

MICHELMAN[®]

Fiber Sizing Fundamentals and Emerging Technologies



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- What is fiber sizing?
- Sizing chemistry, formulation and application
- Sizing challenges
- Sizing benefits
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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)

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**

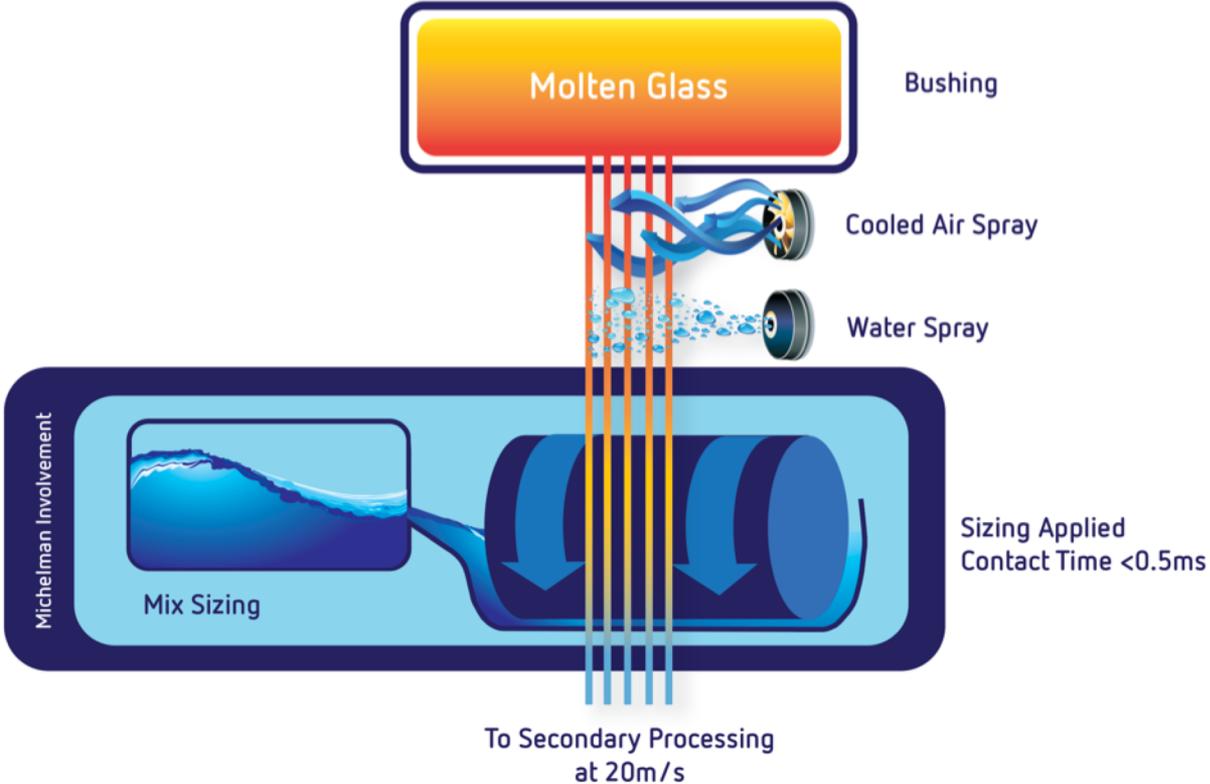


Sizing Formulation

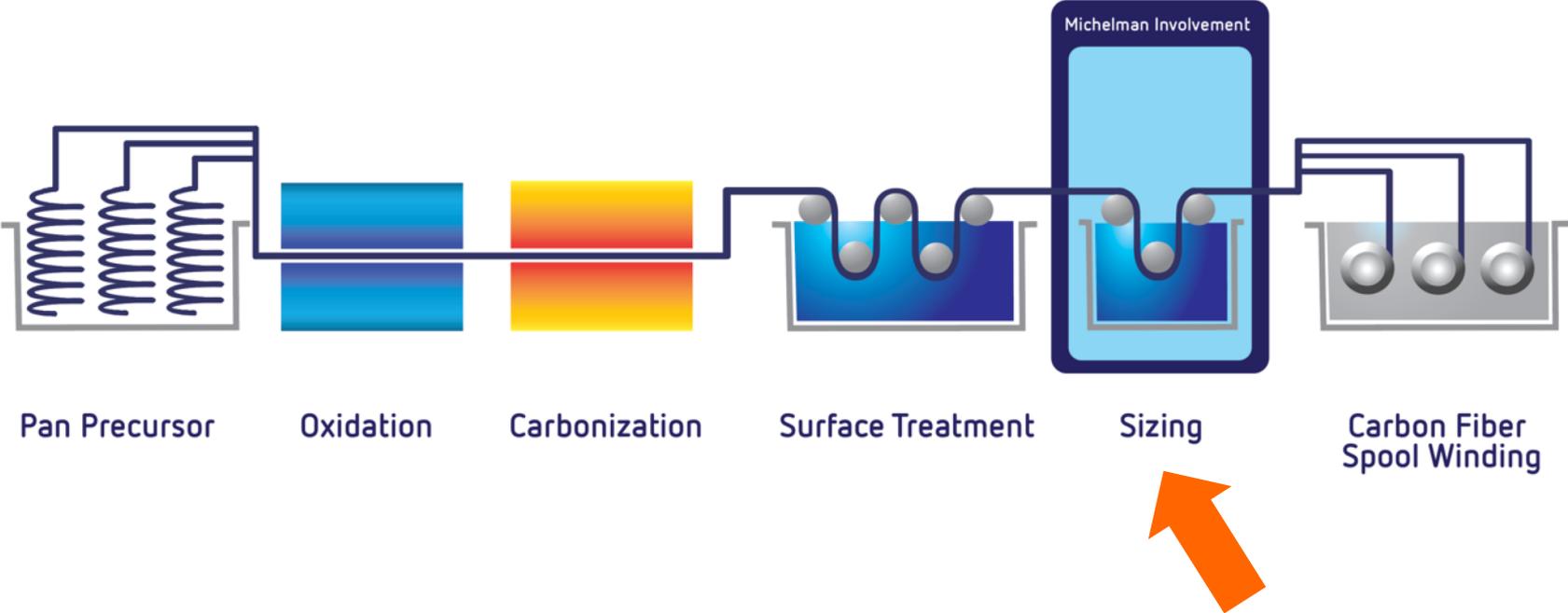
- Hundreds of dispersions are commercially available, but only a small percentage of them are compatible with other sizing ingredients.
- Compatibility with the resin matrix is key to composite properties.
- **Michelman** develops film formers to serve the ALL fiber markets:
 - Glass
 - Carbon
 - Basalt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



Sizing Application – Glass Fiber

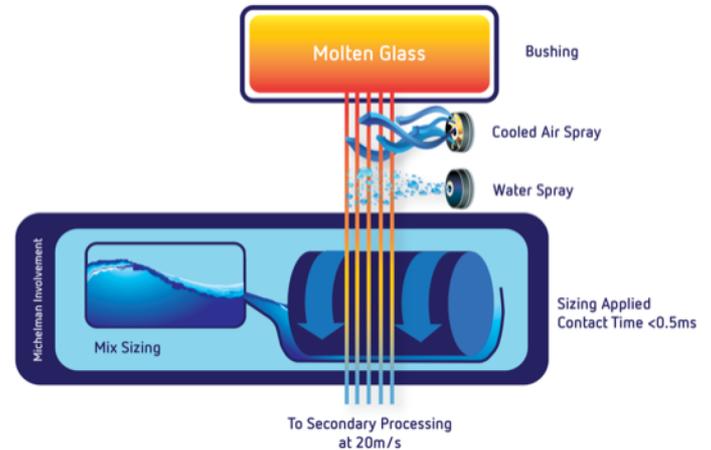
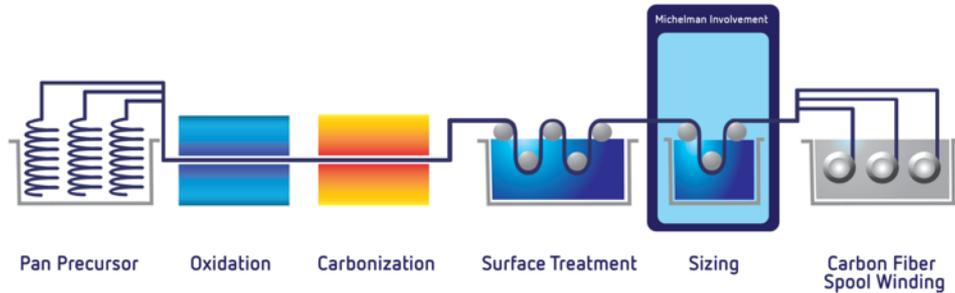


Sizing Application – Carbon Fiber



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



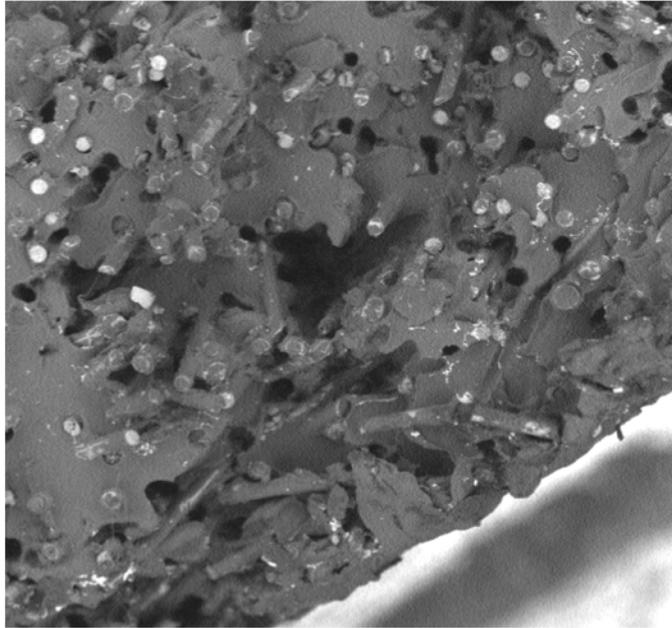
Composite Benefits

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**

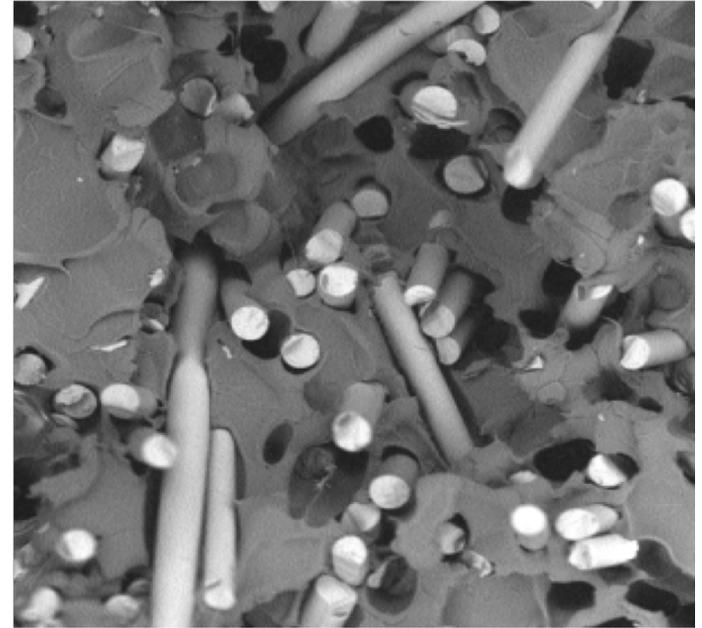


The Interface – Close up



Good Adhesion

(No pull out fibers)



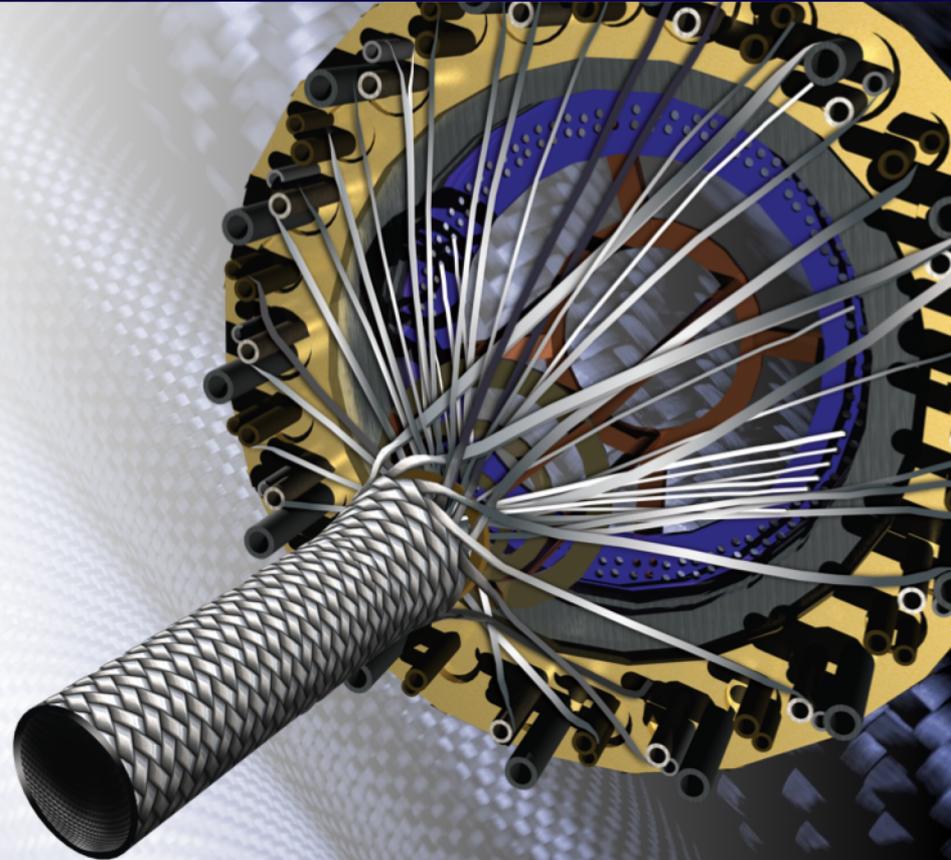
Poor Adhesion

(Fiber slippage)

Sizing Selection

Considerations when choosing a sizing:

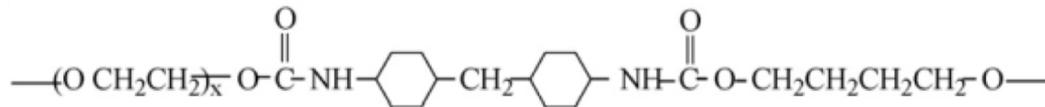
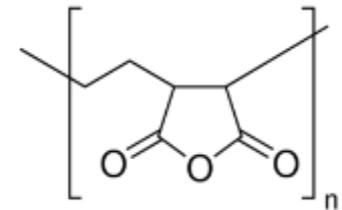
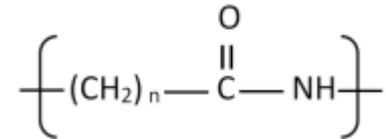
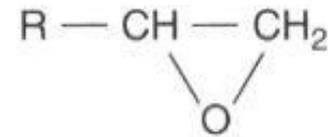
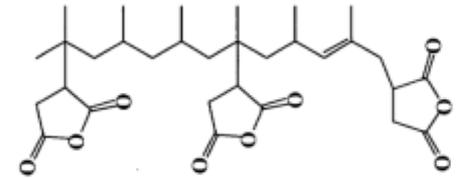
- **Type of resin:** Thermoset or thermoplastic?
- **Fiber:** Chopped or continuous; and what type of fiber?
- **Process:** Manual or automated?
- **Final application:** Automotive, household good or other?



Sizing for Matrix Resin

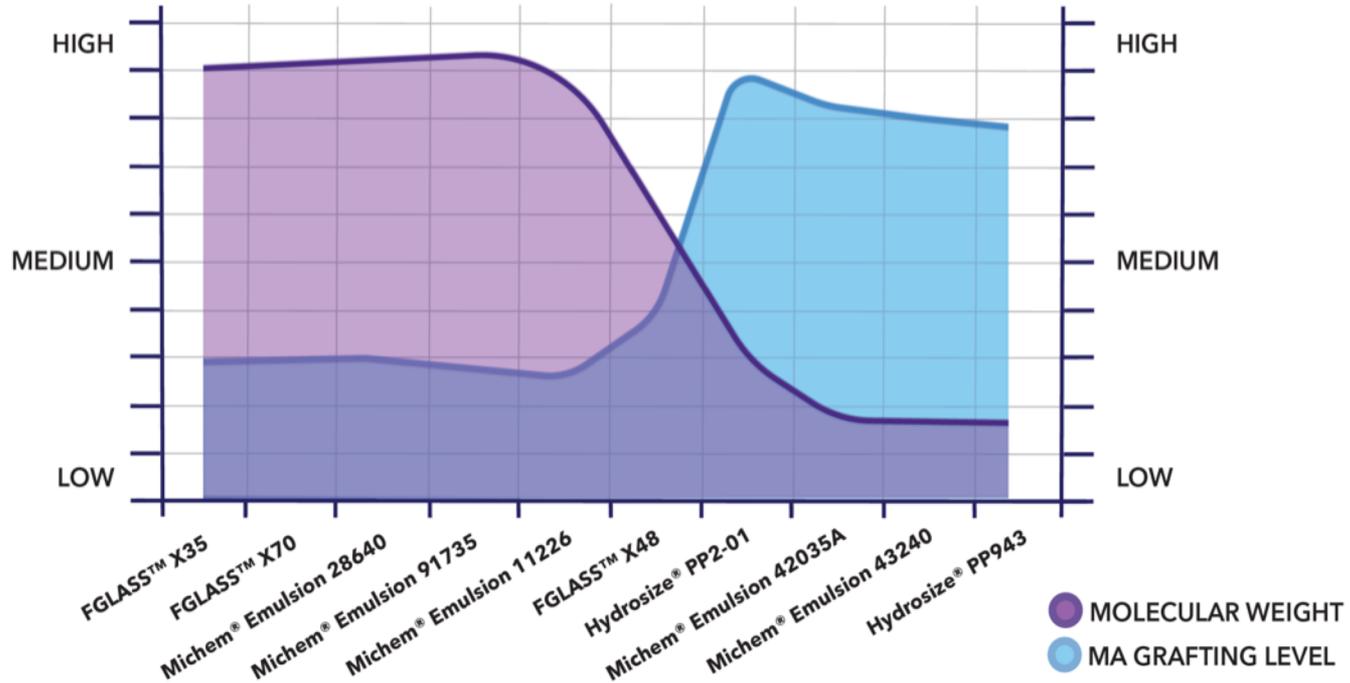
Products are designed for use in the following matrix resins :

- 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.



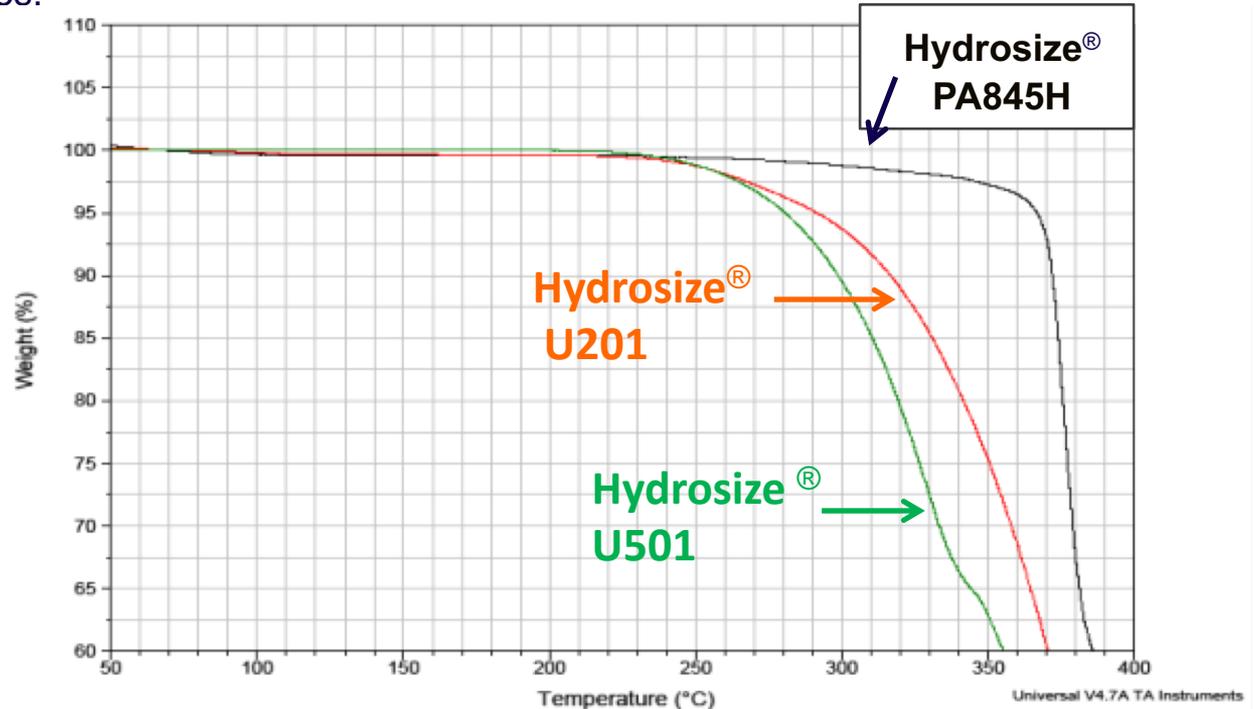
Polyamide Matrix

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	●●●	●●●	●●●		●●●	●●●	●●●

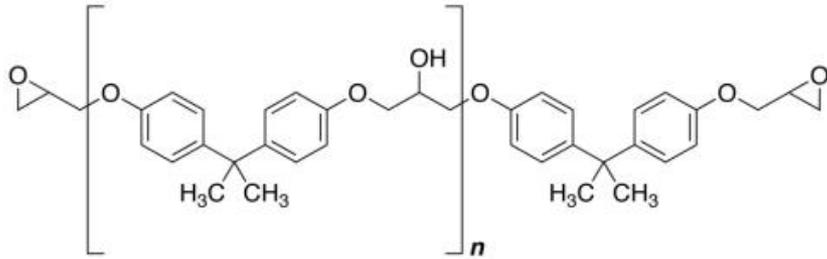
Polyamide – High Temperature

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

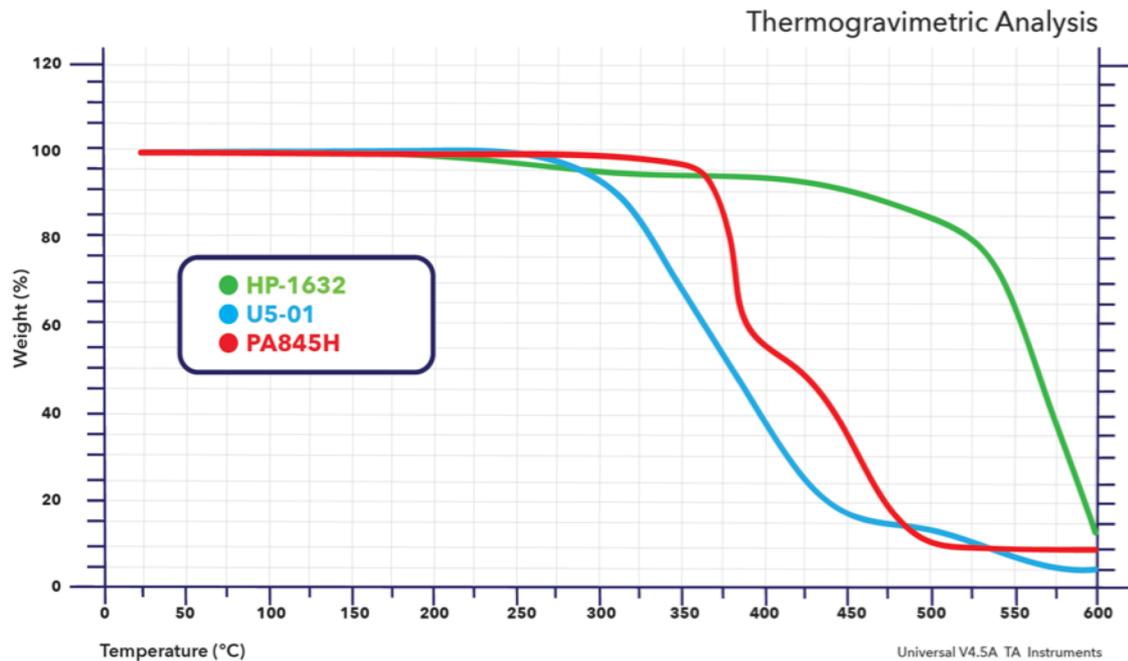
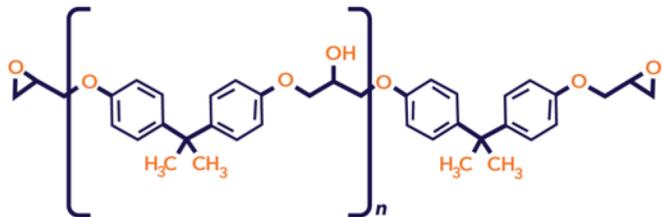
Using a proprietary process, we can make high molecular weight epoxy dispersions without any solvent. The epoxies can be used for thermoplastic polyester and/or unsaturated thermoset polyester applications.



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.

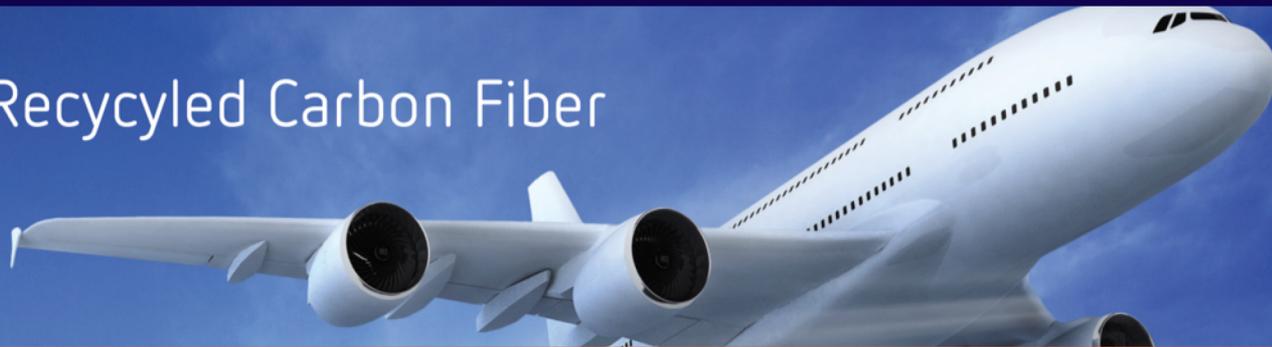
Hydrosize® Link is an enhanced reactive sizing that increase the chemical resistance of polyamide composites.

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



Emerging Applications – Recycled Carbon Fiber

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

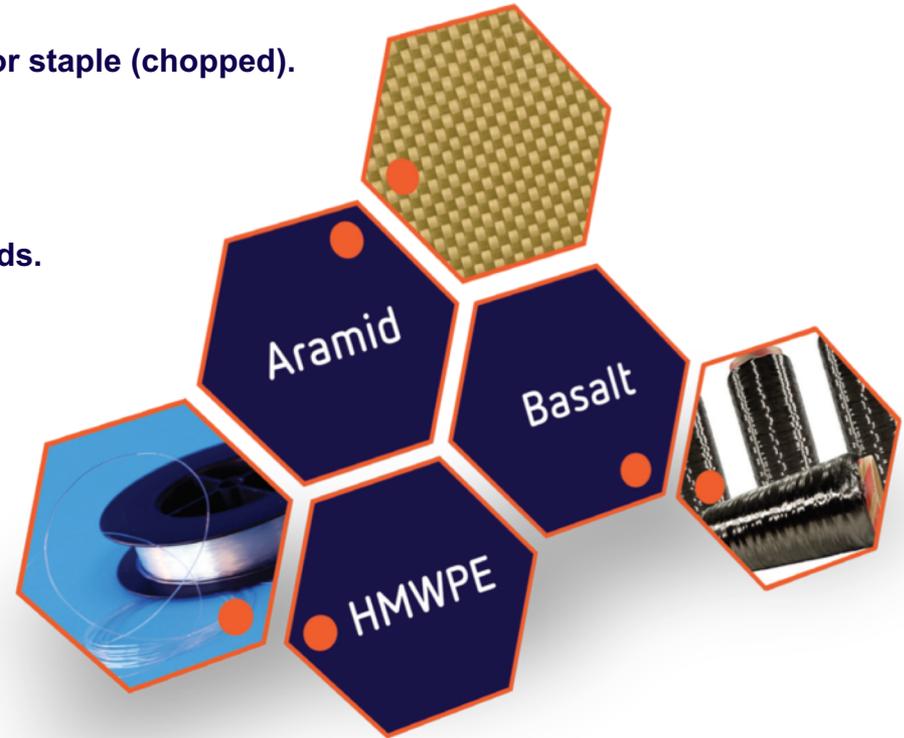


MICHELMAN
Hydrosize® Solutions

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.

Emerging Applications – Alternate Fibers/Fabrics

- 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.



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Thank You!

