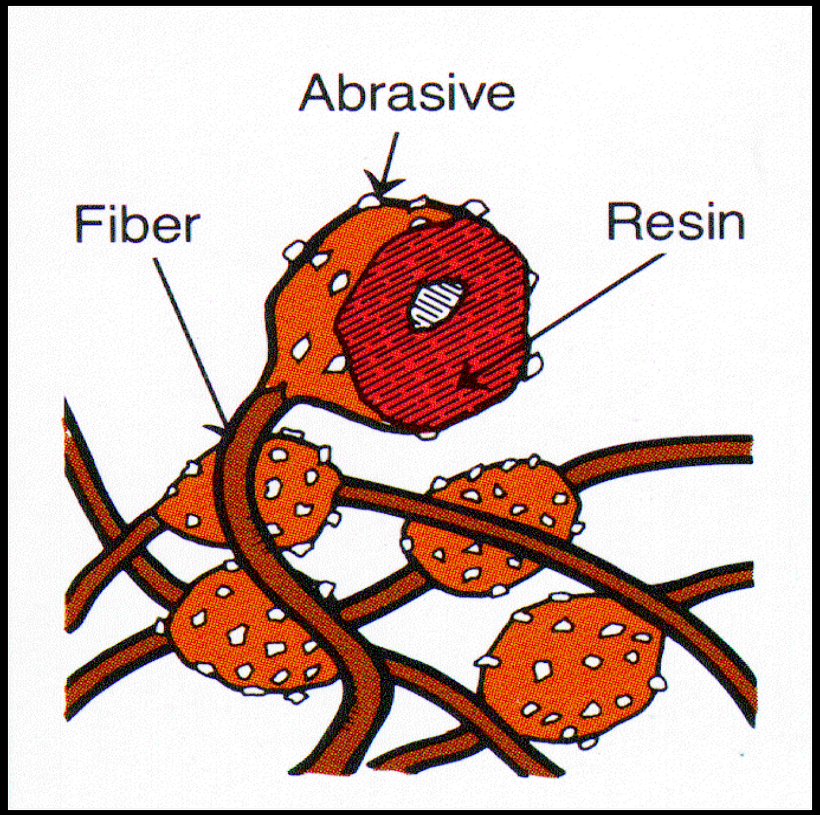
- Facings and structural reinforcement materials are used in a variety of different applications including:
  - headliners,
  - trunkliners,
  - door trim,
  - package trays,
  - sun visors and
  - seats.

Source: Freudenberg Nonwovens

Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Low Density Abrasives





Source: 3M

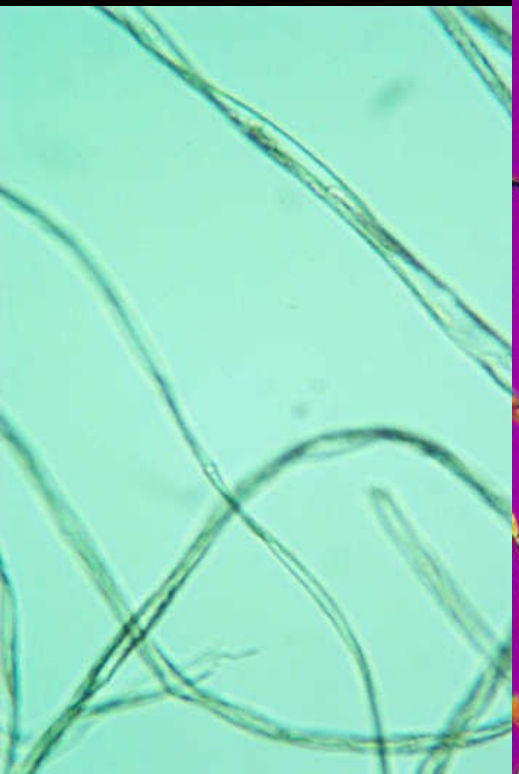
Courtesy: prof. Behnam Pourdeyhimi, The Nonwovens Institute

Thank you

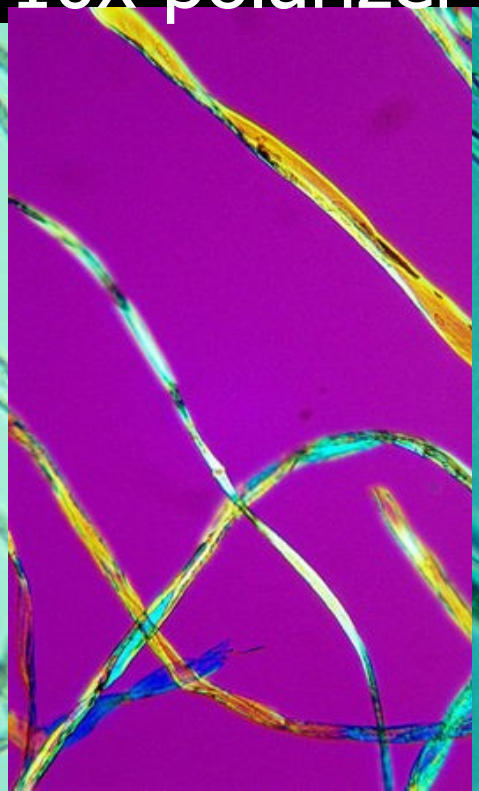
Cotton

Mineral oil, not consistent in color change in crossed polarizer

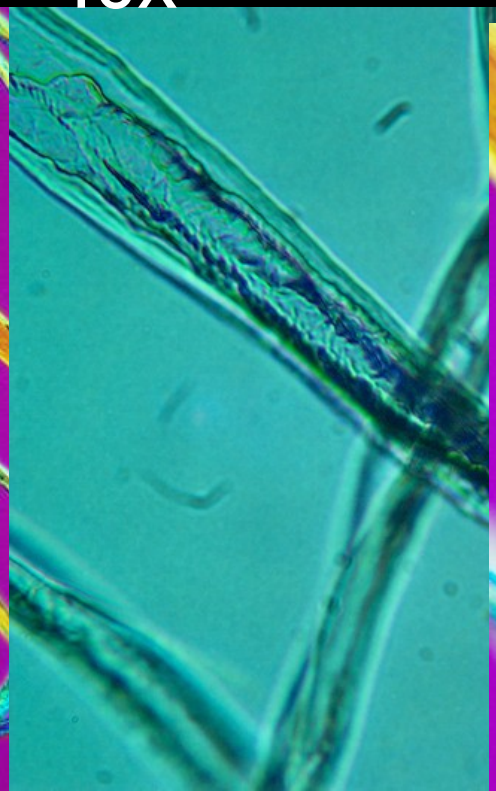
10x



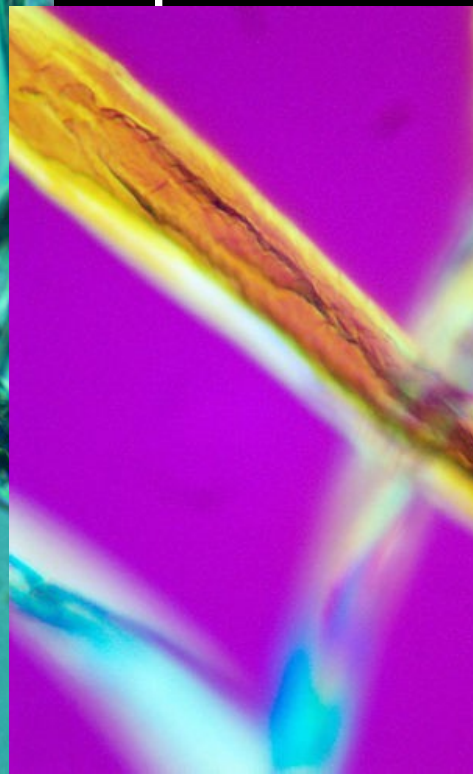
10x polarizer



40x



40x polarizer



Cotton – higher magnification

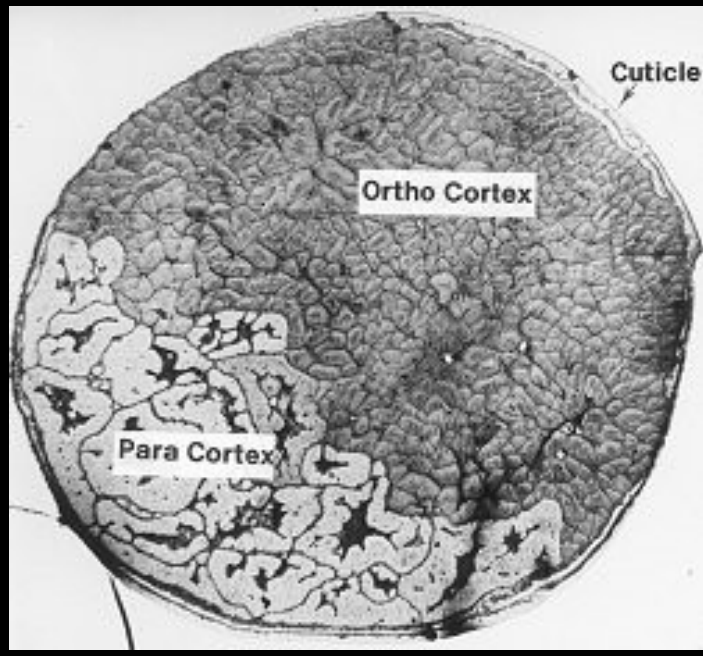
- Use Scanning Electron Microscopy (SEM)
- Shape is
  - Flat, ribbon-like
  - Twisted
  - unique

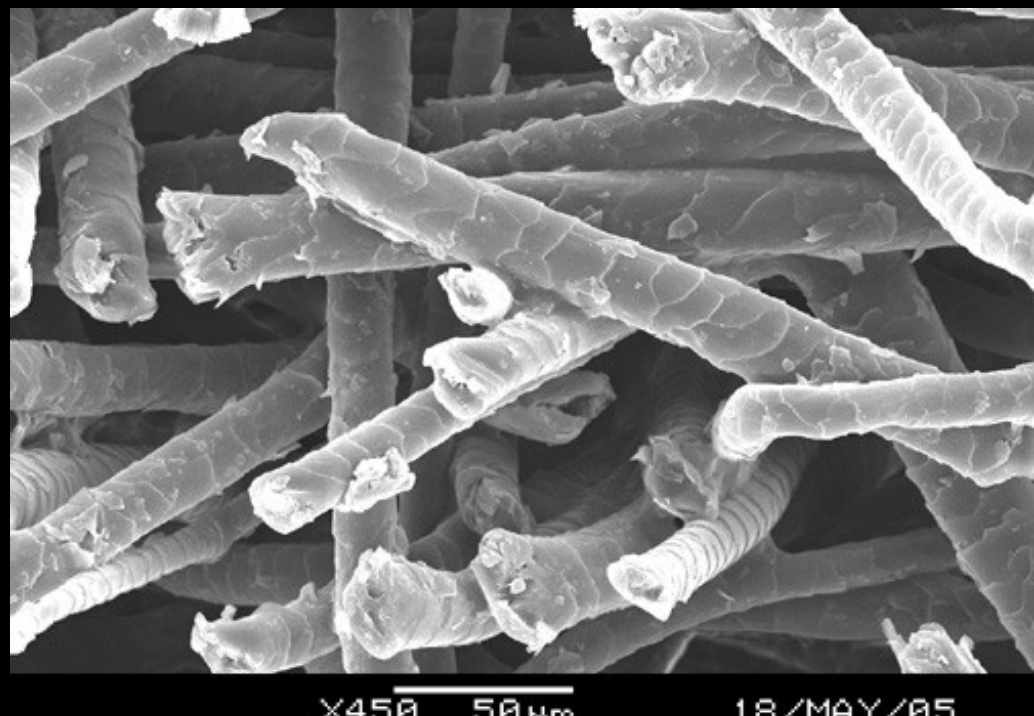
Cotton – Cross-section

- Scanning Electron Microscopy (SEM)

Wool Cross-section

- Wool has unique complex cell structure
- Scales on outer surface



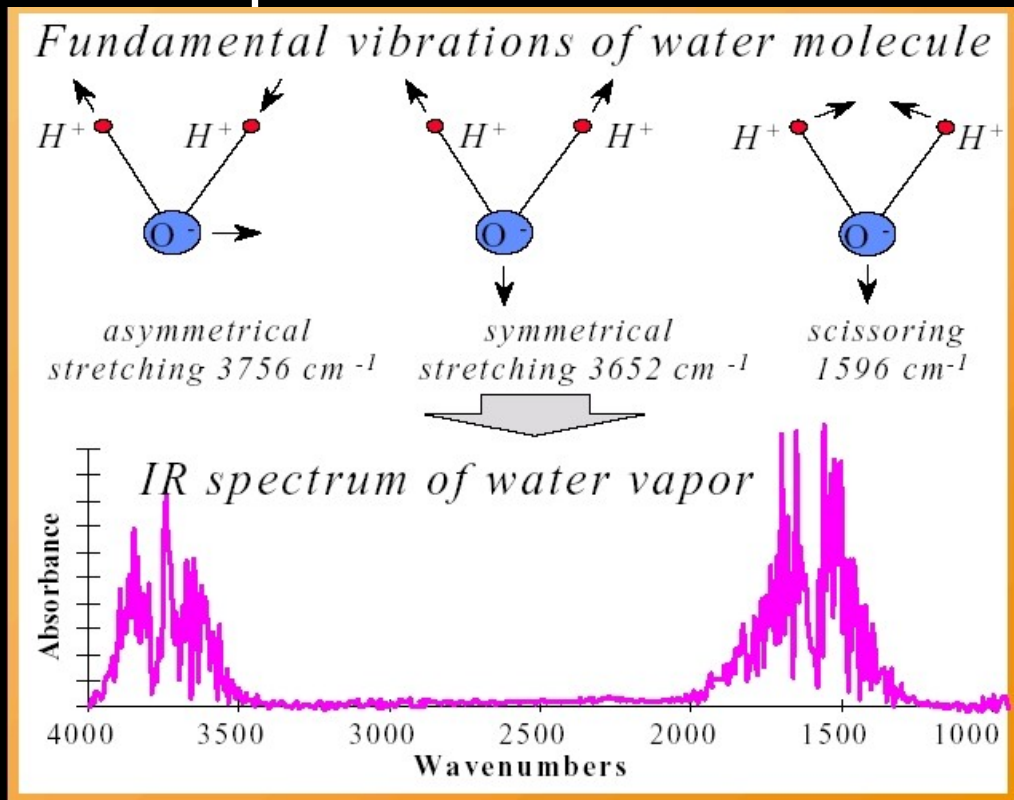


Infra-red analysis

- Best approach for fiber identification is to use both microscopy and IR analysis of fiber surface (and other preferably non-invasive methods)
- No national standard in place for fiber I.D.
- SBI-Raleigh use both PLM and IR
  - Usually conclude whether two fibers are
    a) different, or
    b) data for each fiber are consistent

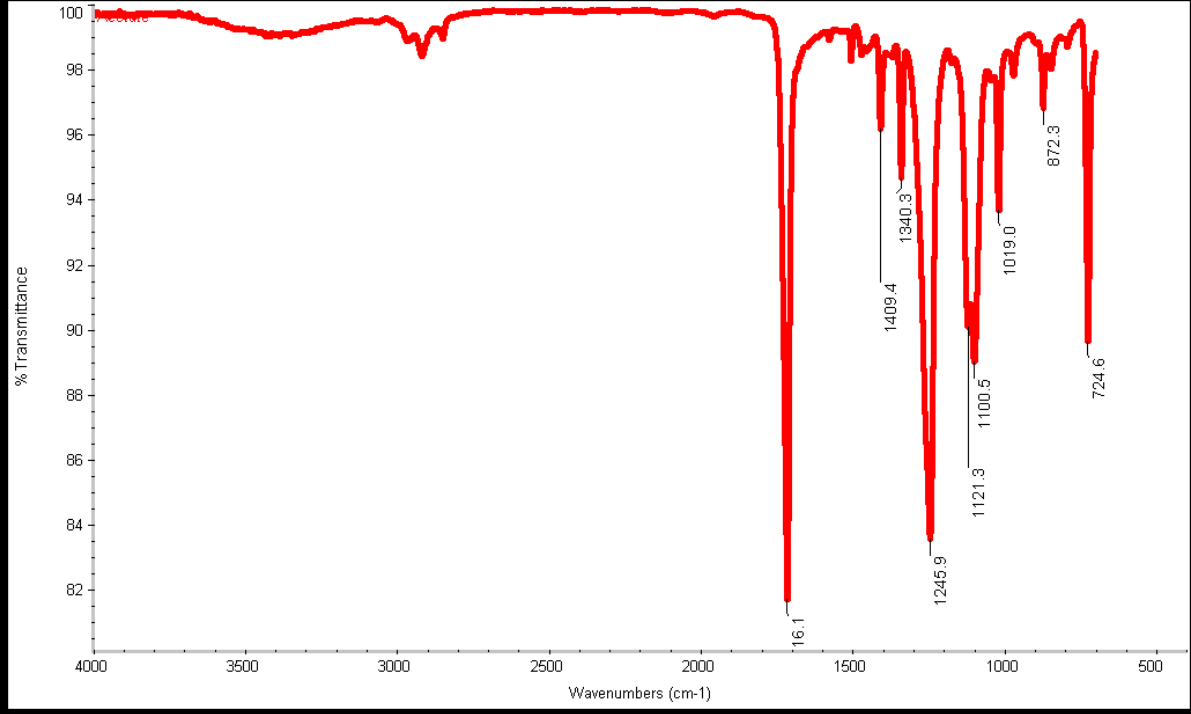
IR analysis of cotton

- Infra-red light has energy to stretch, bend and vibrate bonds in materials
- Energy absorbed is measured and produces a 'finger print' of a fiber
  - Can identify single fiber
  - Mixture of fibers
  - Use IR database (at NCSU)



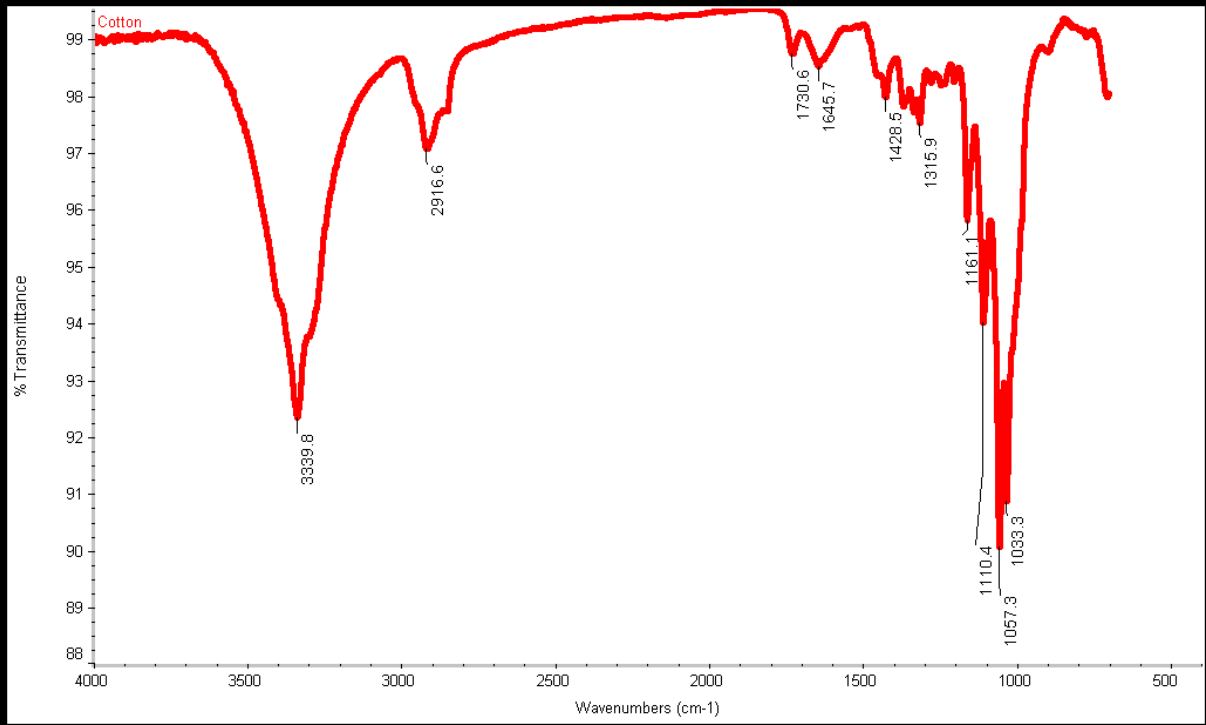
IR spectrum of:

Cellulose Acetate



vs.

Cotton



Sample #14B: Human hair