NC STATE UNIVERSITY

THE NONWOVENS INSTITUTE
For Innovative Fibrous Systems

Nonwovens: Tutorial

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What Is a "Nonwoven Fabric"?

- **INDA (2002): "A Fabric made directly from a web of fiber, without the yarn preparation necessary for weaving and knitting. In a nonwoven the assembly of textile fibers is held together 1) by mechanical interlocking in a random web or mat; 2)by fusing of the fibers, as in the case of thermoplastic fibers; or 3) by bonding wit a cementing medium such as starch, casein, rubber latex, a cellulose derivative or synthetic resin. Initially, the fibers may be oriented in one direction or may be deposited in a random manner. This web or sheet is then bonded together by one of the methods described above. Fiber lengths can range from 0.25 inch to 6 inches for crimped fibers up to continuous filament in spunbonded fabrics."**

- **ASTM D 123: "A textile structure produced by bonding or interlocking of fibers, or both accomplished by mechanical, chemical, thermal or solvent means and combinations of thereof"**

Nonwovens ?

- Nonwovens are Engineered Fabrics
- Nonwovens are manufactured by high-speed, low-cost processes – Large Volume, Lower Cost than traditional processes
- Nonwovens have barriers to imports because of capital requirements & low labor requirements
- Nonwovens are in many applications already, but most are hidden and you do not see them

Nonwovens? Not the Other Textiles…

- The beginnings of the nonwovens industry in the US, on a significant scale, occurred during the 1950's and 1960's.
- On April 16, 1968, a trade association called "The Industrial Nonwovens Disposables Association" (INDA) was formed and announced.
- The evolution and future potential of this industry was also recognized by the publication of "Nonwovens Industry" magazine in 1970.
- Initially, the industry was focused on single-use disposable products.
- Today's nonwovens cover a broad array of single-use (short-life) and multi-use (long-life) products.

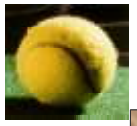
Nonwovens? Not the Other Textiles…

- Historically, the nonwovens industry is organized differently and separately from the textile industry.
- The nonwovens and the textile industries share some common heritage, but the nonwoven industry has grown to present a broad array of engineered fiber and polymer based products that are driven by high-speed, low-cost, innovative, value-added processes.
- The Nonwovens industry has adapted technologies from pulp and paper industry, extrusion industry and the like to bring about the desired products at reasonable costs, and consequently a separation from the more traditional textiles which has been primarily focused on apparel.

Nonwoven Products

- Today's nonwovens are highly engineered solutions made up of a variety of materials including fibers, powders, particles, adhesives, films and other materials that provide specific solution or solutions by providing a multitude of functionalities.

- Hospital Supplies
- Hygiene Applications
- Consumer Products
- Interlinings
- Geotextiles
- Carpet Backings
- Automotive parts
- Filters
- Wipes
- …













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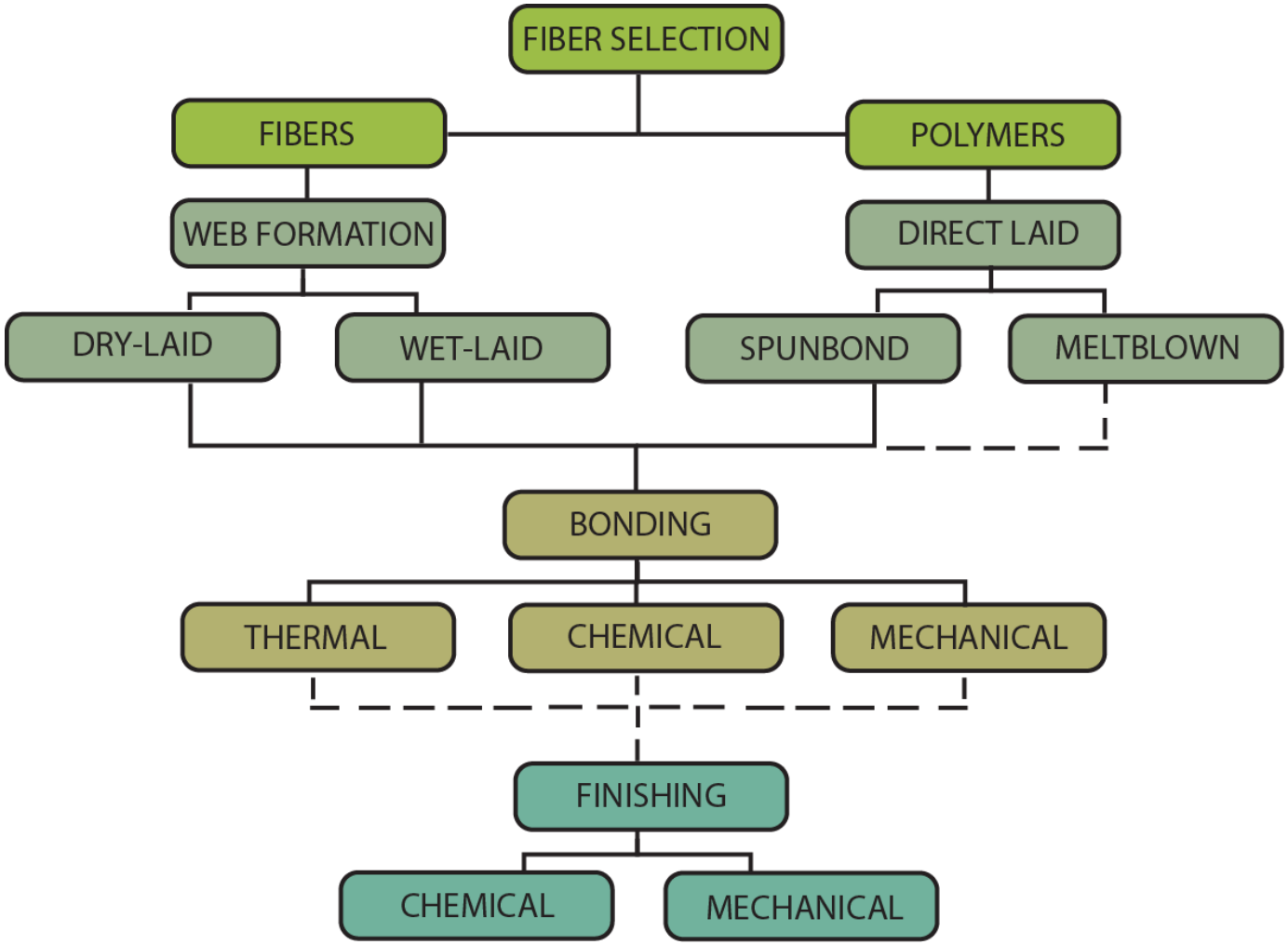
Nonwoven Fabrics Manufacturing Principles

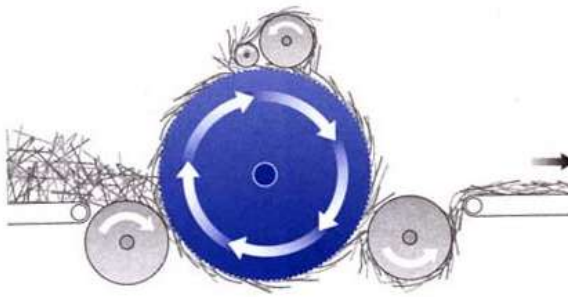
- **Transform Fiber-based materials into flat, flexible, porous, sheet structures with fabric-like characteristics.**

- **Basic Steps are:**
  - Raw material (fiber or raw polymer) selection and preparation
  - Web formation
  - Web consolidation and bonding
  - Finishing

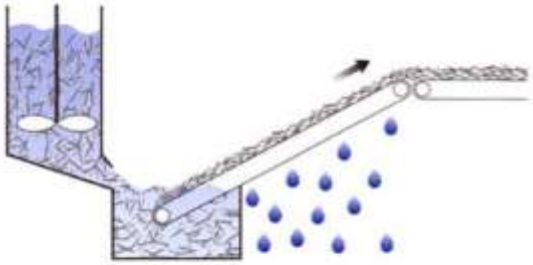
Nonwoven Manufacturing Process



Web Formation

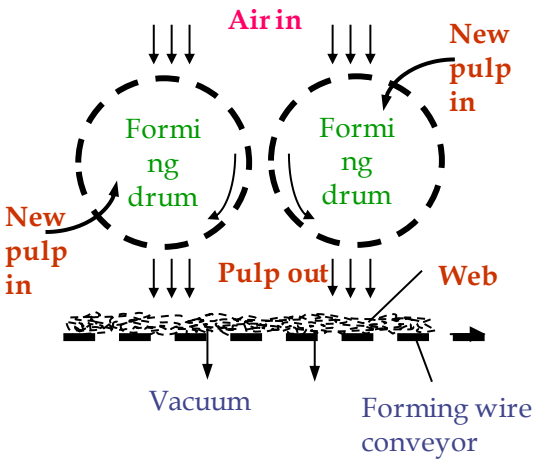


- **The dry-laid process**
  Web is produced from staple fibers Production takes place in a carding machine fitted with rotating rollers.

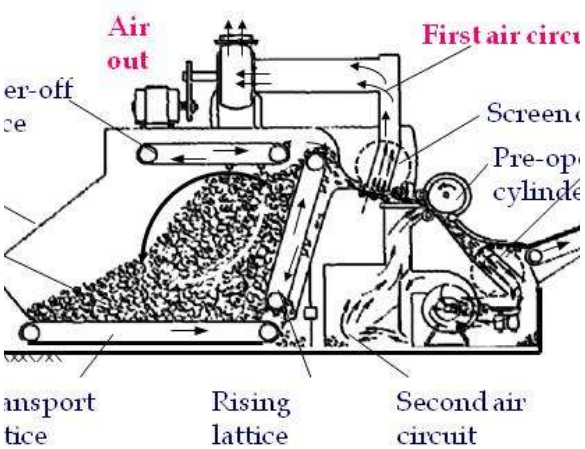


- **The wet-laid process**
  The fibers are separated by water and laid on a circulating screen belt on which the water is drained off.

Web Formation

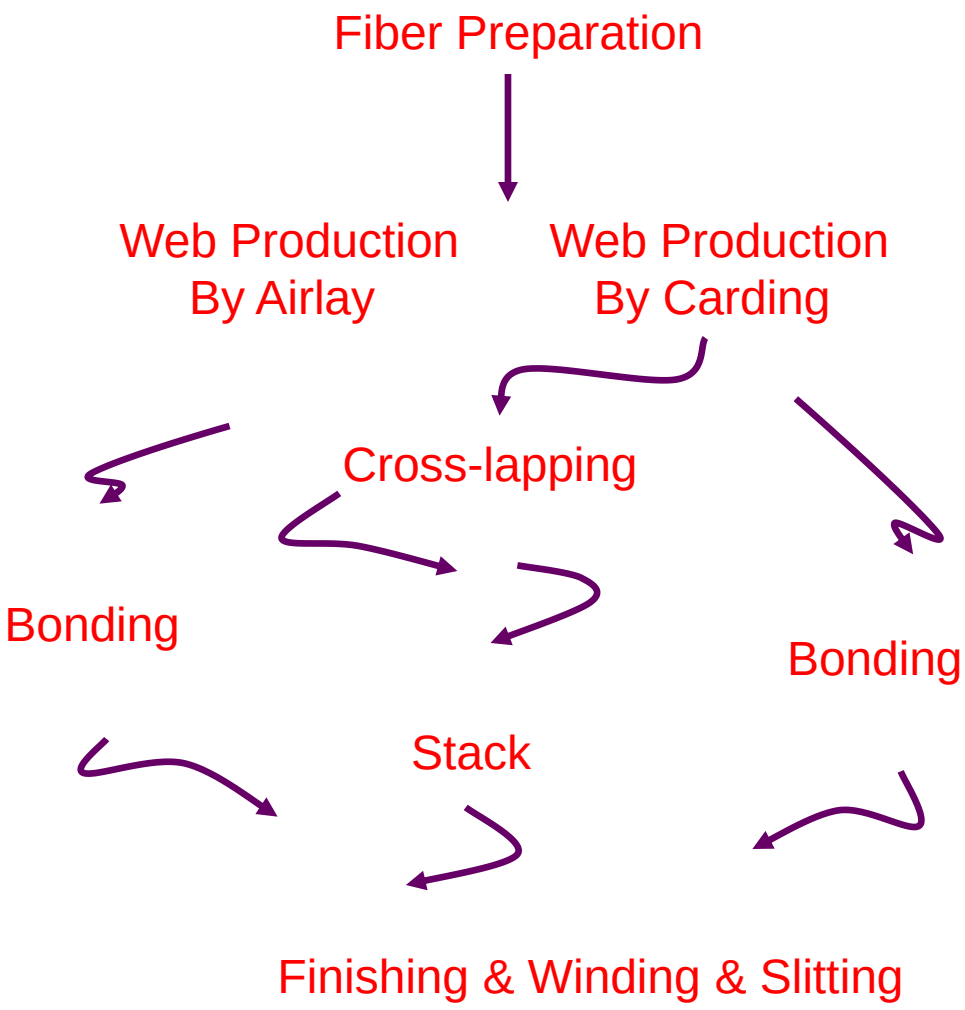


- The pulp-based airlay process This is a continuous production process, from small fibers – pulp
- and powders to web.

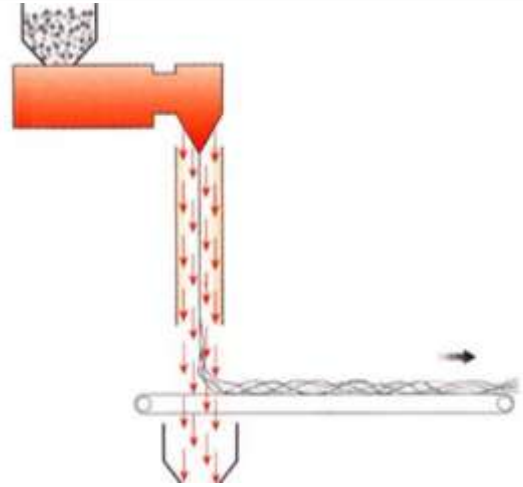


- The Rando airlay process This is a continuous production process, from staple fibers and
- almost anything else to web.

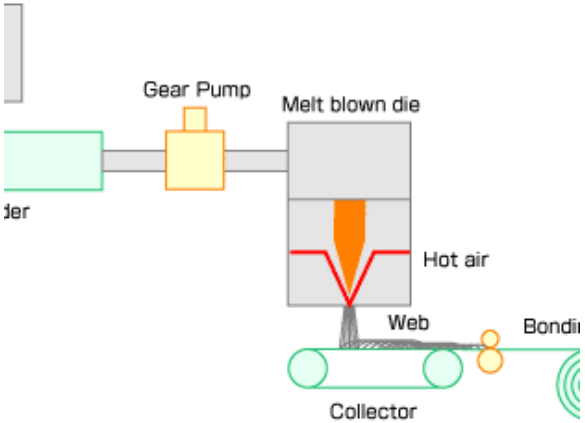
Staple Web Formation – Dry Lay



Web Formation: SpunMelt

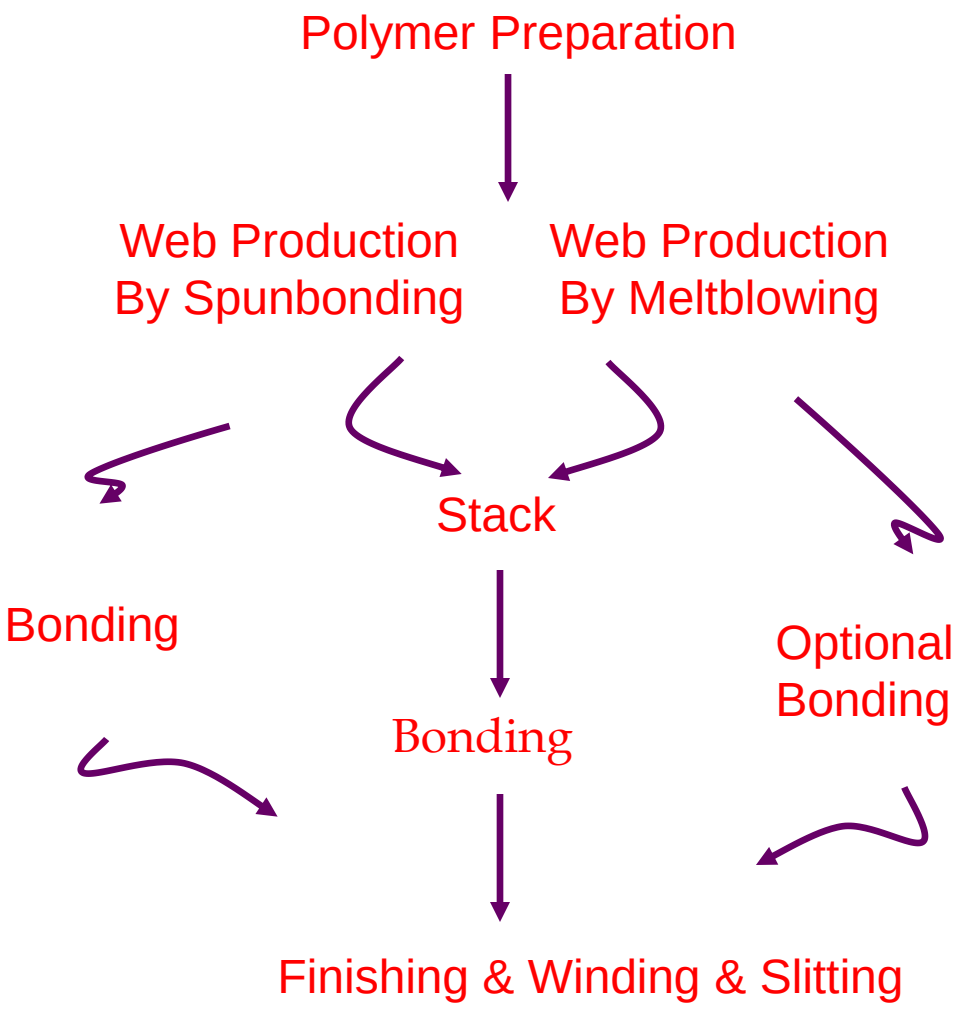


- The sponbonding process
  This is a continuous production process, from raw material (granulate) to web.
- The web requires boding.

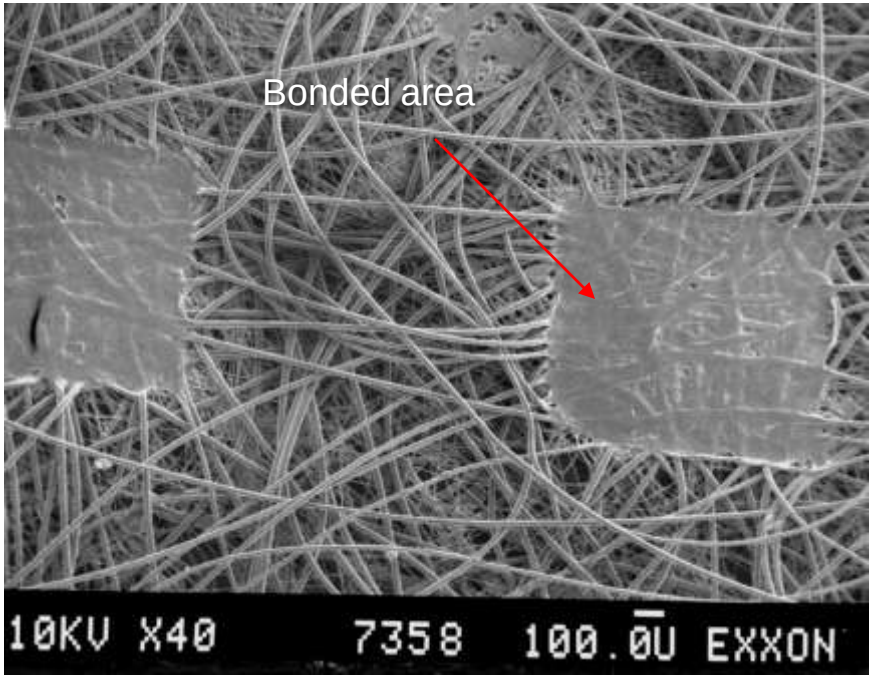


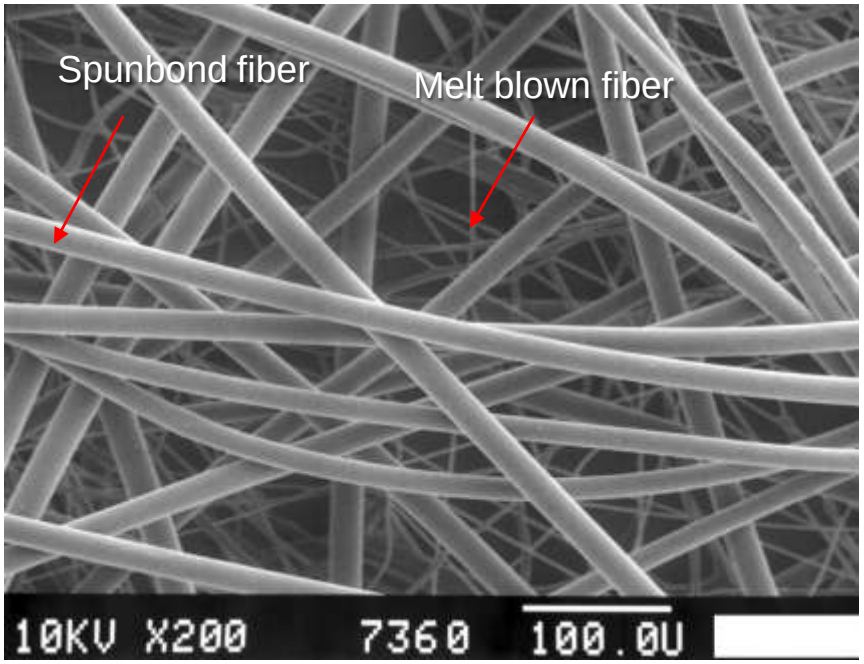
- The meltblowing process
  This is a continuous production process, from raw material (granulate) to web.
- The web requires no bonding.

SpunMelt Web Formation

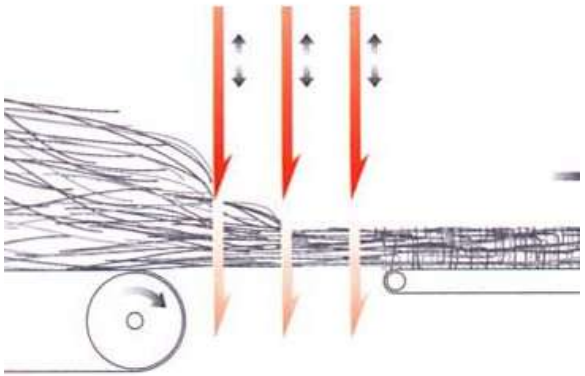


Spunbond/Melt blown/Spunbond (SMS)

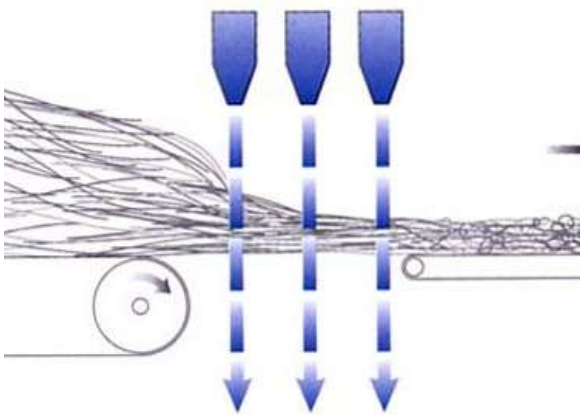




Web Bonding

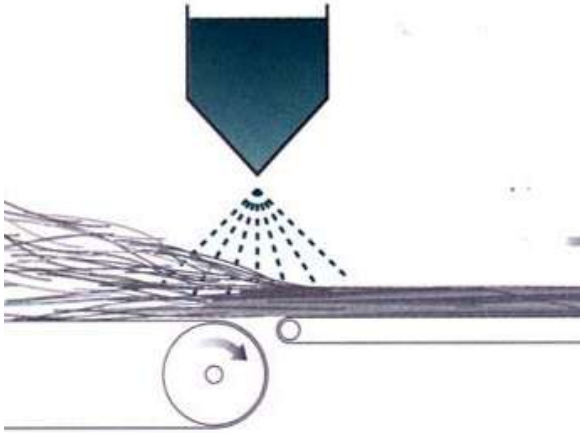


- **Needling**
  Here the fibers are bonded using needles with barbs.

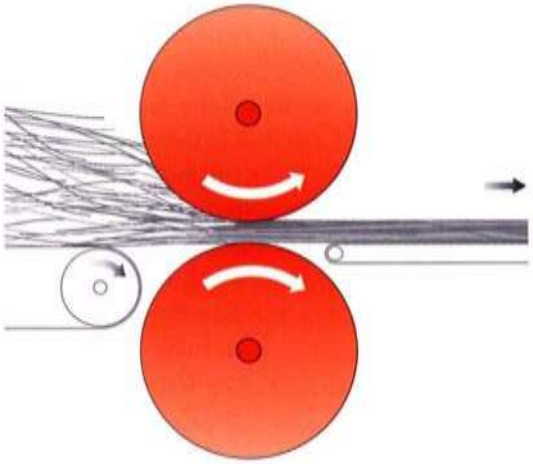


- **Hydroentangling**
  This is mechanical bonding by means of ultrafine, powerful jets of water.

Web Bonding



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



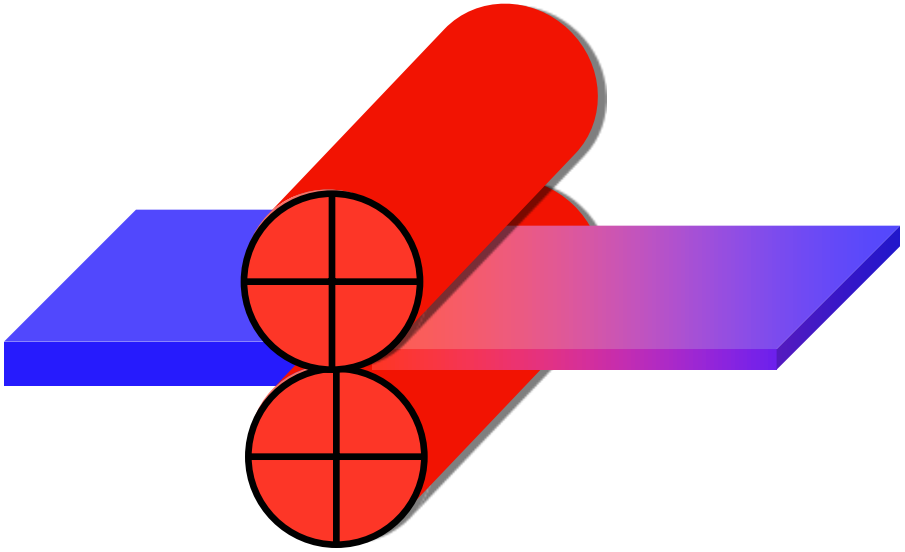
- **Thermal bonding**
  This is homogenous bonding of the fibers between hot, rotating cylinders.

Thermal Bonding

- **Conduction**
  - Calendar bonding
- **Convection**
  - Through air bonding
- **Radiation**
  - Infrared bonding
- **Work**
  - Mechanical (frictional)
    - Ultrasonic bonding
  - Electrical
    - Welding
  - Chemical
    - Solvent

Calendar Bonding: Most Common

- **Web passed between two rolls**
  - One or both are heated internally.
  - One or both may be embossed.
- **Heating via conduction.**
- **Cooling via convection.**



Thermal Bonding - Applications

- Coverstock for sanitary products
- Interlings
- Geotextiles
- Carpet backing
- Insulations
- Upholstery
- Wiping cloths
- Tea bag
- Food coverings

Chemical Bonding Processes

- **Most are based on water-borne latex**
- **Applied from 5% to 60% by weight**
- **Common methods of application include saturation, foam, spray, print and powder bonding.**
- **The binder needs:**
  - Binder application to nonwoven
  - Removal of moisture or solvent
  - Formation of strong bond between binder and nonwoven web

Mechanical Bonding

Hydroentangling

- **Spunlacing**
- **Jet entangling**
- **Water entangling**
- **Hydroentangling**
- **Hydraulic needling**

Needlepunching

- **Felting**
- **Needling**
- **Needlepunching**

Bonding Technique – Mechanical Bonding

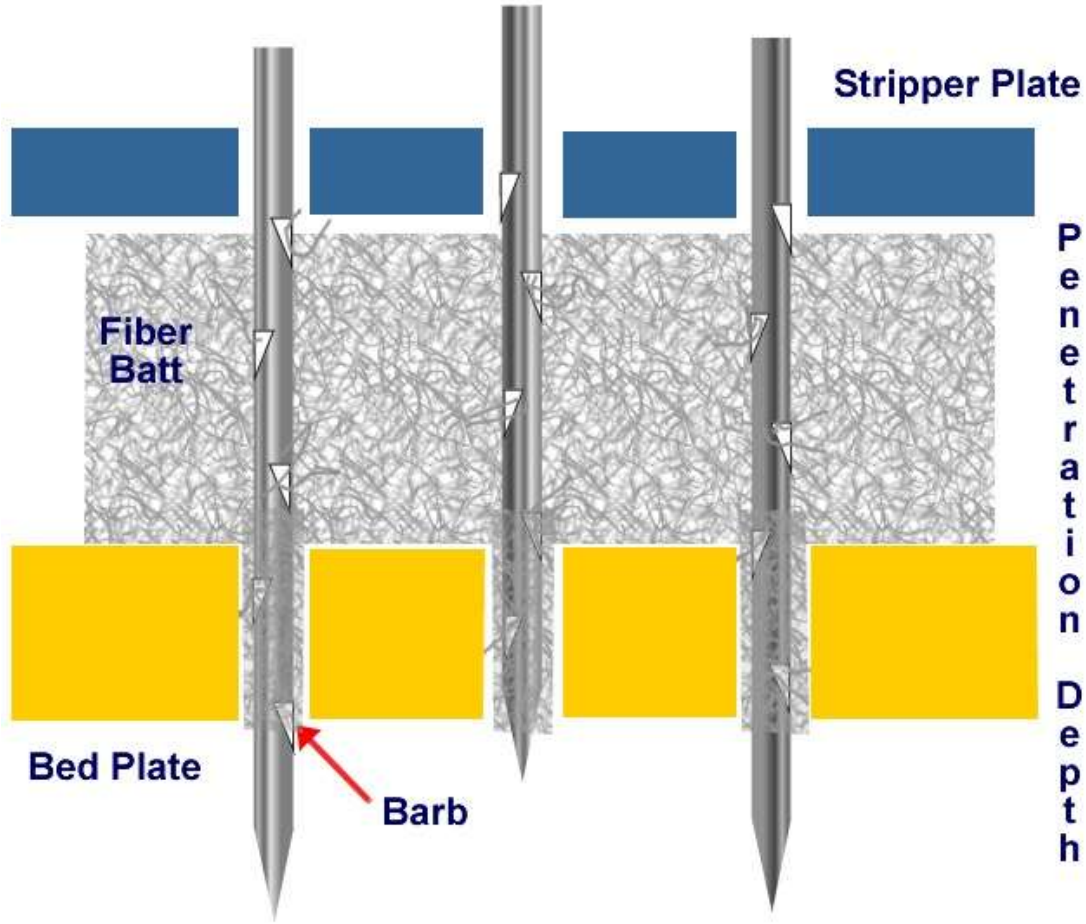
Hydroentangling

- The fibers twist around their neighbors and / or inter-lock with them and also penetrate into the z as well

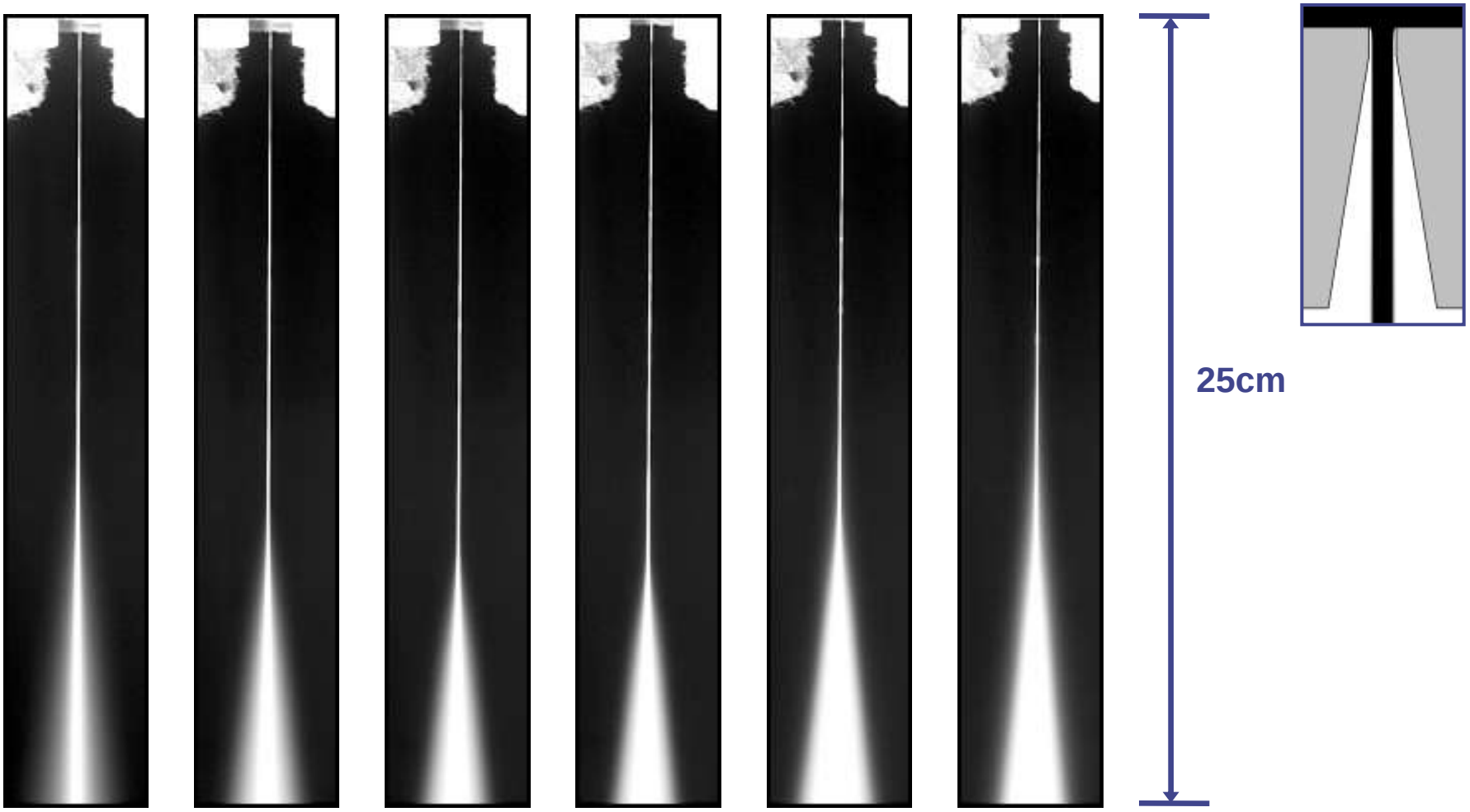
Needlepunching

- The fibers are forced to entangle in the z direction and inter-lock with other neighboring fibers

Needle Punching



Hydroentangling Nozzles



1000 psi 1500 psi 2000 psi 2500 psi 3000 psi 3500 psi

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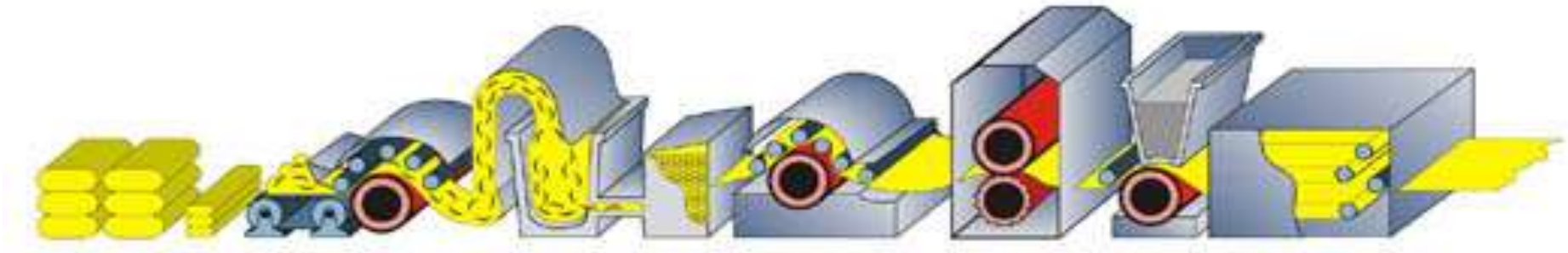
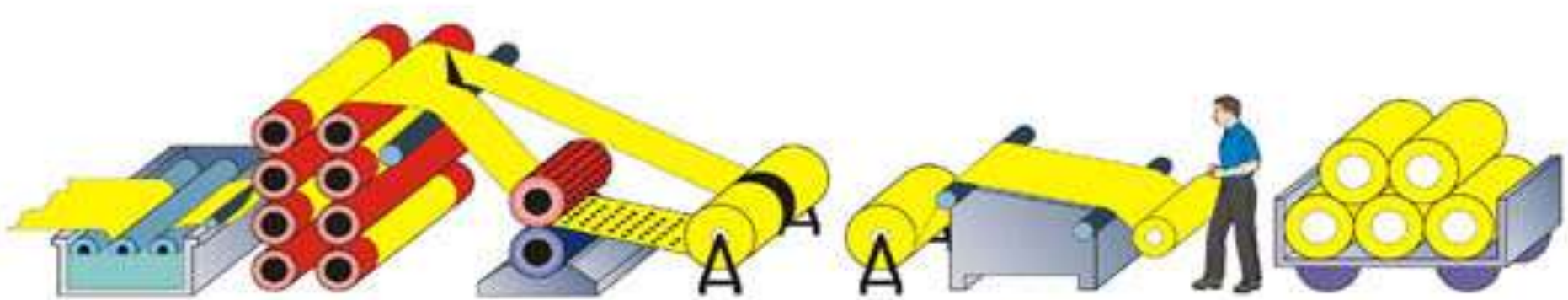
How Do We Make Nonwovens?

Let Us Look at Interlinings



Fiber material | Relaxation and preparation of fibers | Mixture, fiber transport and fiber room | Carding | Calendering | Bonding agent addition | Dryer



Finishing | Drying | Paste application | Sewing interlinings | Final inspection | Packaging and dispatch

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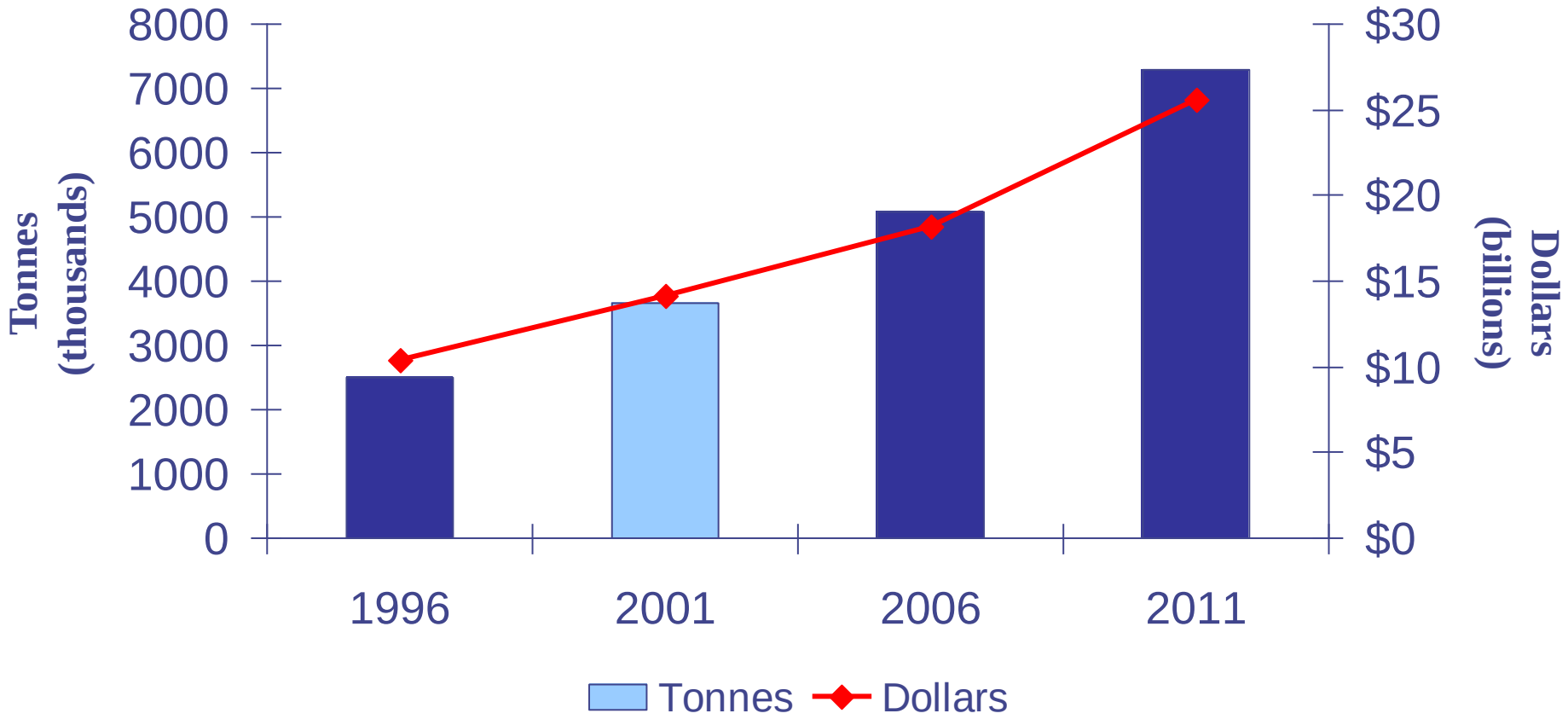
At What Speeds?

- **SpunMelt**
  - > 300-1000 meters per minute – 5 to 7 meters wide
- **High Speed Cards**
  - > 300-400 meters per minute – 5 to 6 meters wide
- **Other processes have to become compatible for these to work. These include winding, bonding, etc…**

Nonwoven Products

- **Most nonwoven products are composites where roll goods are combined with other materials to form the final product**
  - Coating and laminating is a common process
  - Introducing particulates into the web is a common process

World Nonwovens Roll Goods Production



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Nonwovens Markets and Applications

Durables (35-45%)

- Baby Diapers
- Adult Incontinence
- Feminine Hygiene
- Medical
- Wipes

Durables (35-45%)

- Filtration devices
- Protective Garments
- Interlinings
- Home Furnishing
- Geotextiles
- Agricultural
- Automotive
- Carpet Backing
- Wipes

The US Nonwovens Industry

- **Growing at a significant rate**
- **US is the largest market for nonwovens**
- **US industry > 550 firms**
  - employment: > 160,000
  - annual sales: > $50 billion
- **US industry leads world in nonwovens technology and production**
- **The firms are typically small**
  - median employment: 75
  - annual sales: $7.5 million

The US Nonwovens Firms

- **Roll goods manufacturers**
  - Fiberweb, Freudenberg, PGI, DuPont
- **Raw material suppliers**
  - Invista, Goulston, Wellman, FiberVisions, OMNOVA
- **Machinery manufacturers**
  - Fleissner, Nordson, Hills, Reifenhauser, Rieter
- **Downstream processors**
  - Kimberly Clark, P&G, 3M

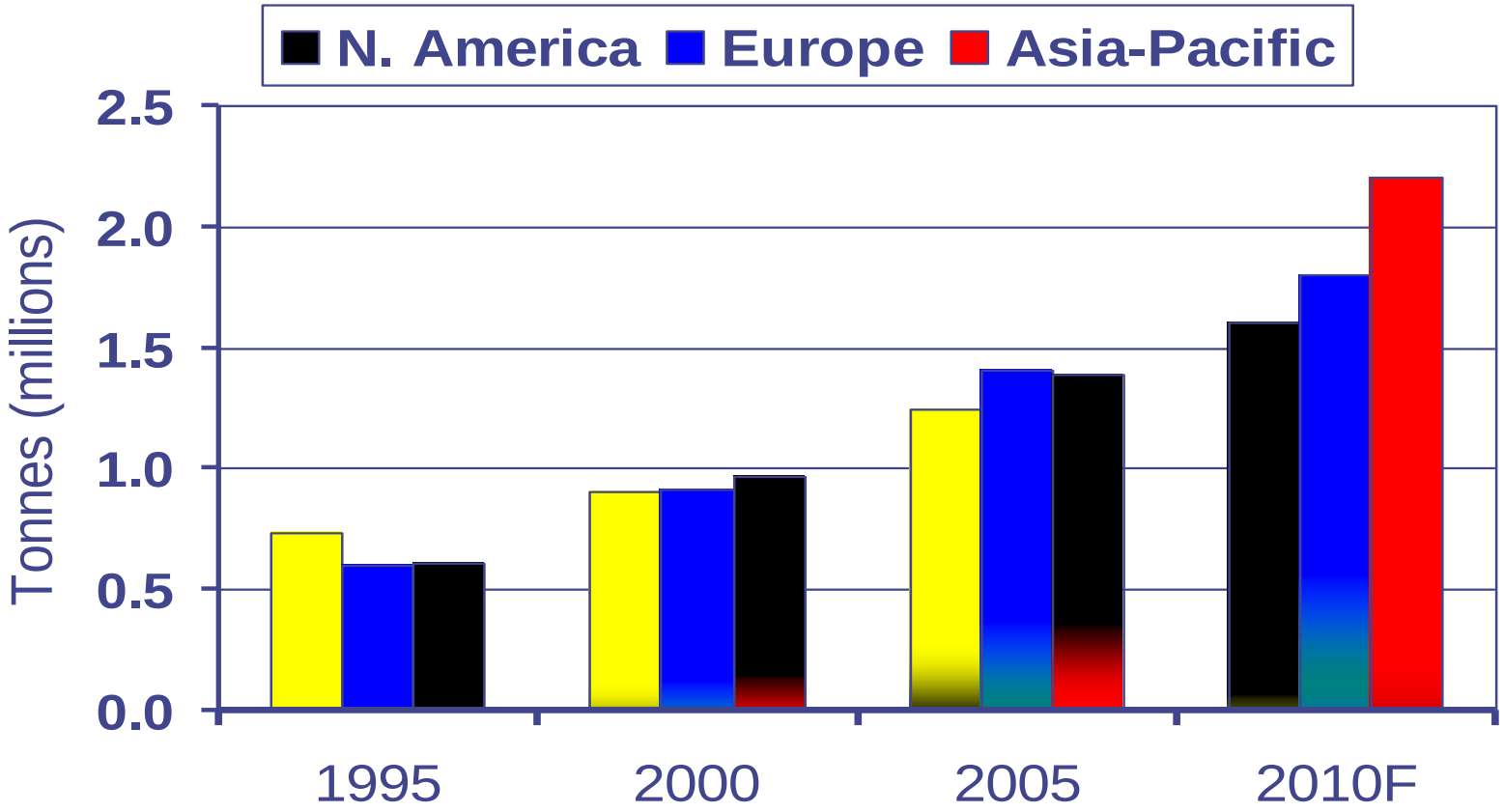
The Core US Nonwovens Firms

- Core nonwovens firms 32 states and the District of Columbia.

- North Carolina has the largest number of core nonwoven firms.

State	Number of Firms
North Carolina	33
Massachusetts	17
Georgia	12
New York	12
South Carolina	10
New Jersey	8
Michigan	6
Virginia	3

World Nonwovens Roll Goods Production



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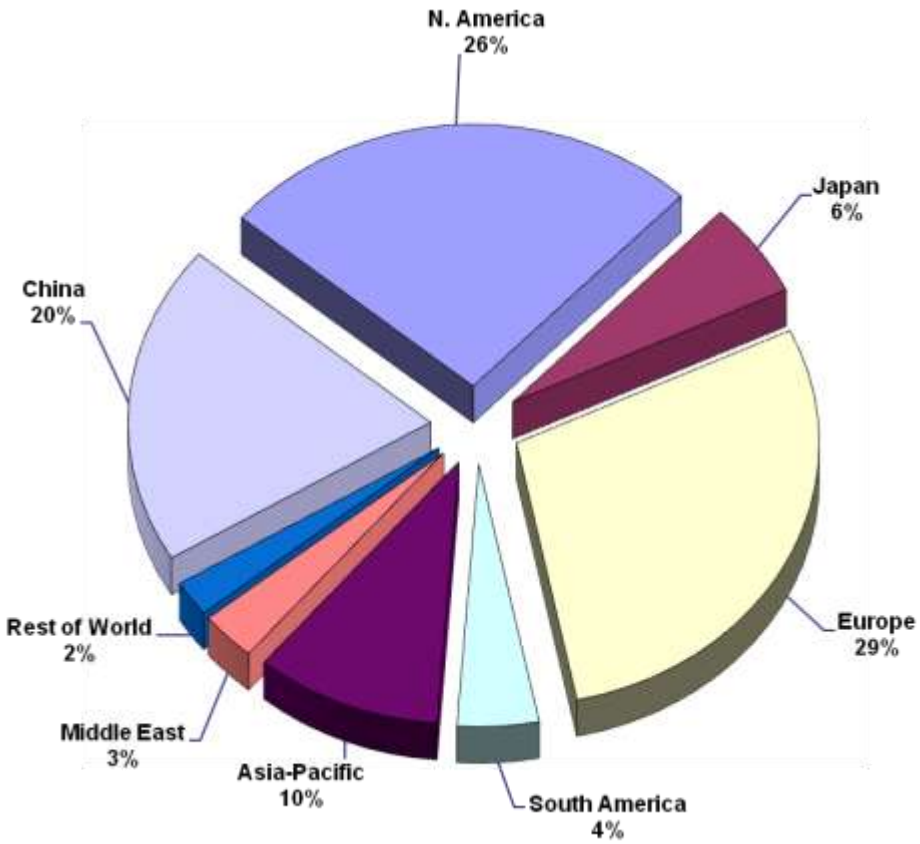
Worldwide Nonwoven Production, 2007
5.751 million tonnes



Region	million tonnes
N. America (NAFTA)	1.491
China	1.136
Japan	.338
Europe	1.659
South America	.25
Asia-Pacific	.573
Middle East	.174
Rest of World	.126

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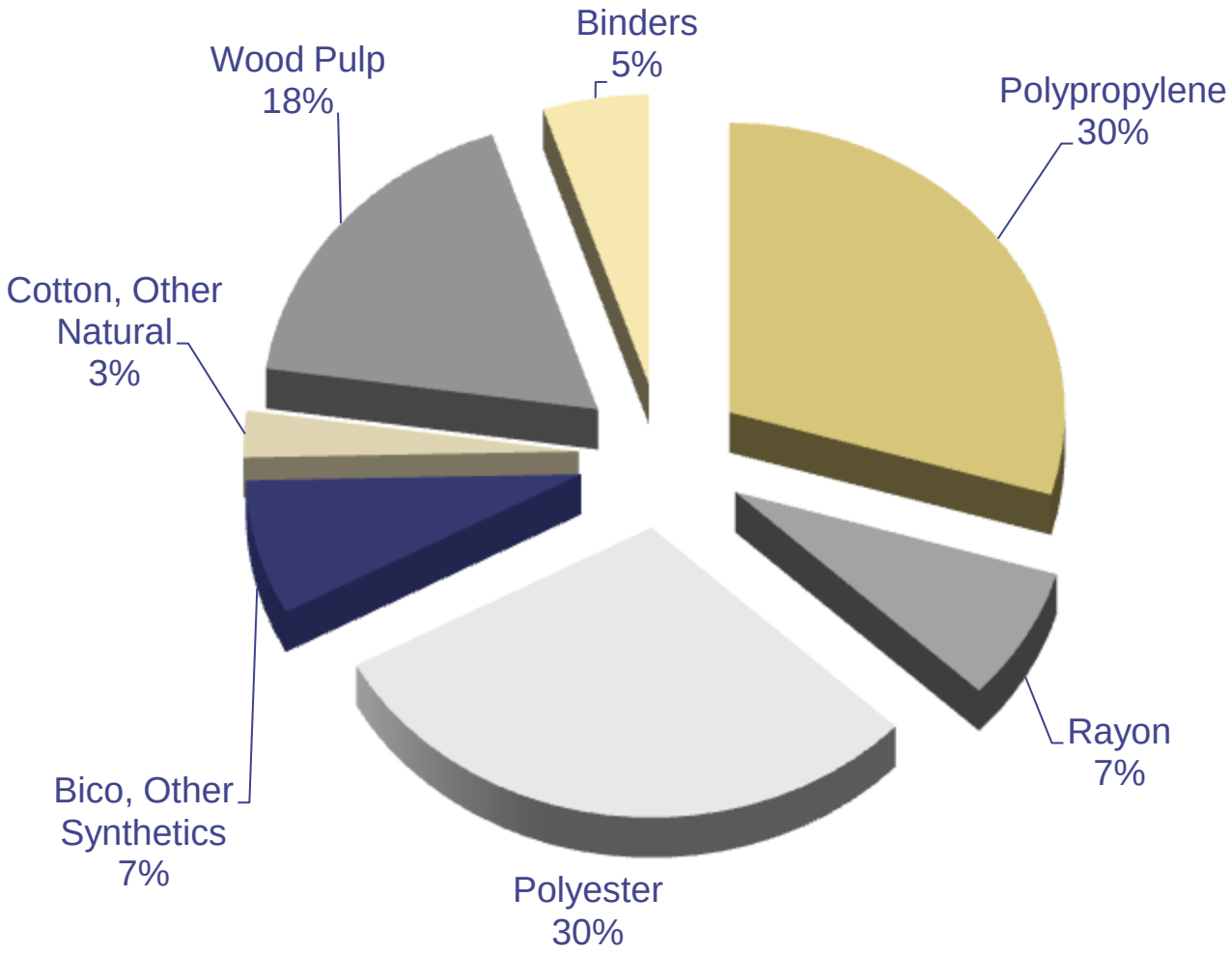
Spunlaid Growth

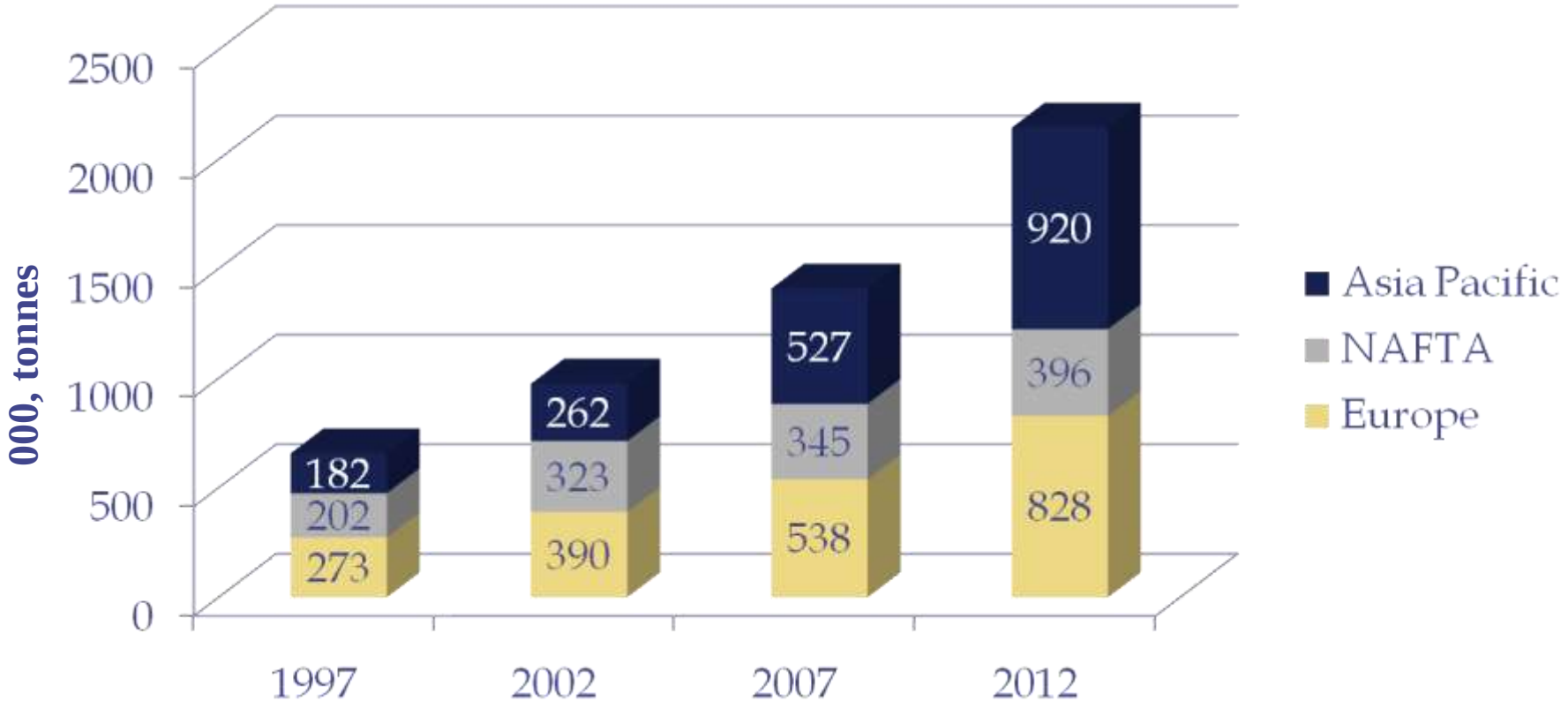
Category	Growth (%) 1997-2007	Expected Growth (%) 2007-2012
Spunbond (and SM Composites)		
Polypropylene	12.6	9.9
Polyester	6.6	5.5
Polyethylene, Nylon, Other	2.1	4.9
Bicomponent	28.0	11.8
Total Spunbond	11.4	9.2
Melt Blown		
Polypropylene	7.7	7.5
Other Resins	6.3	6.8
Total Melt Blown	7.6	7.5

Worldwide Nonwoven Staple Fiber Consumption in 2007



Source: INDA

Hygiene Market By Region



Source: INDA

Wipes Market By Region

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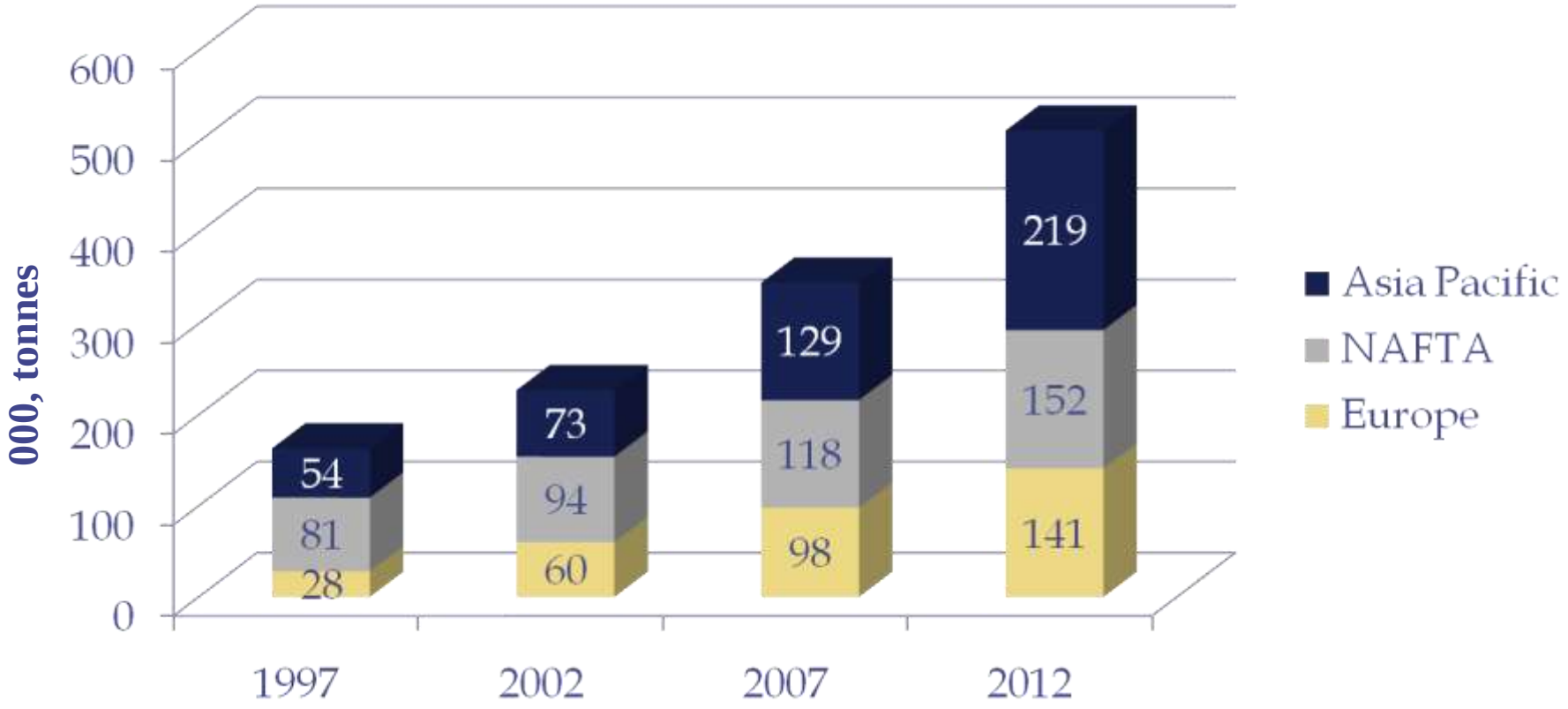
Filtration Market By Region



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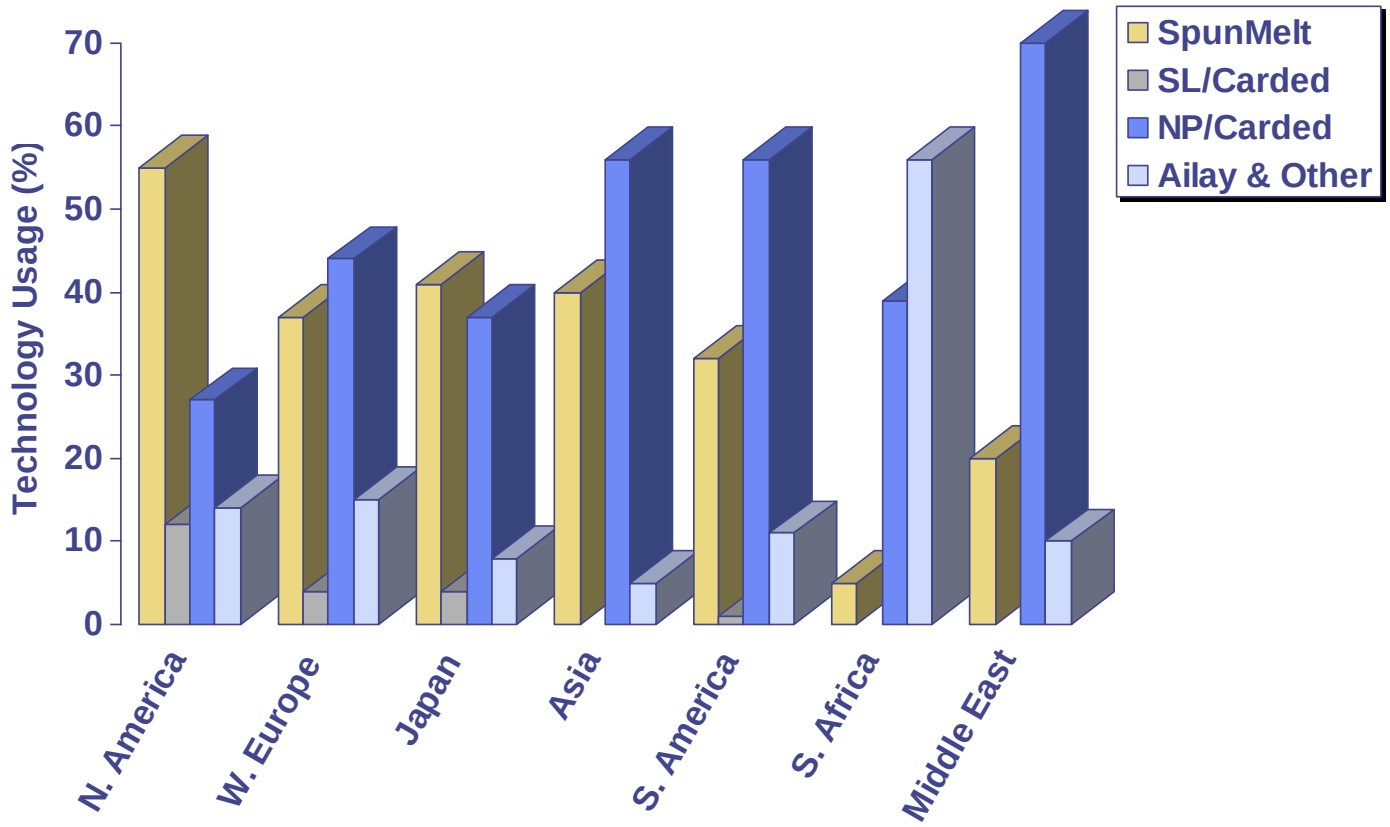
Technology Usage



Introduction to Nonwoven Products

Imagine the possibilities

Nonwovens?

- Nonwovens are Engineered Fabrics
- Nonwovens are manufactured by high-speed, low-cost processes – Large Volume, Lower Cost than traditional processes
- Nonwovens have barriers to imports because of capital requirements & low labor requirements
- Nonwovens are in many applications already, but most are hidden and you do not see them

Hygiene

- Baby diapers
- Incontinence products
- Feminine hygiene items

Medical

- 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.

Medical Bandages

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Wrap – “horse” wrap

Medical Masks

Insulation Products

- **Commercial**
  - Thermal,
  - Acoustical
- **Industrial**
  - Thermal,
  - Acoustical,
  - Vibration Control

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Thermal Insulation

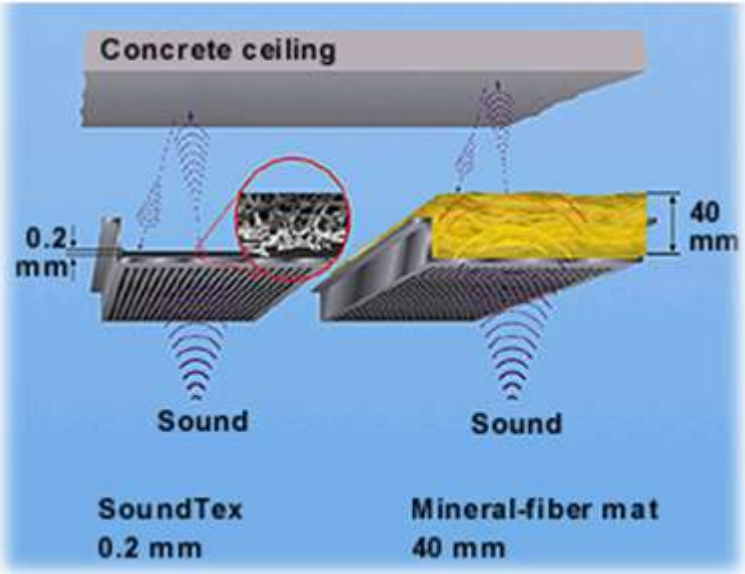
Furniture/Textile Applications

- 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.

Acoustic Nonwovens

- Optimized noise damping ranks among the most important requirements for the architects and engineers designing modern-day offices, administration buildings, airports and communication centers.

- The structure and low weight of acoustic nonwovens offer a significant advantage in perforated ceiling systems compared to conventional soundproofing materials.



Sorbents

- **Commercial**
  - automotive,
  - chemical,
  - emergency response
- **Industrial**
  - chemical,
  - packaging,
  - emergency response

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Horticulture

- In horticultural applications, nonwovens protect the plants against temperature extremes by day and by night, thus creating the foundation for earlier harvests with excellent results. They are permeable to both air and water, UV-stabilized, and resistant to rotting.

Nonwovens for Cables

- Nonwovens for cable bandaging are used in power and telecommunication cables. Nonwovens help to keep the cable fully functional on a long-term basis even under the toughest of conditions.
- Nonwovens act as water-blocking tapes, as fixing, bedding and thermo-tapes, and in an electrically conductive versions for heat-barrier protection.

Composite Materials

- In the glass-fiber-reinforced plastic industry, nonwovens are used for surfacing products like pipes, tanks, container boards, facade panels, skis, surfboards and boats. They very substantially improve resistance to both corrosion and abrasion, as well as improving the mechanical strength of the products.

Window Treatments

- Nonwovens are used in designer window treatment fabrics to enhance both function and appearance.
- Their ability to diffuse light, while maintaining room brightness, enhances the feeling of privacy and helps protect furniture.
- Their natural insulating qualities provide added energy conservation.

In Shoes…

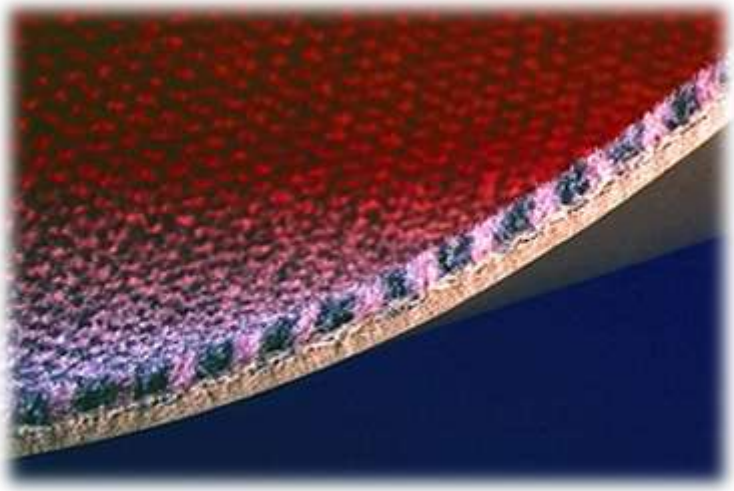
- **A broad spectrum of applications including:**
  - liners,
  - counterliners,
  - interliners and
  - reinforcing materials
- **Membranes and insoles ensure a healthy foot climate and a high degree of foot comfort.**

As Substrates

- Nonwovens perform excellently as substrate for coagulates and coated materials.
- Appropriately finished materials are used not only in shoe and leather goods but also in upholstery and even in the garment industry.

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.



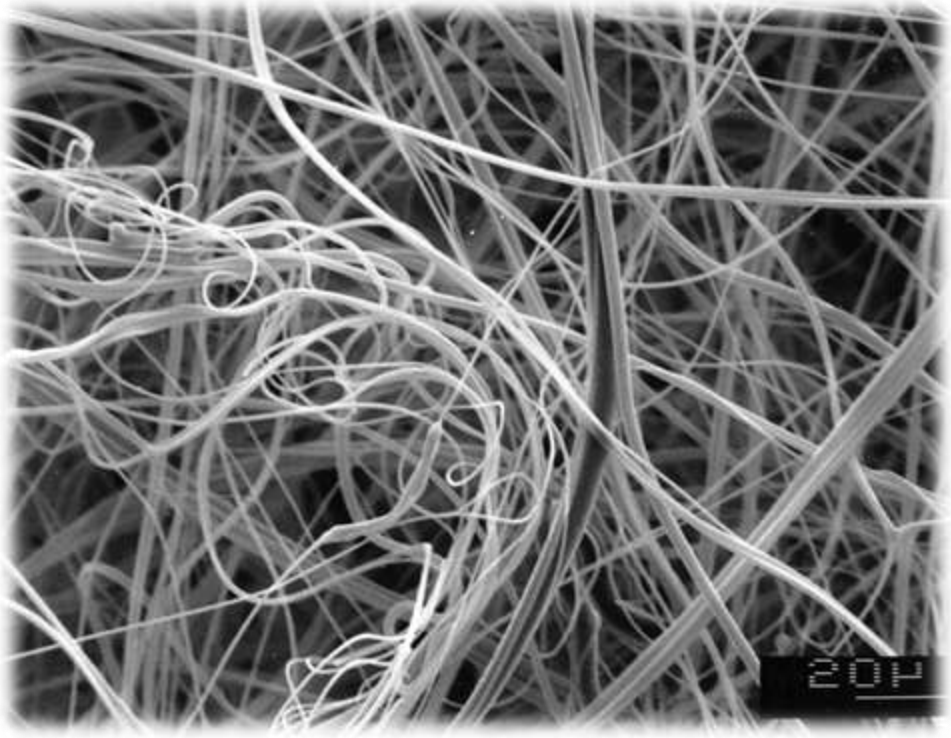
Filtration Products

- **Retail**
  - Room Air Cleaners,
  - Furnace Filters,
  - Vacuum Bags
- **Commercial**
  - Cabin Air Filters,
  - Appliance,
  - HVAC
- **Industrial**
  - Air Filters,
  - Liquid Filter Bags,
  - Cartridges

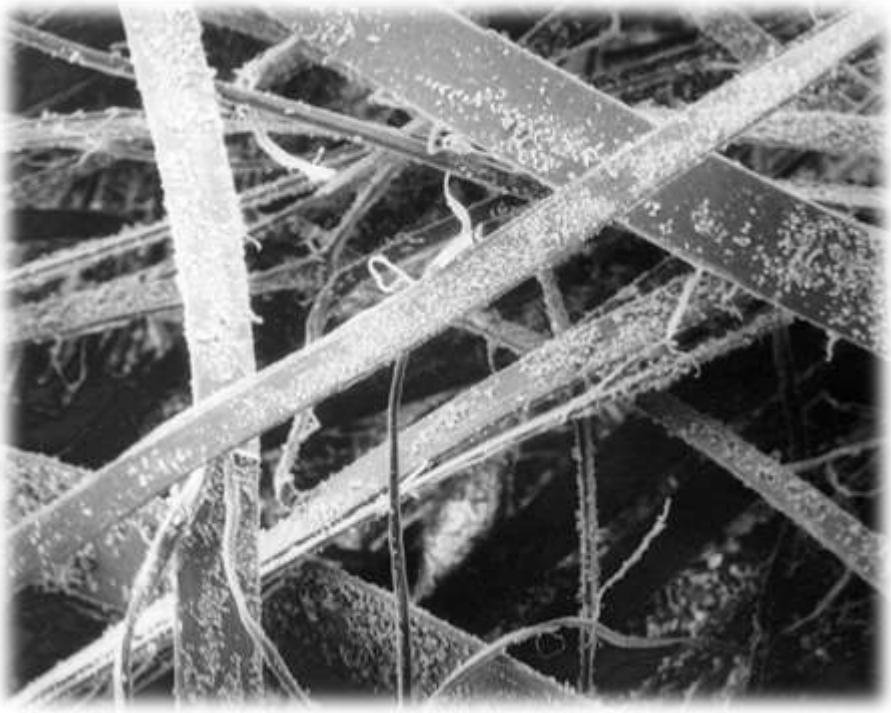
Indoor Climate Control and Air Filtration

- **Air filters for intake, exhaust and recirculated air filtration in indoor climate control systems:**
  - filter mats
  - pocket filters
  - activated-carbon
  - combination filters
  - cassette filters
  - HEPA/ULPA filters
  - depth-loading filter cartridges
  - high-temperature filters

Filtration Media Technology



Meltblown



Split Film

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For Innovative Fibrous Systems

Dust Removal

- **Filter cartridges, filter plates, filter bags and EcoProtec safety filters for industrial dust removal applications, with high-performance filter media made of nonwovens.**

Cartridge Filter & Bags

Filtrete™

You'll breathe the difference...

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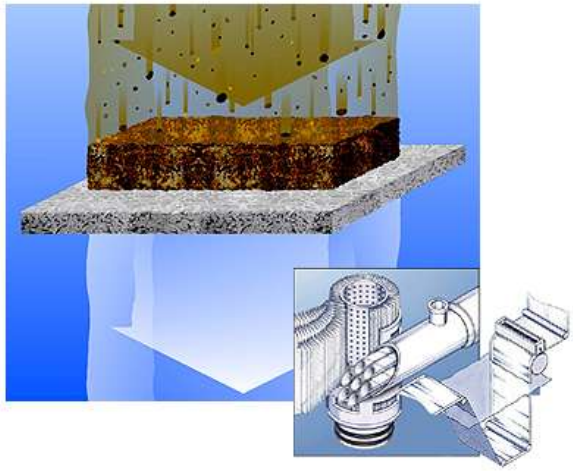
Special Filtration

- Respirators
- Vacuum cleaners
- Kitchen hood filters
- …

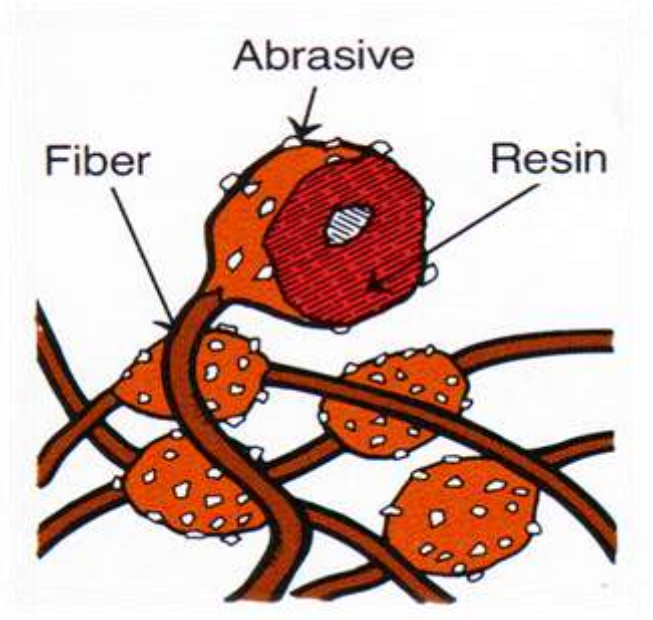
Liquid Filtration

- Nonwovens for filtering coolants and lubricants, as well as washing, phosphating and coagulation baths in the metal-processing industry.
- Nonwovens for filtering milk, frying fats, drinking water, and blood plasma.
- Membrane support nonwovens for filtering fruit juices, enzymes, electro-dip-coating and effluents.



Low Density Abrasives

- **Retail**
  - hand pads,
  - wipes,
  - sponge laminates
- **Commercial**
  - hand pads,
  - wipes,
  - sponge laminates,
  - floor pads
- **Industrial**
  - hand pads,
  - brushes,
  - wheels,
  - belts



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Polishing Pads

- Polishing pads are used in the manufacture of semiconductor wafers, memory discs, precision optics and metallurgical components.

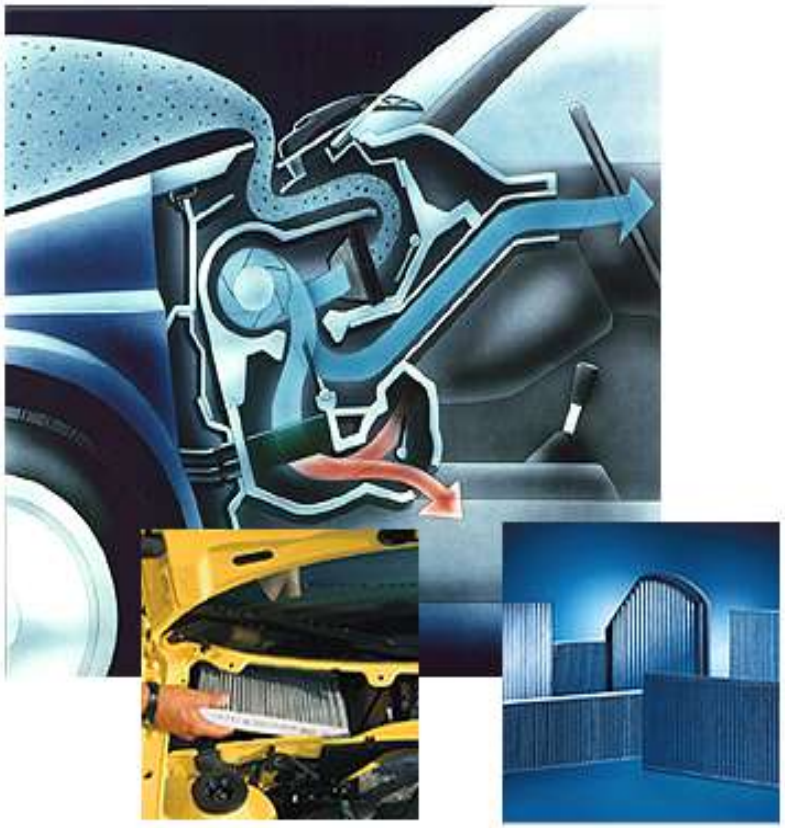
- The purpose of these pads is to produce a surface finish, in terms of planar uniformity and smoothness, that can meet the highest tolerances.

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.

Auto Air Filtration

- micronAir particle filters, with their high-arrestance microfiber nonwovens, protect driver and passengers of a vehicle from pollen, dust, soot and other harmful particles penetrating inside their car via the intake air flow.



Major Trends

- **Materials**
  - Permanently Hydrophilic Polypropylene/Polyesters
  - New sustainable materials – PLA, Bio PET, Kenaf
  - Bicomponent Staple Fibers
- **Processes**
  - Innovative SpunMelt
    - Bicomponent meltblown/spunbond products
  - High speed/high volume processing – Carding
  - New Innovative/Combined processes – Coform
- **Post-Processes**
  - Surface treatments
  - Coatings/laminations
- **Product Innovations**
  - Composites
  - Coforms

Engineering the Product Composites

- **Composite Nonwovens (CN) are made:**
  - from 2 or more fibers
    - Homogeneous blends and gradients
    - Layered structures
  - from fibers and particulates
  - from 2 or more layers with at least one being a nonwoven

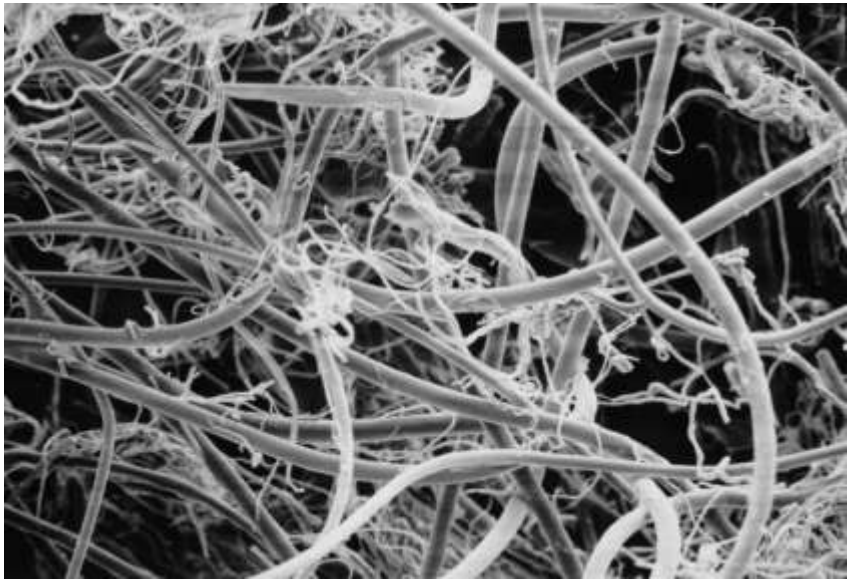
Why Composites?

- **Economical solution:**
  - Eliminate steps
  - One product replaces two or more
- **Best technical solution – Engineered solution**
- **Profit improvement**
  - Specialized solution

CN Made From Fibers & Filaments Examples

- Thinsulate® from 3M composed of large fibers + sub-denier fibers

- Synthetic leather composed of Spunlaced splittable fibers



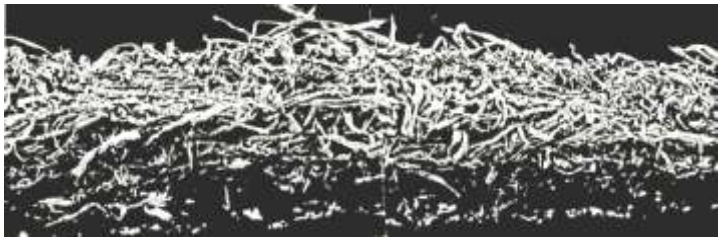
Layered Composites

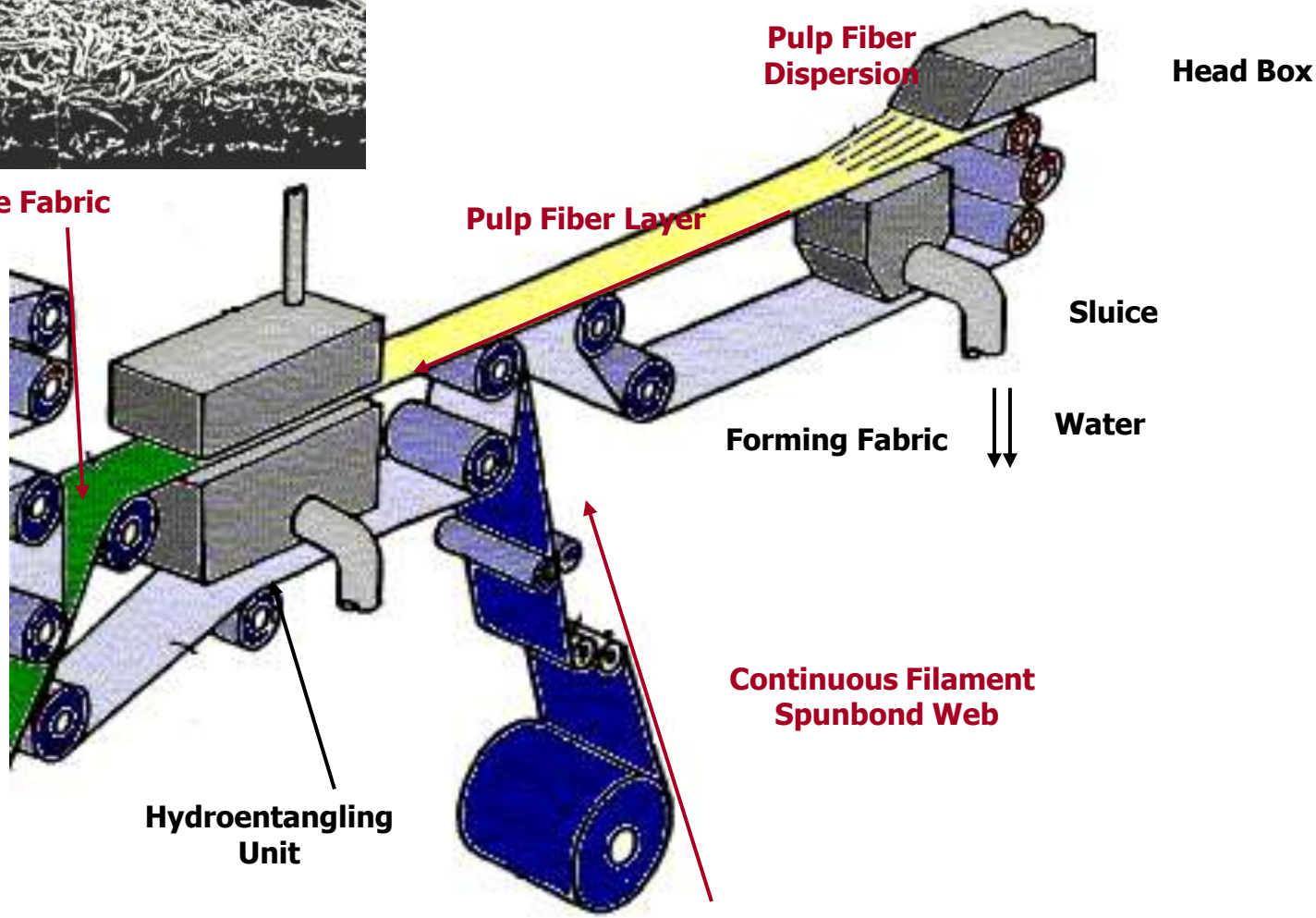
- **Processes with more than one forming section adding different fibers or filament to a web. Examples are:**
  - multi-card process,
  - multi-forming box air-laid process,
  - multi-beam spunbond process,
  - combinations of various forming processes like SMS

Composites Made by Lamination

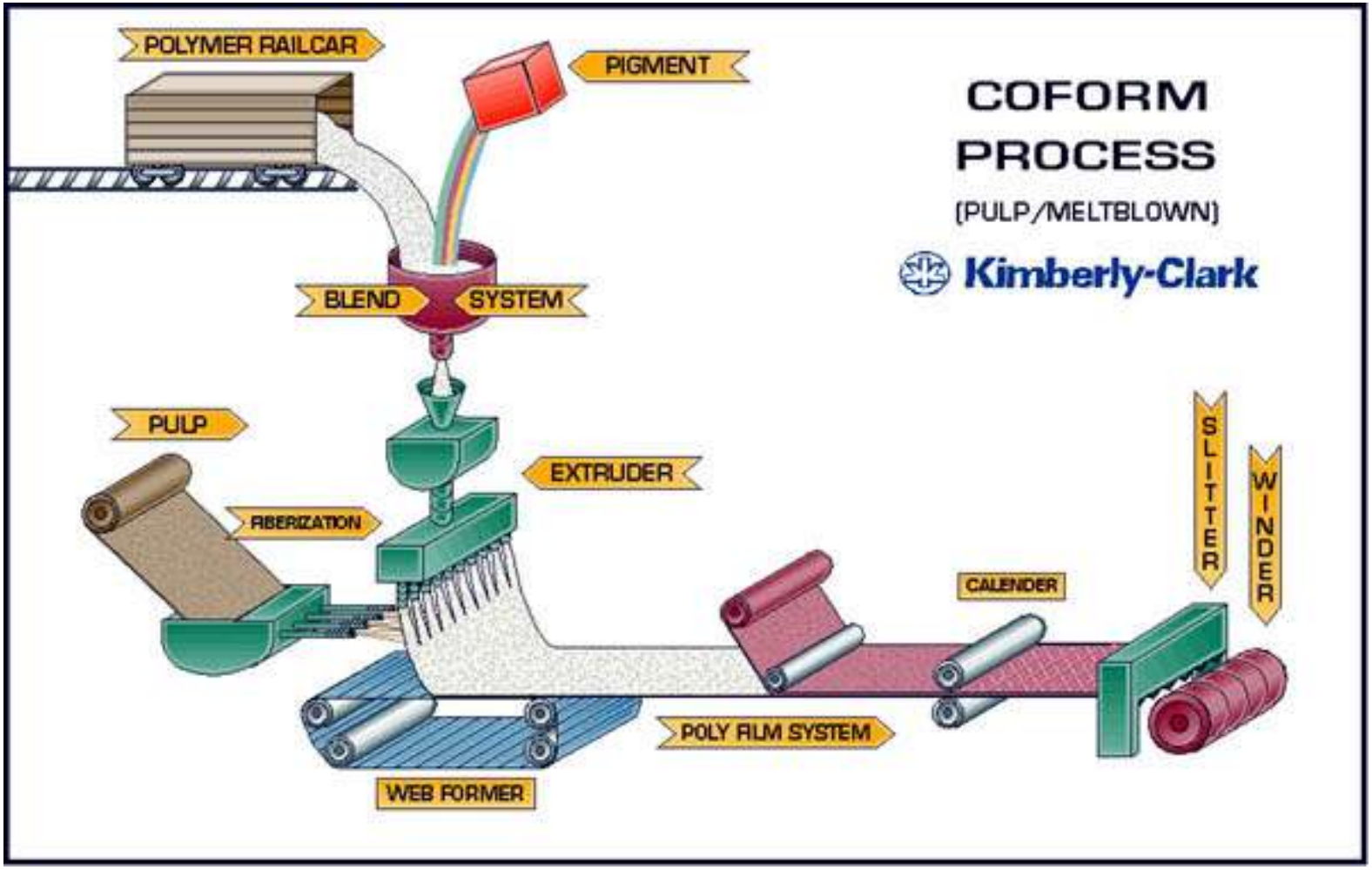
- **Lamination are made by thermal bonding, ultrasonic bonding, adhesive bonding, extrusion coating, needling and spunlacing. The laminates are:**
  - made up from two or more layers of nonwovens or
  - made up from at least one nonwoven and at least one different layer (film, reinforcement net, etc…)

Spunbond+Spunlace - Hydroknit® (KC)





Coform – A Great Example



Layered Composites Examples

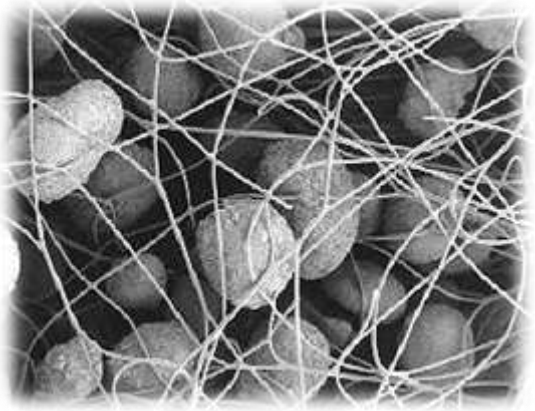
- **Spunlaced fabrics made of wood pulp and synthetic fibers**
  - Tissues paper layered on top of carded web prior to hydroentanglement
  - Fabric has one side rich in wood pulp fiber
  - Treatment is added to wood pulp fibers to achieve barrier properties

CN With Particulates

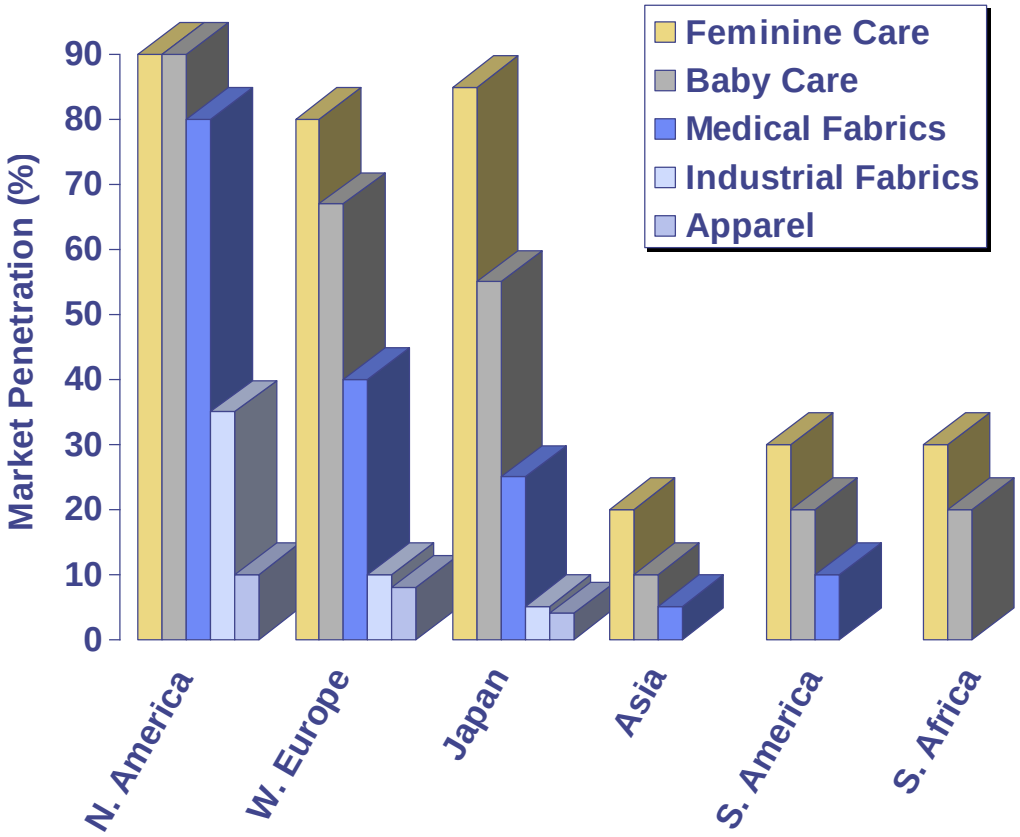
- Nonwovens where particulates are bonded to the fiber or filament with an adhesive (e.g. Abrasive pad where abrasive particulates are bonded to the fibers with a latex. Same approach has been used for carbon black)

CN With Particulates

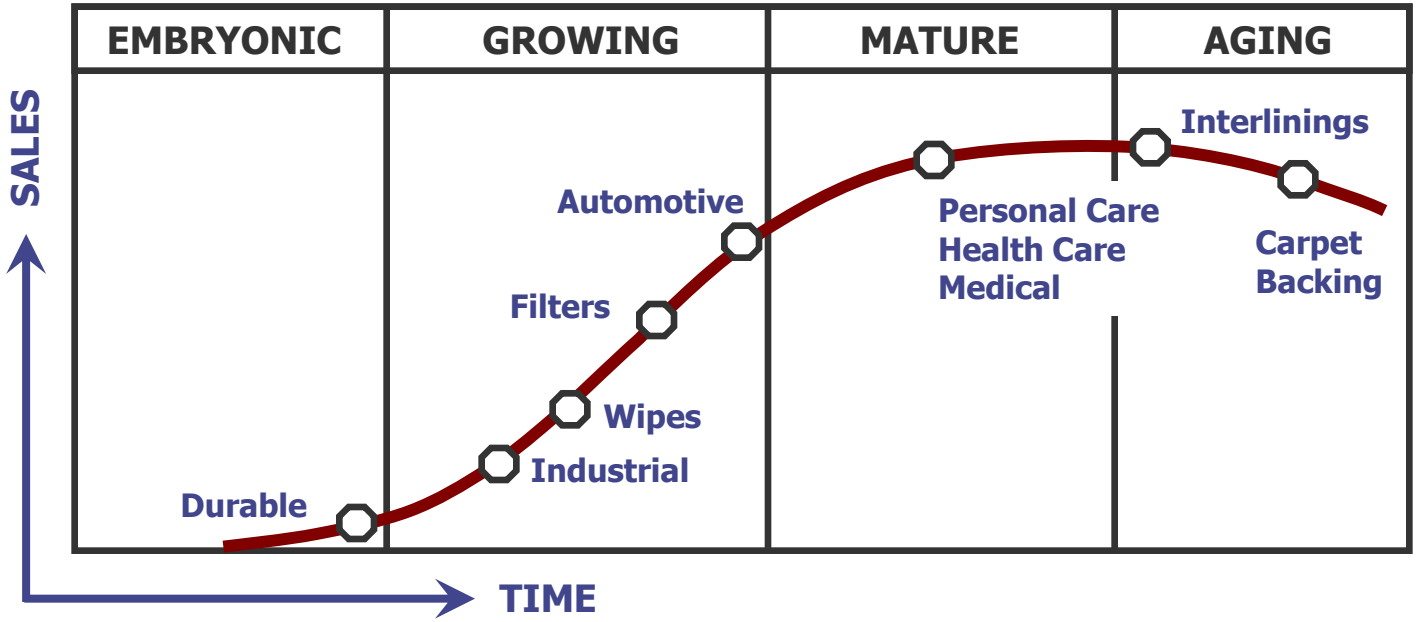
- Nonwovens made up of bicomponent fibers, where the outer layer is melted to form bonds between the fibers and between the fibers and the particulates.



Potentials for Growth



Market Segments…



Enabling Technologies

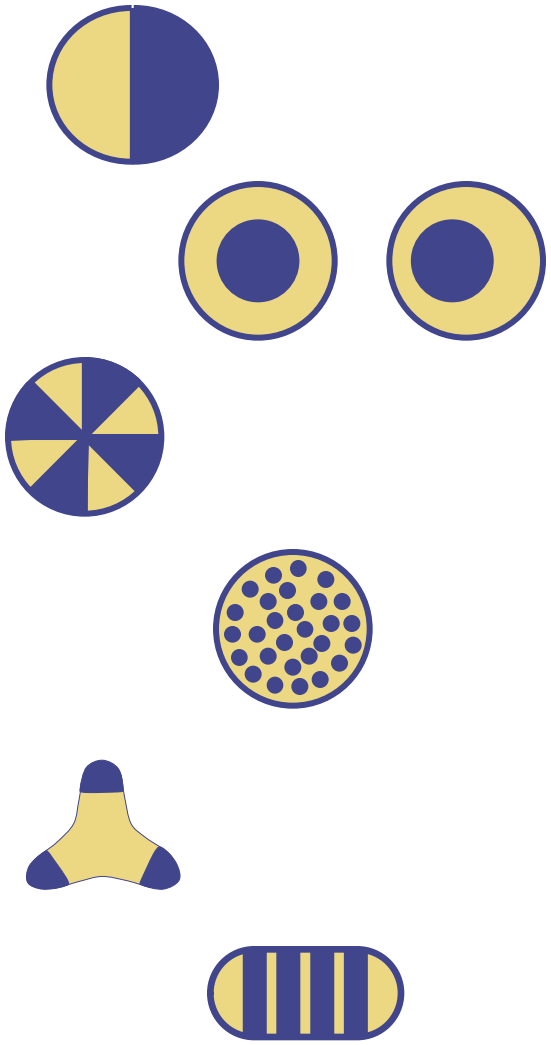
- **Major innovations in products will be based on:**
  - Materials
    - New innovative (sustainable) materials
    - Bicomponent/multi-component fiber technologies
  - Processes
    - New innovative processes – Apex,
    - Co-forms
  - Products
    - Composites

Why Bicomponent Fibers?

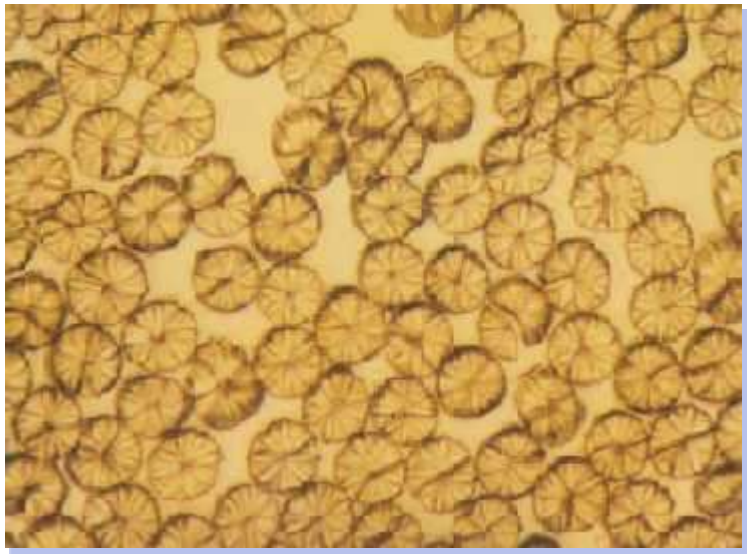
- To utilize the properties of two polymers
- To exploit capabilities not existing in each of the individual polymers
- To improve the material performance suitable for specific needs by tailoring one or more properties with minimal sacrifice of other properties
- To bring about multifunctional properties without the loss of mechanical properties

Classification

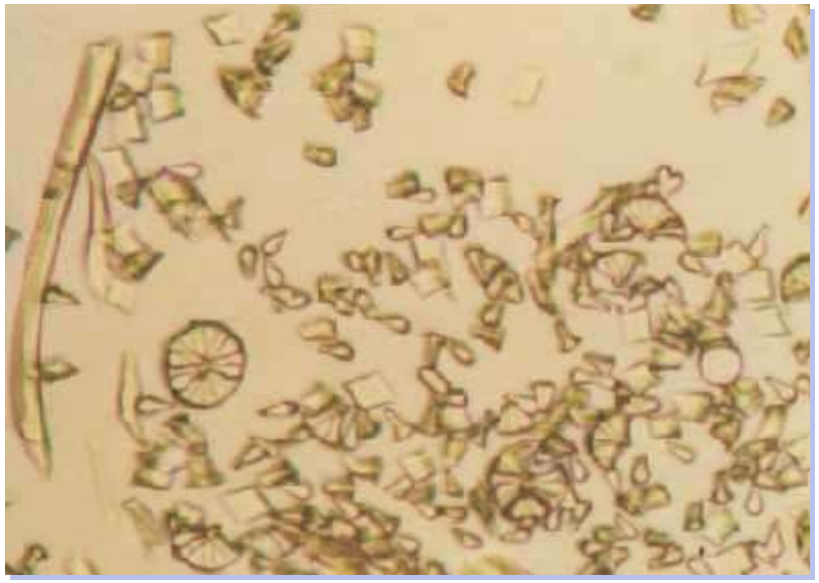
- Side-by-side
- Sheath-core
- Segmented-pie
- Islands-in-the-sea
- Tipped
- Segmented-ribbon



Segment-Pie: Splitting by Carding



Card-splittable fiber before splitting

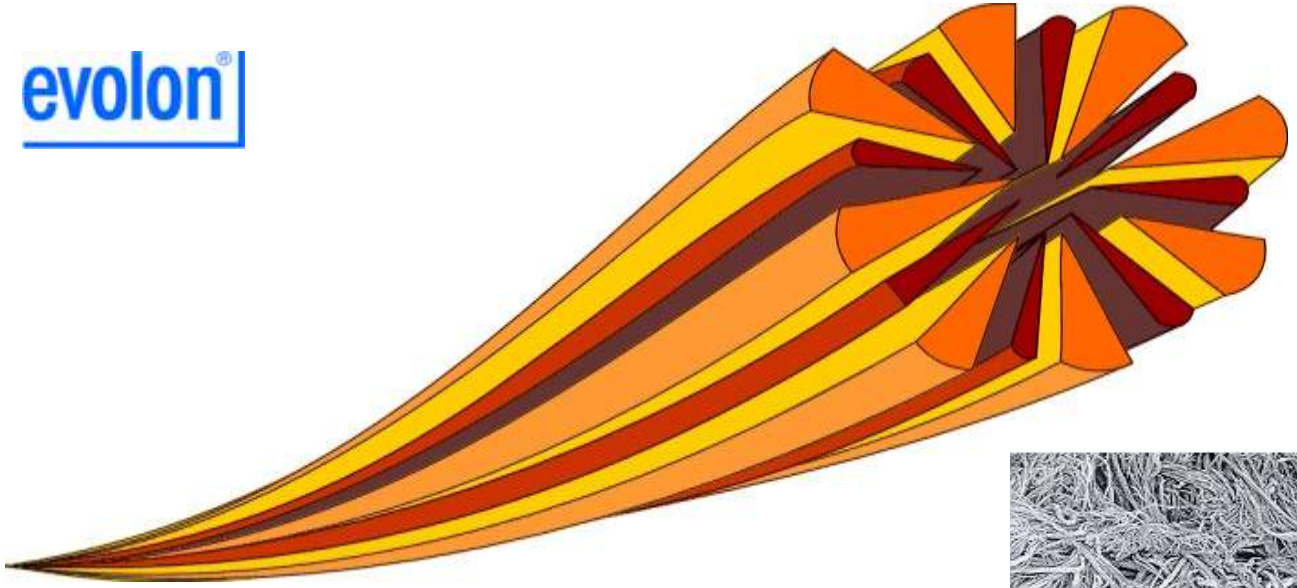


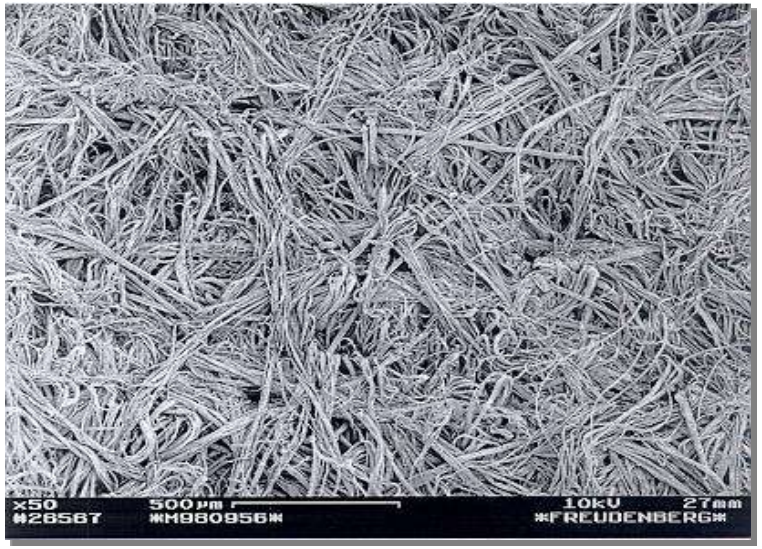
Card-splittable fiber after carding

Ref: Middlebrooks, M. C.

Increased Surface Area
Evolon… The Next Generation

evolon®





Ref: Freudenberg

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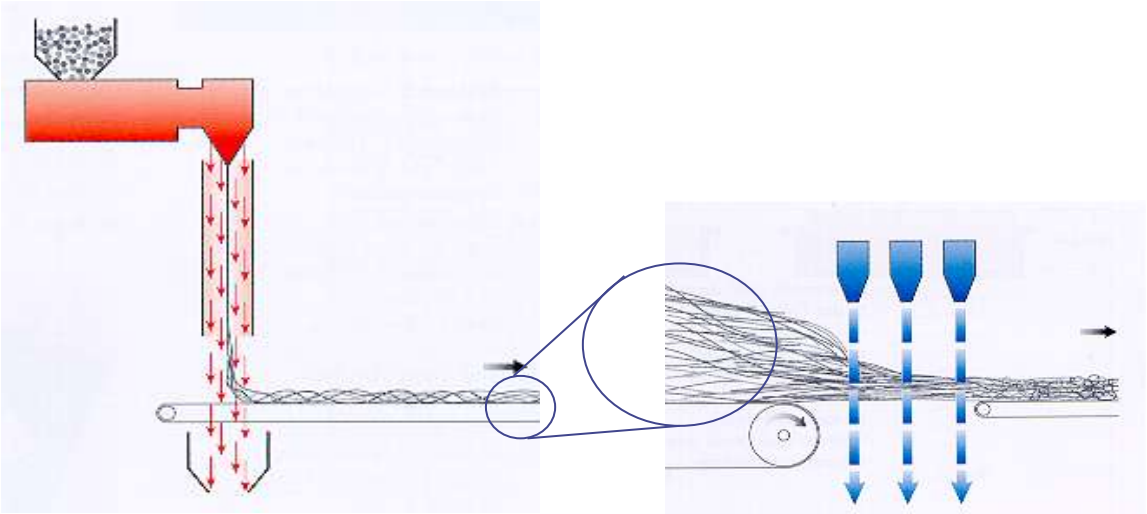
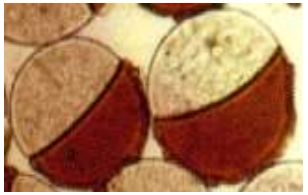
Evolon… The Technology

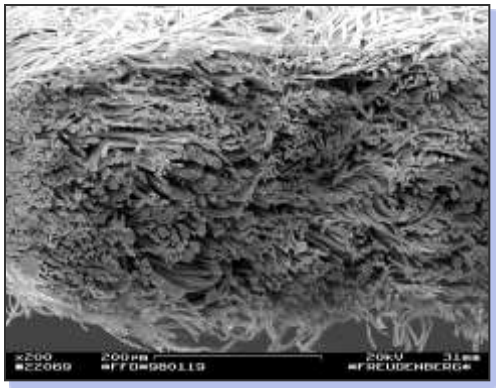


microfilament fabrics

16 Sector PIE ~ 0.1 dtex



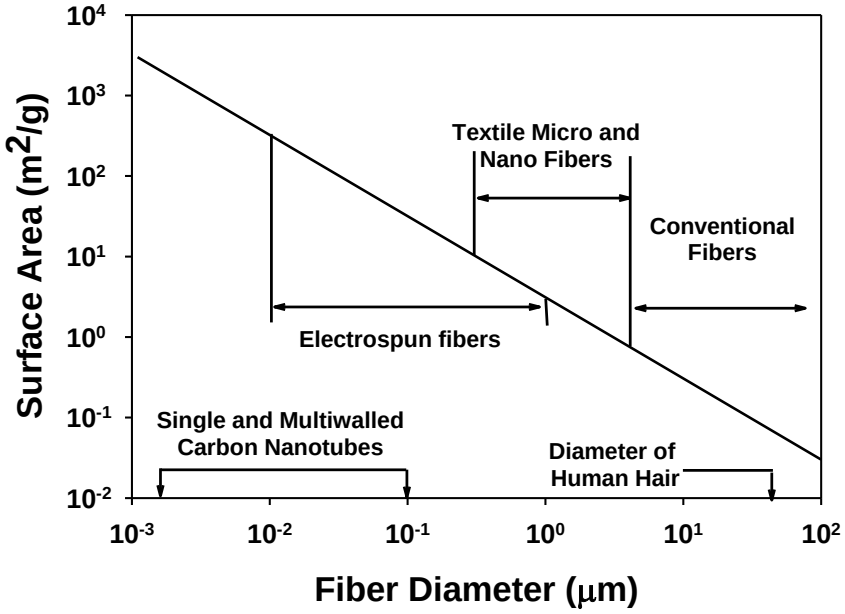
2 Sector S/S ~ 1 dtex



Ref: Freudenberg

Increased Surface Area
How About Nano Fibers?

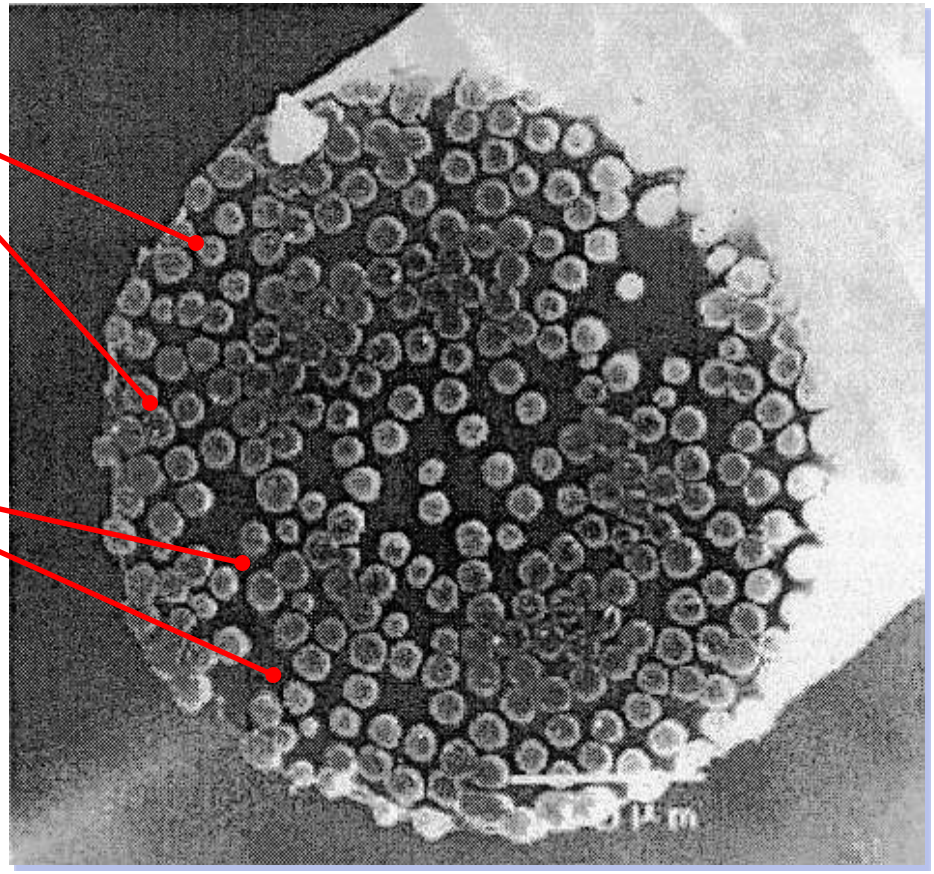
- **Electrospinning**
  - 10 to 200 nm
- **Meltblowing**
  - 500 nm to 10 μm
- **Bicomponent fibers**
  - 200 nm to 1000 nm
- **Bicomponent Fibers in spunbonding**
- **Bicomponent Fibers in meltblowing**



300 Islands-in-the-sea As-spun Fiber

Islands: PTT

Sea: EVOH



Acknowledgements

The following individuals and organizations are gratefully acknowledged for helping with this presentation:

David Nelsen, 3M
Pierre Grondin, PGI
Terry O'Regan, Freudenberg
Arnold Wilke, Hills
INDA