About Textile Fibers -
Their Chemical Make Up
And Manufacture

What's a fiber?

- A textile fiber - not fiber optic or dietary.
- A textile fiber is has a high length to width ratio is relatively fine and flexible.
- The Global Market For Fibers.

THE GLOBAL MARKET FOR FIBERS IN POUNDS

<table>
<thead>
<tr>
<th>FIBER GENERIC TYPE</th>
<th>ANNUAL GLOBAL PRODUCTION PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>46%</td>
</tr>
</tbody>
</table>
The Vast Majority Of Textile Fibers Both Natural And
Synthetic Are Made Of Polymers

- This gives textile fibers some very unique and valuable properties.
- Polymers are large molecules that possess a chain like character.
- These chains consist of repeating groups of atoms that are covalently bonded to one another.
- The word polymer comes from the Greek in which poly means many and meros means part.
- Polyester is a polymer with a relatively simple repeat unit – your DNA is an example of a polymer with a very complex repeat unit. Let's look at some molecular models of polymers.
- An exception: glass

Synthetic Polymerization

- We take a collection of mers and take them from an unreactive to reactive state often by use of heat, pressure and a catalyst.
- Via this technique we can take ethylene gas and turn it into polyethylene plastic for example.
- As we change the elements composing the mer molecule so we change the attributes of the final fiber extruded.
A Molecule Or Mer of Ethylene Gas

Hydrogen is white, carbon is black. Both double and single bonds are present.

A Polymer Chain Of Polyethylene
A Molecule Or Mer of Propylene Gas
A Polymer Chain Of Polypropylene With Repeat Units In The Form Of The Isotactic Isomer Used In Fibers

The Incorporation Of The Methyl Side Group Gives Polypropylene Some Important Differences From Polyethylene

- Polypropylene has a higher melting point
- Polypropylene is more brittle than polyethylene
- 9 g/d tenacity and 18% elongation at break for polypropylene vs. 3 g/d tenacity and 40% elongation at break for conventional
Polyethylene And Polypropylene can be made in 6 different isomers only one of which – head to tail isotactic is used in commerce to form fibers. Polyethylene is tougher than polypropylene rather like some nylons are tougher than some polyesters.

Polyethylene And Polypropylene Share Some Things In Common

- Neither of these fiber types dye well as they are bereft of dye sites
- They are both in the olefin generic class.
- Both carry the same generic name: olefin.
- Both have low specific gravities as can be determined by AATCC Test Method 20 - of around 0.9

Having Some Understanding Of Textile Fiber Polymers

- Provides a solid foundation for understanding how fibers behave.
- How they dye.
- How they burn and react to heat.
- How they shrink.
- How strong they are.
- How colorfast they are.

Wallace Carothers And The Invention Of Nylon
Wallace Carothers is credited with the invention of synthetic rubber and nylon around 1933 at Dupont.

Fiber went commercial around 1938 and is still used extensively today.

Dupont recouped all investment in nylon 6,6 within 30 days of plant startup as there had been nothing like it before.
Fiber Properties And Polymer Chain Entanglement

- Due to the way in which polymer chains group themselves together in a fiber, fibers are endowed with unique characteristics in-between those of brittle plastics and rubber elastics.
- In a fiber we have a two phase system: Crystals contribute strength and amorphous regions give stretch.
- All other things being equal as we increase polymer chain length so we increase fiber strength.
**Comparison Of Conventional And Ultra High Molecular Weight Polyethylene**

<table>
<thead>
<tr>
<th>Spectra® Ultra High Molecular Weight Polyethylene</th>
<th>Conventional Polyethylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Typical polymer repeat length in the tens of thousands.</td>
<td>• Typical polymer repeat length in the thousands.</td>
</tr>
<tr>
<td>• 3% elongation at break.</td>
<td>• 40% elongation at break.</td>
</tr>
<tr>
<td>• Tenacity 38 g/denier.</td>
<td>• Tenacity 3g/denier.</td>
</tr>
</tbody>
</table>

**Pendant Groups, Side Groups or Functional Groups**

- By adding various atoms or molecules along the polymer backbone, be it all carbon or otherwise we can radically effect fiber properties.
- We can add dye sites to impart specific dye affinity for example cationic and dyeable polyester.
- We can add flame resistance as seen in Treviera CS and similar fibers.
- If we take a carbon carbon backbone like we have in the olefins and add a particular pendant nitrogen containing group – what fiber do we end up with?
Atactic polyacrylonitrile – the core constituent of acrylic fiber.
Note that this fiber is copolymerised with other polymers like vinyl acetate and vinyl chloride – if over 15% by weight of copolymer then according to the FTC we have a modacrylic fiber.

**Thermoplasticity**

- The softening and melting behavior of textile fibers is a direct result of the way in which the polymer chains are interconnected. If the polymer chains are free to move when heated then they will soften and melt. If applied heat breaks up the chains before they are free to move then the fiber merely chars when heated rather than melting.
- In general those fibers which soften and melt can be heatset. This process in an extremely valuable finishing technique that can impart very high dimensional stability to fabrics so treated.
Let's compare the force elongation or strength characteristics of the various classes of textile fibers.

**What To Think About In Addition To Force Elongation Curves**

- What is the fiber's ability to recover from repeated cyclic stress?
- What is the fiber's stress strain curve in solvents and in water?
- What is the relationship between toughness and tensile strength with respect to the force elongation curve? Our units of toughness (the area under the force elongation curve): joules or energy to break.

**The Relationship Between Fiber Bending**
Stiffness And Diameter

- Bending stiffness is proportional to diameter to the fourth power.
- So if we increase the diameter of a fiber threefold the bending stiffness increases $3^4 = 81$ times.
- This is the reason why multi-strand copper wire is so much more flexible than single strand wire of the same thickness.

Explaining The Behavior Of Microdenier Fibers Using The Bending Stiffness And Specific Area Rules

- Microdenier fibers produce yarns and fabrics that are very soft due to the reduced bending stiffness explained by our bending stiffness-diameter rule.
- Microdenier fibers require more dye per unit weight than do thicker fibers to achieve the same depth of shade, a phenomenon explained by the large additional surface area that must be dyed to a given color depth.

Specialty Synthetic Fibers

- Specialty synthetic fibers are rather like specialty animal fibers. There are quite a few of them but not a huge amount of poundage is produced in any of them.
- They serve some very important end uses such as body armor.
- There are many of these, with special characteristics such as anti-bacterial performance, high or low wicking, UV resistance flame resistance and high strength.
## Summary Of Generic Fiber To Polymer Type Relationships

<table>
<thead>
<tr>
<th>Generic Fiber Type</th>
<th>Typical Polymeric Make Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>Cellulose</td>
</tr>
<tr>
<td>Polyester</td>
<td>Polyethyleneterephthalate</td>
</tr>
<tr>
<td>Rayon</td>
<td>Cellulose</td>
</tr>
<tr>
<td>Nylon</td>
<td>Polyamide</td>
</tr>
<tr>
<td>Acrylic</td>
<td>Polyacrylonitrile</td>
</tr>
<tr>
<td>Acetate</td>
<td>Cellulose diacetate</td>
</tr>
<tr>
<td>Olefin</td>
<td>Polyethylene or Polypropylene</td>
</tr>
<tr>
<td>Ramie</td>
<td>Cellulose</td>
</tr>
<tr>
<td>Linen</td>
<td>Cellulose</td>
</tr>
<tr>
<td>Wool</td>
<td>Alpha Keratin</td>
</tr>
<tr>
<td>Cashmere</td>
<td>Alpha Keratin</td>
</tr>
<tr>
<td>Silk</td>
<td>Fibroin</td>
</tr>
</tbody>
</table>

## There Are Three Main Systems For Extruding Synthetic Fibers
- Dry Spinning
- Wet Spinning
- Melt Spinning
- The extrusion system can effect characteristics like fiber cross section.
Wet Spinning Of Polyacrylonitrile

Dry Spinning Of Polyacrylonitrile
Melt Spinning Of Polyacrylonitrile
The Effect Of Extrusion System On Cross Section
Things We Might Add To Liquid Polymer Prior To Extrusion:

- Titanium Dioxide (Luster control typically 0.5% by weight.)
- Pigment (Very good colorfastness)
- Anti-oxidants (Prevent yellowing)
- UV Inhibitors (Prevent strength loss)
- Flame retardants. (Add value)
- Trace Elements (Help to identify fiber)

Lab Extrusion Of Vinyon As Seen On The
Vartest Technology Portal

- Vinyon polymer a co-polymer of vinyl chloride and vinyl acetate.
- We dissolved the polymer chains into acetone and then wet spin into a water bath.
- We draw the extrudate onto a take up roll further drawing is possible.
- The chlorine present in this fiber give it good flame resistance characteristics.
- The acetyl groups of the vinyl acetate monomer of this fiber and the principle of “like dissolves like” explains solubility in acetone.

Test Methods For The Identification Of Fibers

There are two types of methods.

- Qualitative – What type of fiber is it? What is the correct generic class for the fiber?
- Quantitative – How much of a given (typically generic) fiber type is present.
- Qualitative analysis is covered by AATCC TM 20 (See AATCC Technical Manual).
- Quantitative is covered by AATCC TM 20A (See AATCC Technical Manual).