

MICHELMAN[®]

Fiber Sizing 101 + Emerging Technologies



Contents

- What is fiber sizing?
- Sizing chemistry, formulation and application
- Sizing challenges
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- Sizing selection & product portfolio
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Michelman

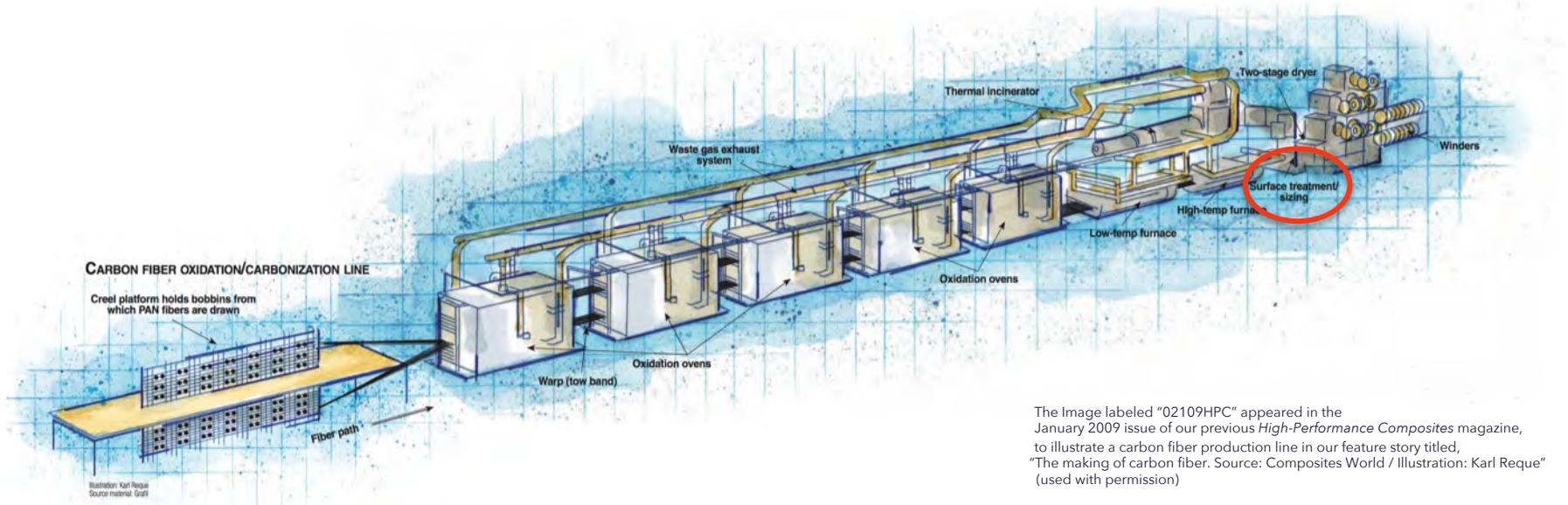
- Established in 1949
 - Specialty chemicals
 - Customer focused
 - Family enterprise
- Today, Michelman is:
 - Global
 - 455+ employees
 - Family owned



Global Headquarters - Cincinnati, OH

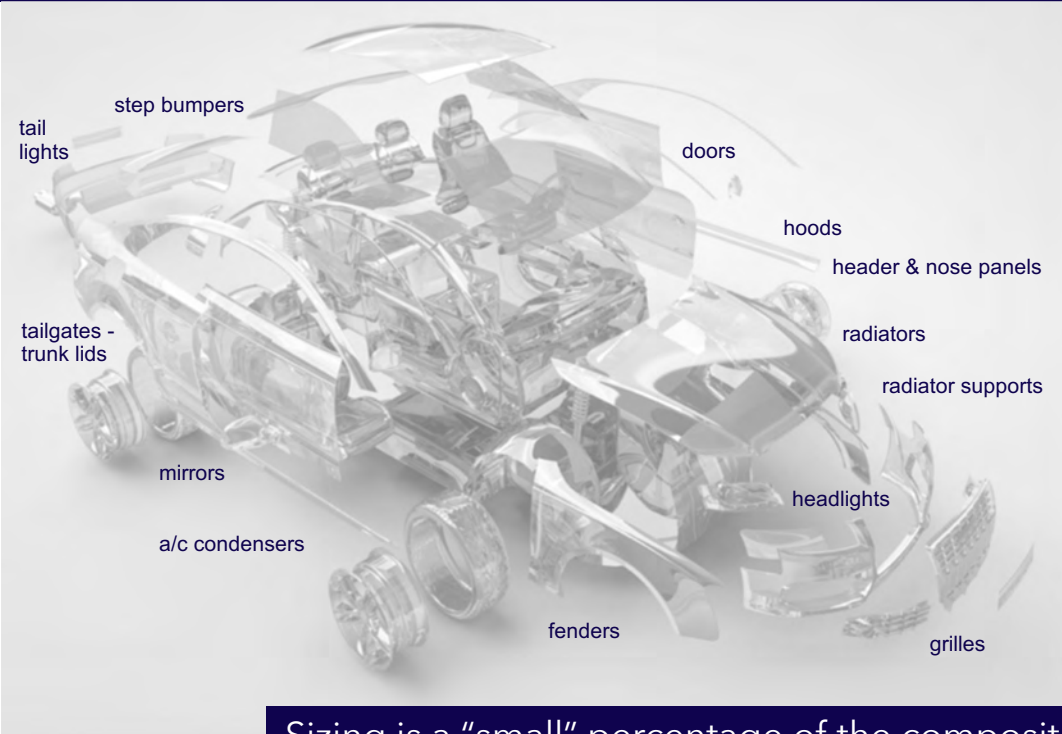
What is fiber sizing?

It is a thin homogeneous coating applied on the fiber surface during manufacturing. Sizing protects the fiber during handling, processing, compounding and molding.

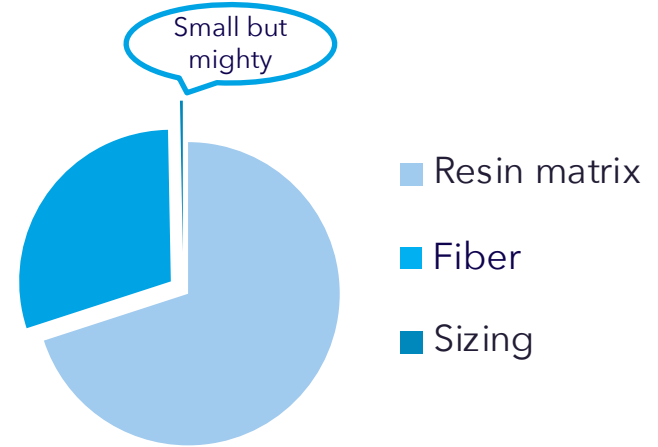


The image labeled "02109HPC" appeared in the January 2009 issue of our previous *High-Performance Composites* magazine, to illustrate a carbon fiber production line in our feature story titled, "The making of carbon fiber." Source: *Composites World* / Illustration: Karl Reque" (used with permission)

Fiber Sizing



Sizing is a "small" percentage of the composite, but has "huge" impact on the mechanical properties.



In a 100 Kg. composite made from a 30% glass - filled polymer



Fiber sizing is typically less than 0.3 Kg

Sizing Formulation

- **Components**
 - Coupling agents
 - Film formers
 - Additives or modifiers
 - Water
- These ingredients are mixed together and delivered to the fiber
- The water is removed and the dry fiber is ready to reinforce composites



Sizing Formulation – Glass Fiber

- **80-90% Film Former “Major Component”**
 - Facilitates fiber manufacturing
 - Bonds filaments together to aid processing
 - Compatibility and adhesion promoter between fiber and resin
- **5-10% Silane Coupling Agent - Glass Fiber**
 - Adhesion promoter - glass surface
 - Wet strength
- **5-15% Size Modifiers**
 - Lubricants, anti-stats, emulsifiers, chopping aids, antioxidants, wetting agents, color modifiers, processing aids

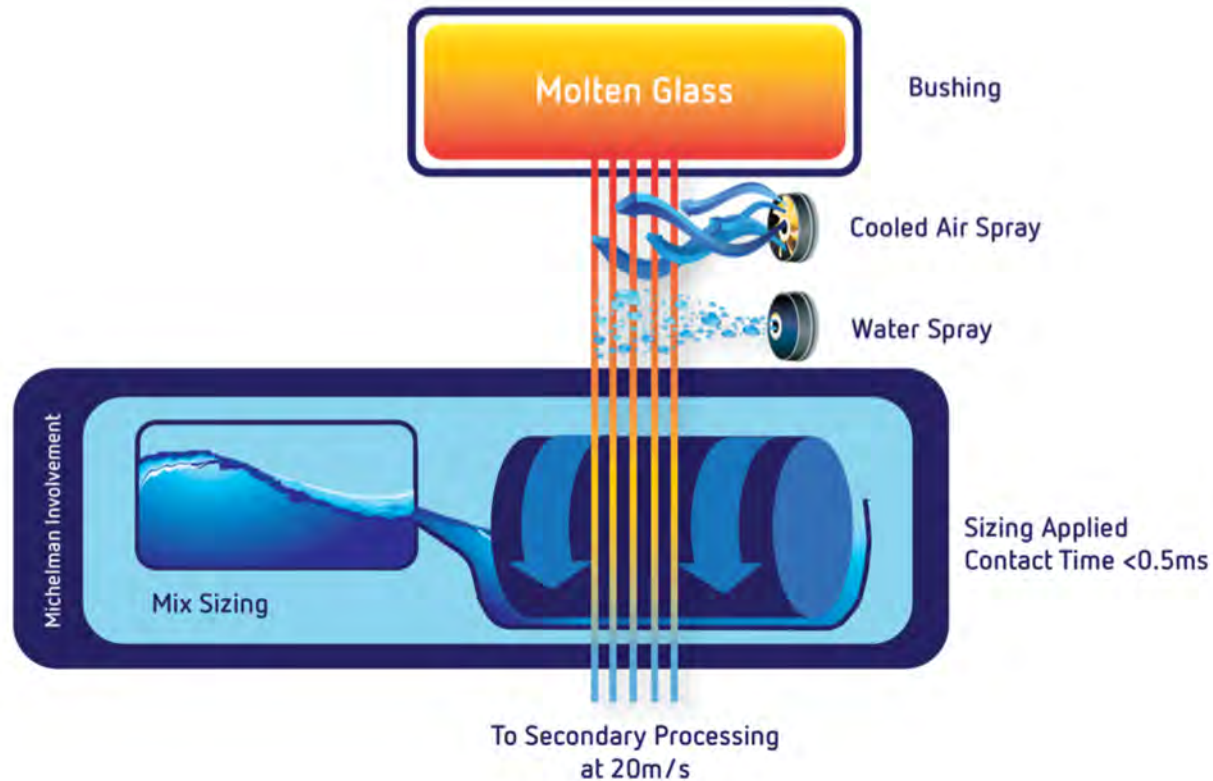


Sizing Formulation

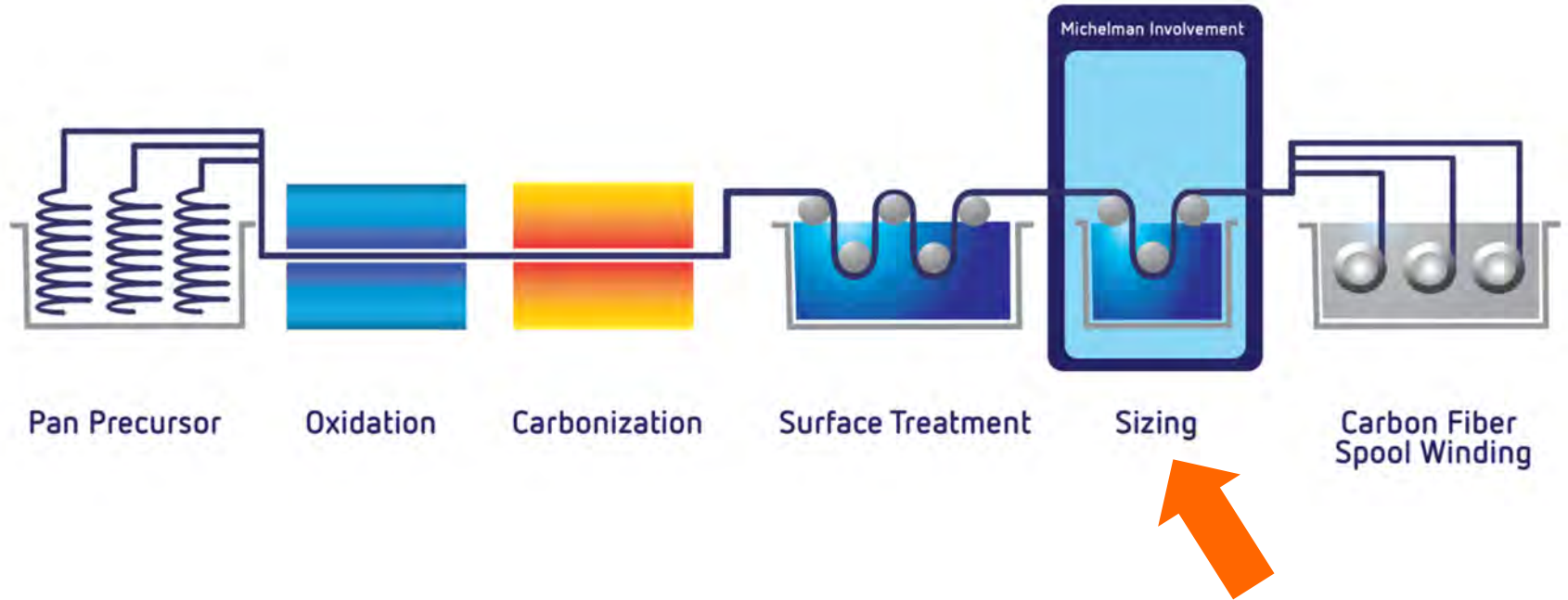
- Hundreds of dispersions are commercially available, but only a small percentage of them are compatible with other sizing ingredients.
- Compatibility with the resin matrix is key to composite properties.
- **Michelman** develops film formers to serve the ALL fiber markets:
 - Glass
 - Carbon
 - Basalt
 - Natural
 - Synthetic



Sizing Application – Glass Fiber



Sizing Application – Carbon Fiber



Sizing Stability Problems

Cause	Effect on Fiber
Particle size	Changes in LOI
Short shelf-life	Increase manufacturing downtime
pH changes	Increase or decrease of sizing on fiber
Foam	Fuzz, changes in LOI, uneven coverage



Sizing Benefits

Changes in sizing film formers can affect the fiber physical characteristics & composite properties.

Fiber

discoloration

solubility

resin wetting

ease of chopping

reduction of static

FDA compliance

reduction of fuzz

bundle integrity



Composite

thermal stability

degradation

surface finish

water resistance

chemical resistance

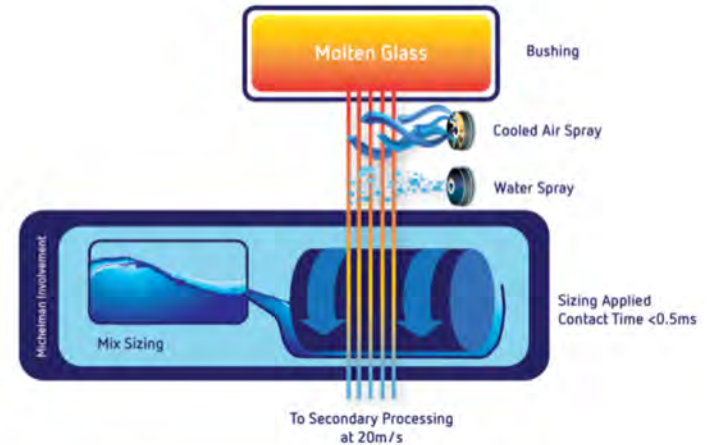
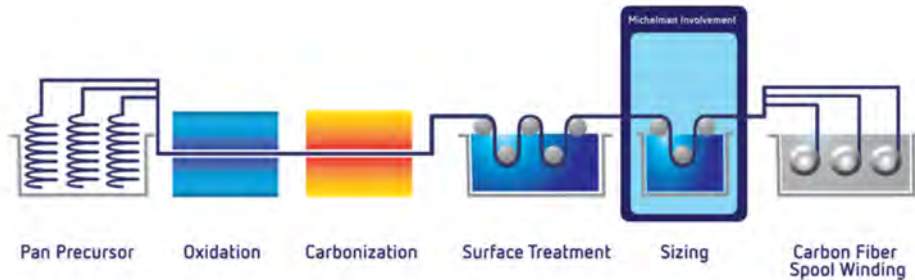
color

fiber length

adhesion

Manufacturing Benefits

- Protects the freshly formed fiber surface from abrasion.
- Prevents fiber breakage at contact points.
- Keeps chopped bundles of fiber together.



Processing Benefits

- **Integrity:** Keeps the chopped bundles together
- **Chopping:** Increases the chopper's blade life and reduces fuzz generation
- **Unwinding:** Keeps strand together
- **Weaving:** Provides lubricity and flexibility to prevent breaks



Composite Benefits

Sizing enhances composite **mechanical** and **chemical** properties due to the role it plays at the interface of the fiber and matrix.

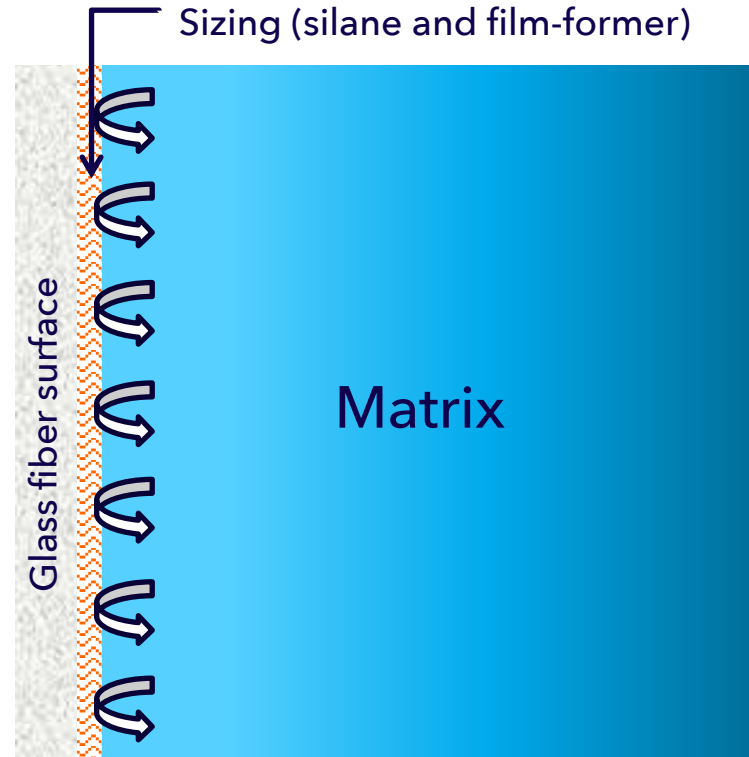
- Thermal and hydrolytic stability
- Corrosion resistance
- Heat and oil resistance
- Impact strength
- Tensile and flexural strengths
- Compressive strength
- Fatigue performance
- Electrical conductivity
- And many others



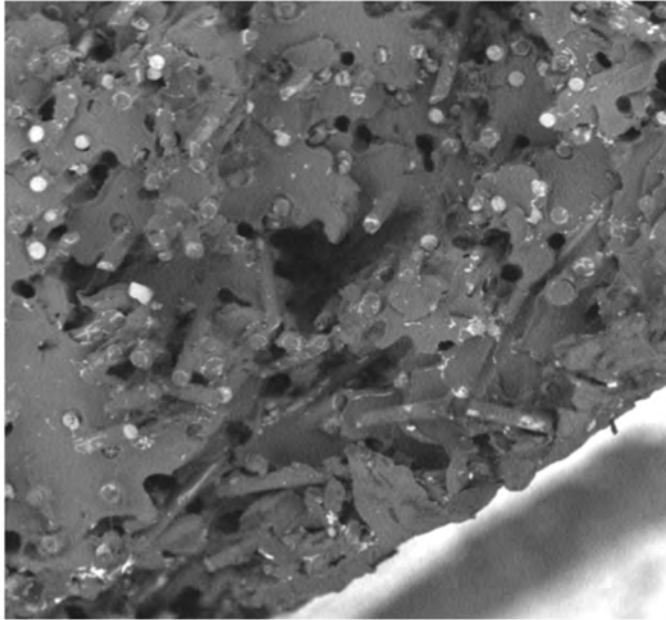
The Interface – Schematic

When the sized fiber is introduced to the resin matrix the sizing becomes the “glue”.

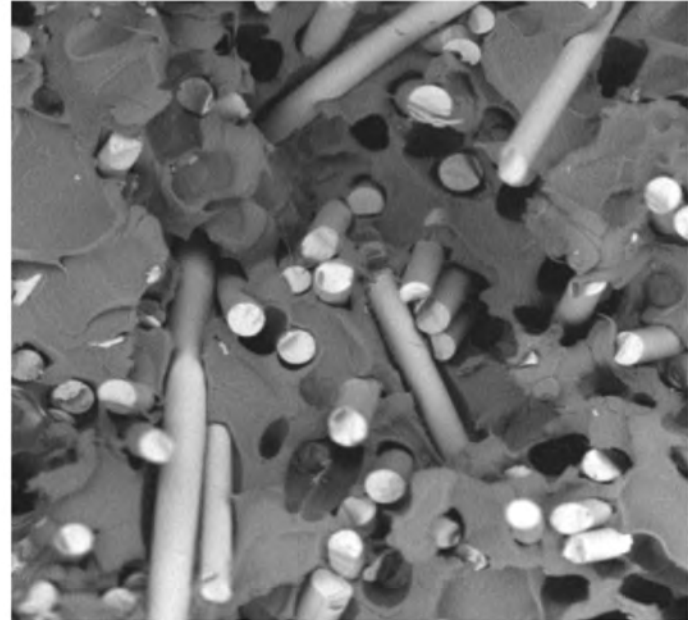
The forces between sizing and matrix can be chemical bonding, hydrogen bonding and Van der Waals interaction.



The Interface – Close Up



Good Adhesion
(No pull out fibers)

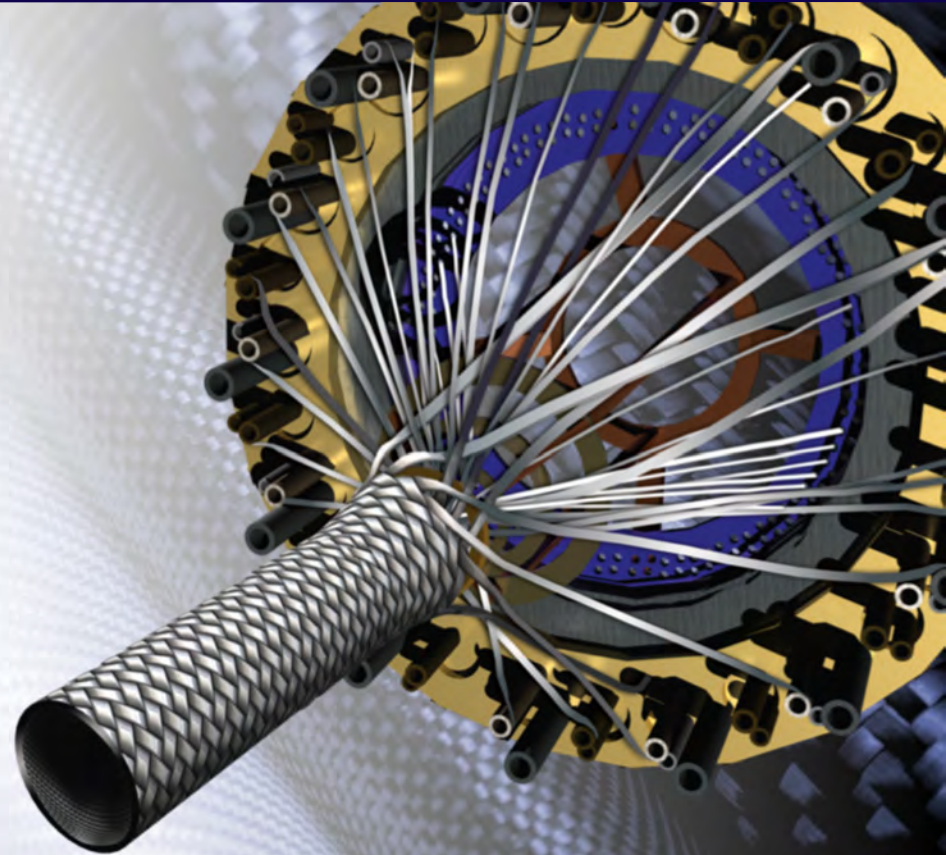


Poor Adhesion
(Fiber slippage)

Sizing Selection

Considerations when choosing a sizing:

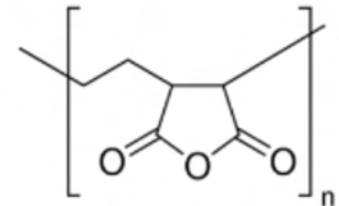
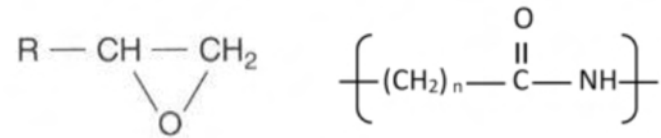
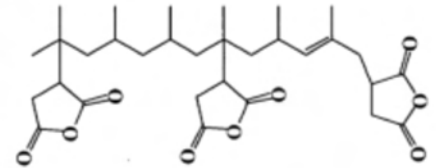
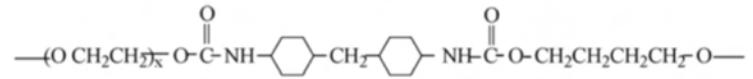
- **Type of resin:** Thermoset or thermoplastic?
- **Fiber:** Chopped or continuous; and what type of fiber?
- **Process:** Manual or automated?
- **Final application:** Automotive, household good or other?



Sizing for Matrix Resin

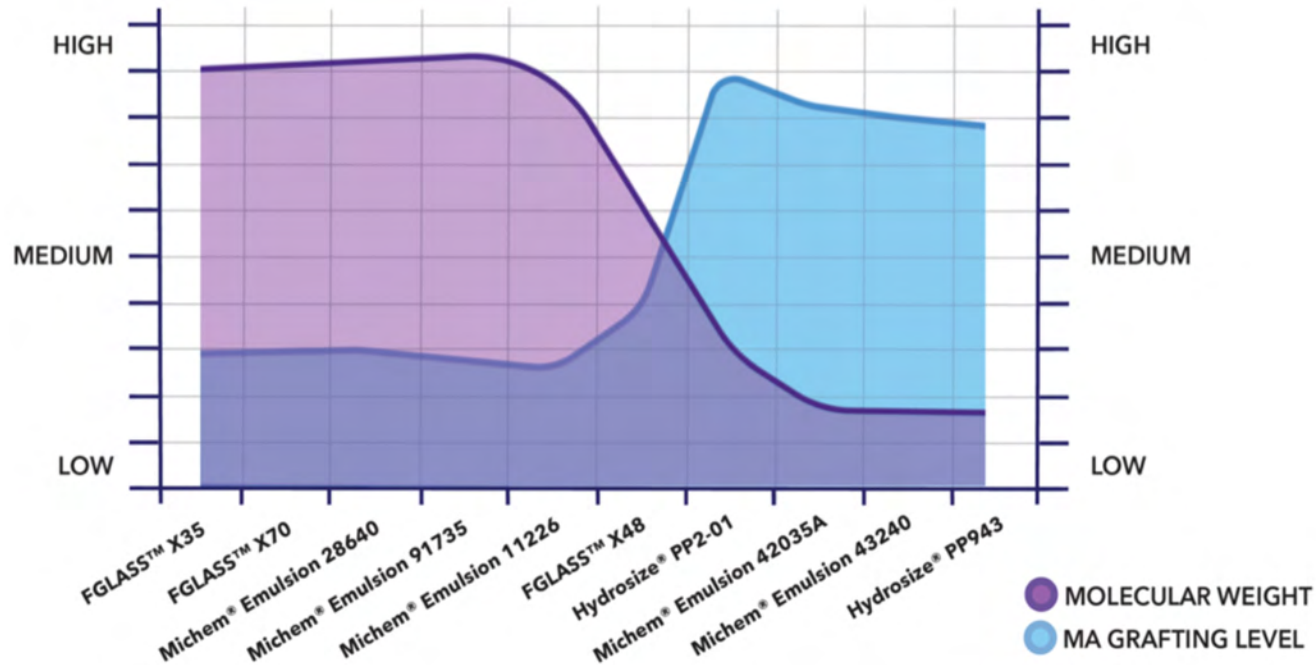
Products are designed for use in the following matrix resins :

- Polypropylene (PP)
- Polyethylene (PE)
- Polyamide (PA)
- Polyether Imide (PEI)
- Polyether Ether Ketone (PEEK)
- Polyphenylene Sulfide (PPS)
- Thermoplastic Polyurethane (TPU)
- Polyester, (Un)saturated
- Vinylester
- Epoxy
- Products tailored to meet the specific applications, environmental footprint



Polypropylene Matrix

Michelman offers an extensive line of emulsions made to fit PP composite properties.



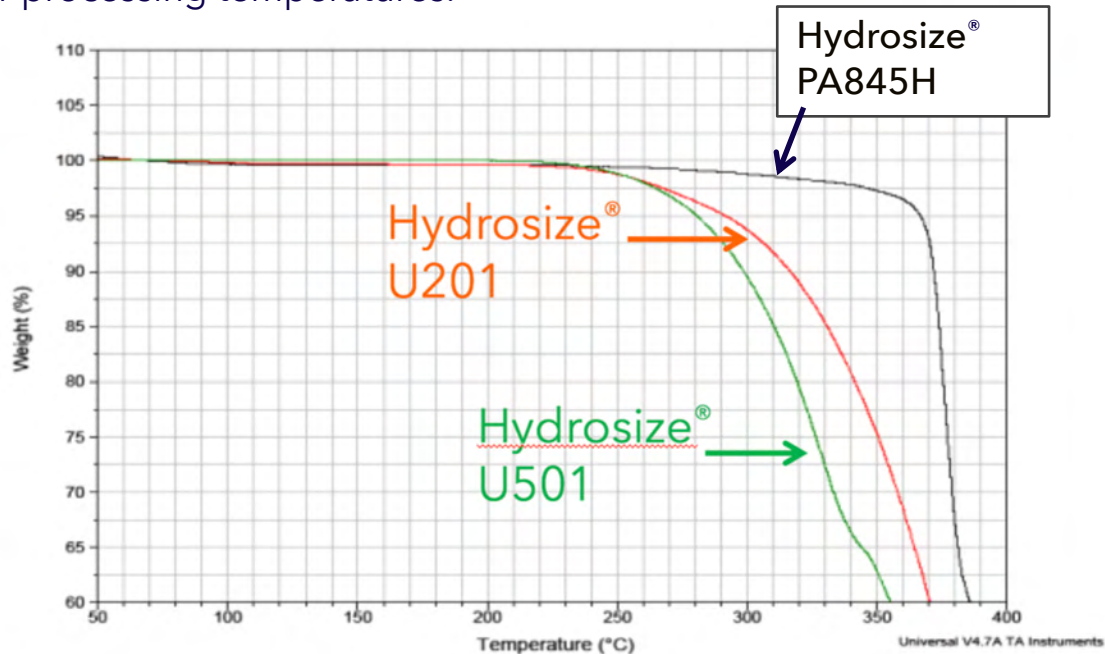
Polyamide Matrix

Polyurethane dispersions have been the sizing of choice for polyamide (PA) reinforced composites. Polyurethanes are tough materials with good adhesion to PA6 and PA66. We design our own polyurethanes to meet our customer needs by changing the chemistry to modify flexibility, toughness, Tg, chemical resistance, mechanical properties, etc.

Hydrosize®	Mechanical Performance	Glycol Resistance	Thermal Resistance	EU Food Compliance	Strand Integrity	Chopped Strand	Long Fiber Reinforced Thermoplastic
U2023	●●	●●	●●●	Yes	●●	●●●	●●
U5-01	●●●	●●●	●●●		●●●	●●●	●
U5-02	●●	●●●	●●●	Yes	●●	●●●	●●
U6-01	●●	●●	●●		●●●	●●	●●●
U8-02	●●	●●	●●	Yes	●●	●●	●●●
Link U470	●●●	●●●	●●●		●●●	●●●	●
Link U480	●●●	●●●	●●●		●●●	●●●	●●●

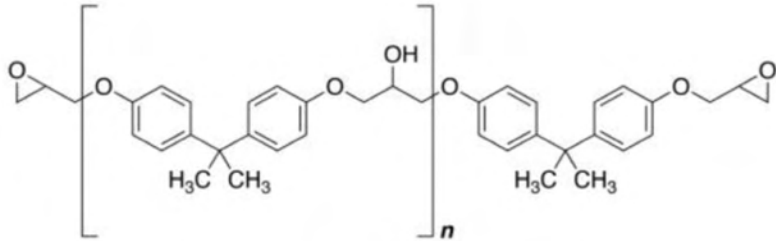
Polyamide – High Temperature

We use a proprietary technology to make polyamide dispersions. These products are designed with thermal resistance in mind. Compared to polyurethanes, polyamide (Hydrosize® PA845H) dispersions can withstand higher processing temperatures.



Polyester Matrix Epoxies

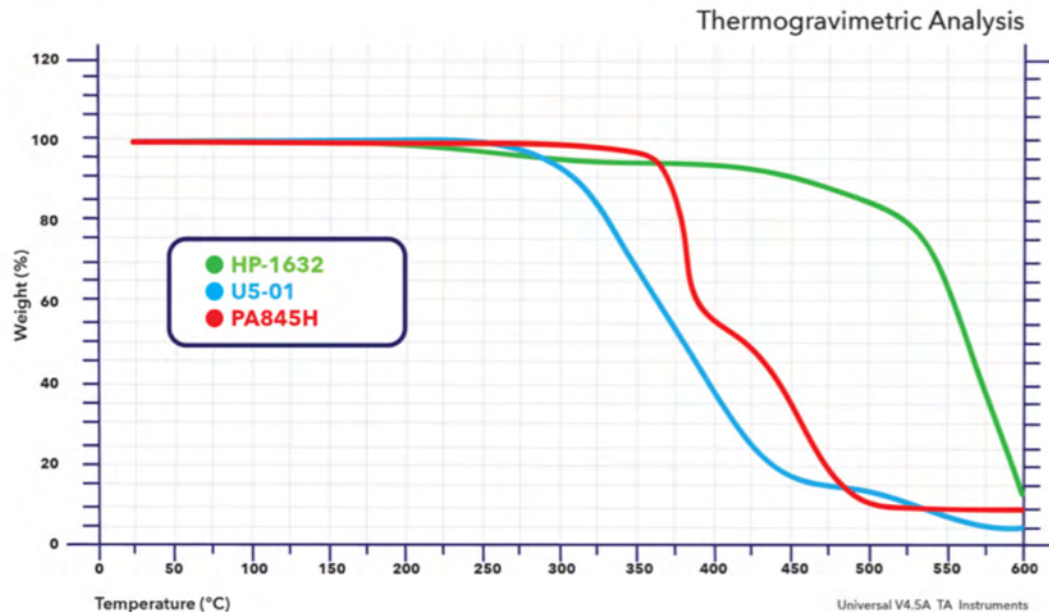
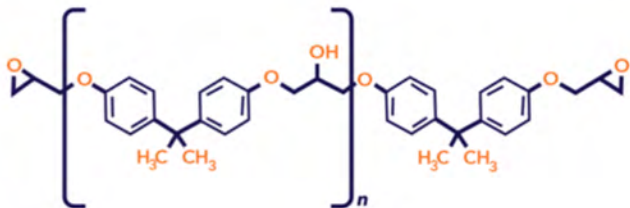
Using a proprietary process, we can make high molecular weight epoxy dispersions without any solvent. The epoxies can be used for thermoplastic polyester and/or unsaturated thermoset polyester applications.



Product Name	Description
Hydrosize®EP876	Medium mwt, 1500
Hydrosize®EP871	High mwt, 2000

High Temperature Sizing

RESIN COMPATIBILITY				
Hydrosize®	PEEK	PEI	PPS	PPA
HP-1632	●	●	●	
PA845H				●
U5-01			●	●



New Products – Hydrosize® Link

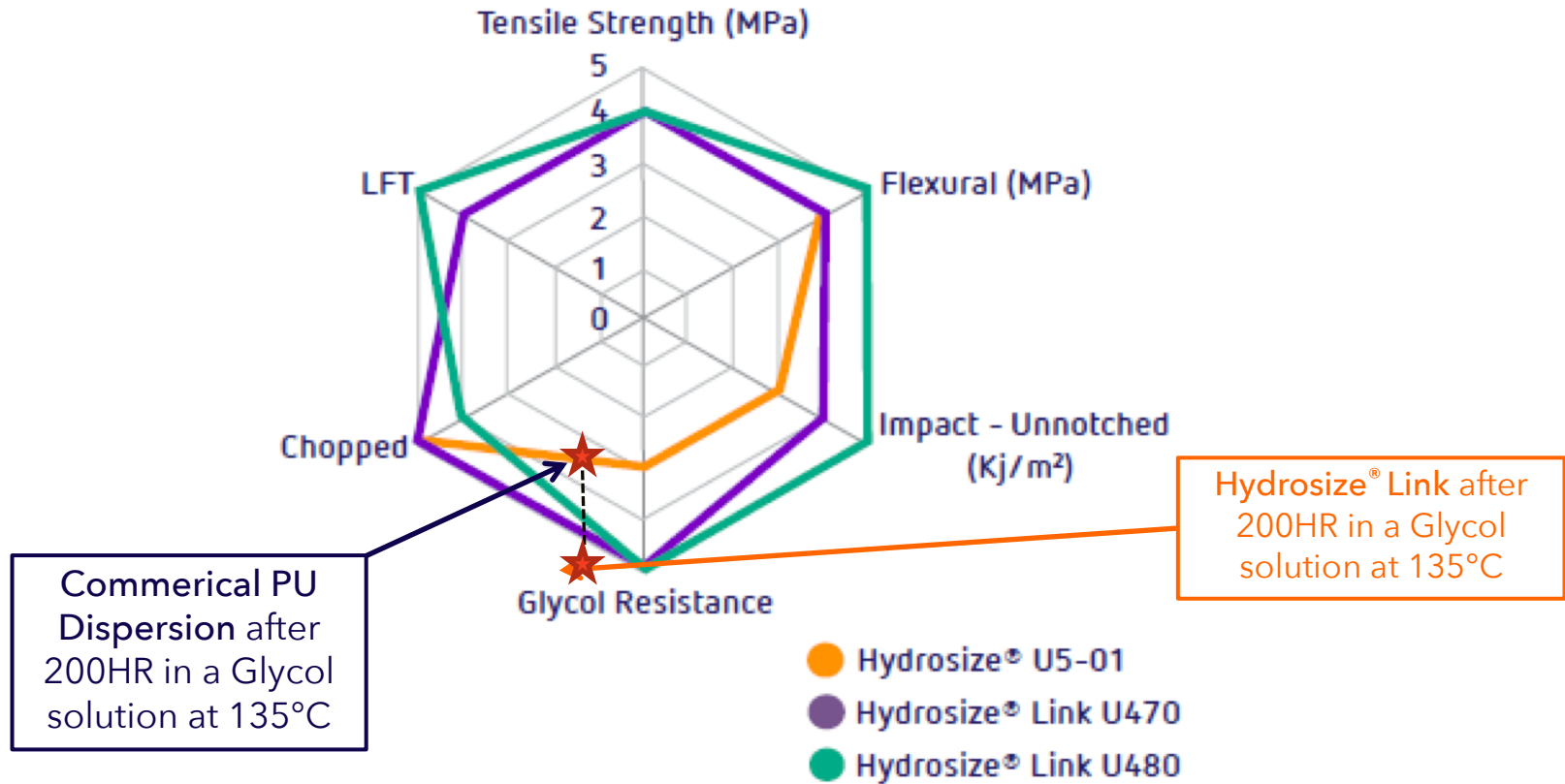
We offer the industry a high performance portfolio of materials designed for long-term performance - including exposure to aggressive fuels.

Hydrosize® Link is an enhanced reactive sizing that increase the chemical resistance of polyamide composites.

This allows automakers to cost-effectively meet emissions regulations and increase fuel efficiency.



New Products – Hydrosize® Link



New Application

Sizing for Recycled Carbon Fiber



Increased use of carbon fiber in aerospace application generates scrap fiber previously sized with epoxy



Recycling initiative and environmental sustainability

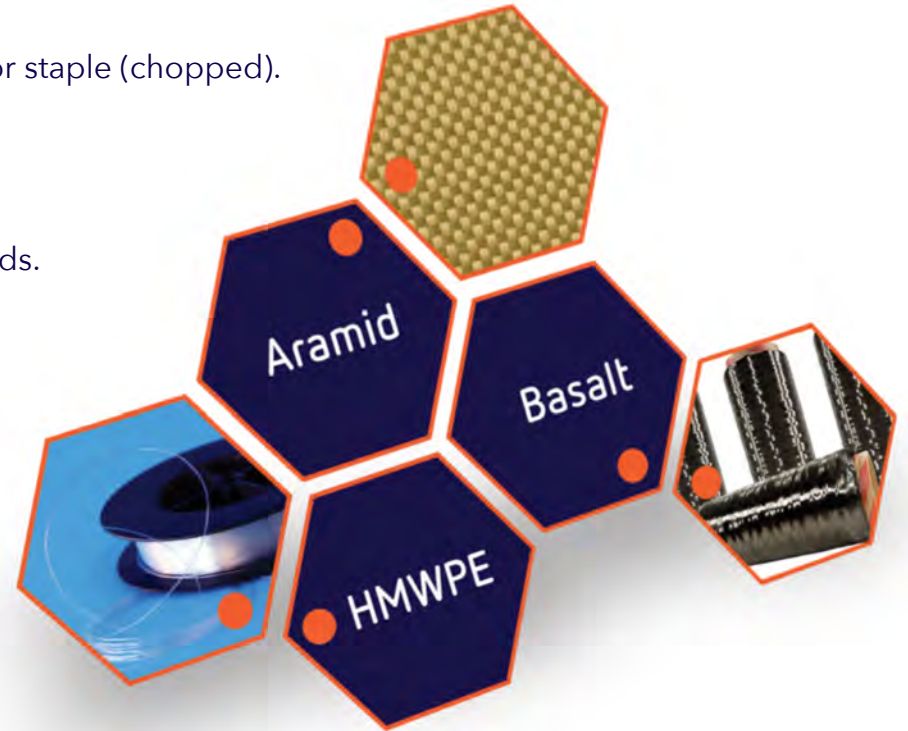


MICHELMAN
Hydrosize® Solutions

Hydrosize®	Resin Compatibility	Can be oversized (on epoxy based sizing)	Key Characteristics
U2-04	PA, PC & Esters	Yes	Compatible with epoxy, this polyurethane dispersion can be applied on a fiber already sized to improve adhesion with polyamides, polyesters and vinyl esters.
HP3-02	PC & Esters	Yes	This phenoxy dispersion is particularly designed to improve the compatibility of the carbon fiber with polycarbonate and PBT.
PA845H	PPA, HTN & PA4,6	Yes	This unique dispersion performs very well in applications using high temperature resistant polyamides (PPA).
HP-1632	PEI, PEEK	Yes (but not ideal to achieve the best performance)	The best solution on the market for high temperature resistance.

New Application

- With the exception of cellulosic, fibers can be continuous or staple (chopped).
- Multiple fiber types can be used in one textile fabric.
Example: carbon for strength and aramid for flex.
- Each fiber type has its own unique sizing and bonding needs.
- Surface modification of fibers and fabric can improve performance in nearly all technical textile applications.
- Our core competency around fiber sizing and surface modification is a direct fit with market/customer needs.
- We use our expertise to accelerate innovation with our customers' fabric consolidation and/or pre-preg.



New Application

Optimized Sizing for Vinyl Ester / Carbon Fiber Composites

Michelman has joined a new IACMI project focused on the optimization of vinyl ester resins and fiber sizing for the fabrication of carbon fiber composites.

The effort will identify styrene-free pre-preg formulations with longer room temperature shelf life, shorter cycle times, and reduced cost. Advancements in these areas will increase productivity, decrease scrap and material costs, and enable adoption into the automotive industry.

The logo for Michelman, featuring the word "MICHELMAN" in a bold, blue, sans-serif font with a small orange horizontal bar above the letter "I".The logo for UDRI, featuring the letters "UDRI" in a large, bold, red, serif font.

Examples of New Solutions

Basalt Fiber

Resin: PPA

Need: Heat resistant at 280° C

Recommendation: Michelman recommends new dispersion, Hydrosize® PA874 which is stable at high temperatures compatible with PPA.



Natural & Synthetic

Resin: TPU

Need: Better adhesion between synthetic fiber and resin

Recommendation: Michelman recommends Michem® Prime 2960 and 5931 to improve the interface between high molecular weight PE fiber and TPU.





Please contact us at sizing@michelman.com or +1 513-793-7766 to consult with a fiber sizing expert.