The Carbon Fiber Process

What is Carbon Fiber?

Carbon fiber is a building material constructed from chemically isolated carbon in extremely pure filaments which is organized and grouped into flat sheets, woven fabric or other specialized shapes using methods familiar to the textile industry. The ability to easily form the fabric into customized shapes allows for unparalleled control over aerodynamic characteristics.

The carbon strands have extremely high tensile strength, higher than steel by a significant margin (actual values vary by grade). Designs and layups that take advantage of this tensile strength can be extremely strong compared to a metal based body – and can therefore be built much lighter with no compromise in strength.

The flexibility of design and light weight constructions that result from a high strength-to-weight ratio make Carbon Fiber especially desirable for bicycle products.

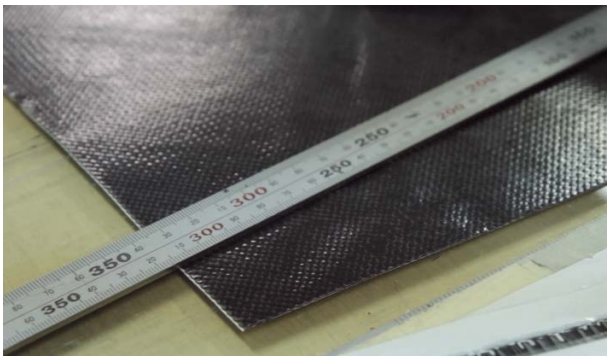
What kinds of Carbon Fiber are used for Bicycles?

While there are many kinds of Carbon Fiber available, for the most part, use in the bicycle industry is limited to Uni-Directional (UD) fiber and various weaves (denoted by the number of threads per bunch, ie 3K, 12K, 15K). A few cases will call for tubes woven on continuous weave machines, but these applications are rare since it is usually more desirable to use custom molds to create more aerodynamic shapes.

Factory sealed pre-preg UD fiber on the cutting table

There are also different grades of Carbon Fiber. These are typically denoted by the number of the manufacturer (ie T700 or T560). Each different grade is chosen for its unique characteristics, including tensile strength (MSI) and Young's modulus (stiffness), which are then used in each different layer according to the stresses experienced by that part. For example, a frame might use two layers of T700 UD in 45 degree offset from the center axis (90 degrees opposed), covered by a layer of lower modulus T560. This can be described as a "triaxial" layup and is fairly common.

There are additional composite technologies that can be used in various places, such as microspheres and even nanofibers and expanding fillers which can really maximize strength in areas of angled transition (ie around the BB).



Factory sealed pre-preg 3K weave on the cutting table

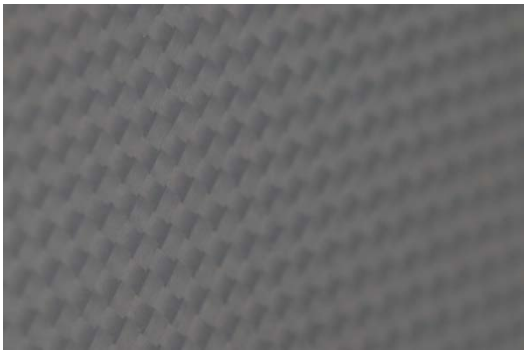
There is another element in carbon fiber products – the resin.

The resin keeps the carbon fiber in place so the carbon can bear the load. The strength of the item comes from the carbon fiber, but it is necessary to have some resin. But resin isn't as strong as carbon, so the more resin you have in the product, the heavier it will be. The type of resin used can make a huge difference, especially in rims, which can encounter very high temperatures.

For the most part, wheel and frame designs tend to stick to two or three different types and grades of fiber. All of these will be made using "pre-preg" fiber, which is chemically treated to maximize adherence of the

resin to the fibers and enable the maximum reduction in excess resin for the highest strength-to-weight ratio possible. To further this goal, Pro-Lite also uses special thick-wall silicon bladders which allow higher pressures during the forming stage to squeeze out even more of the resin.

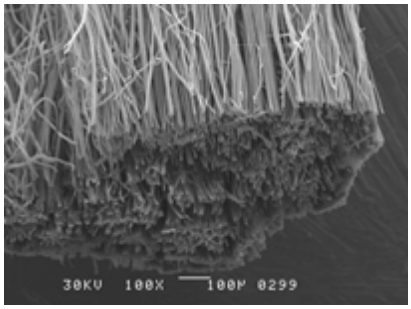
A final consideration is the weave type. While carbon fiber can be available in similar weave patterns to cloth used for clothing, it is not commonly used for bicycles. Available weave types include various ratios of Twill or a plain weave. Plain weaves are a standard weave, where the tow goes over one bundle, then under one bundle, etc. Twill weaves will pass over more than one bundle. Visually, this creates a 'diagonal rows' look, but also results in a stronger fabric.



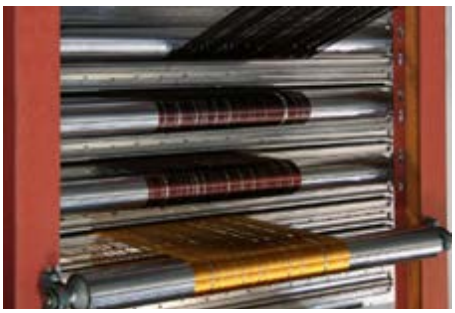
3K Plain weave top layer for omni-directional strength in the Padova Disc Wheel

How is it made?

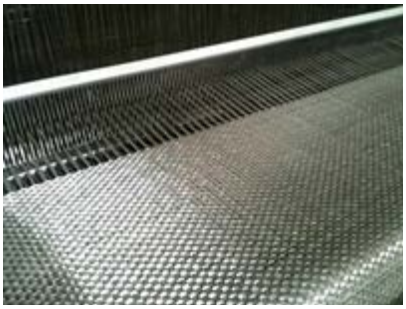
Carbon fiber is made by processing a filament made of an organic polymer to become a nearly 100% pure carbon thread.



Raw PAN Fiber (1)

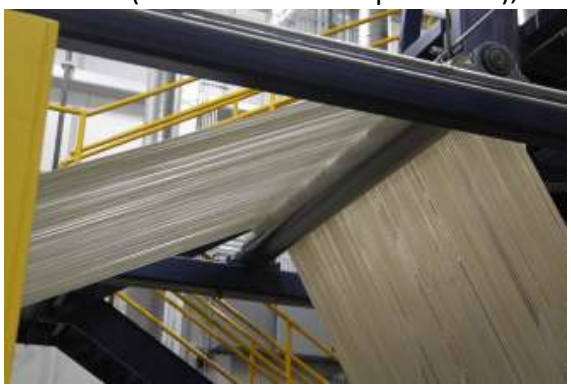


Three stages of oxidation (2)



Woven into cloth (3)

Starting as a filament of Polyacrylonitrile (PAN) (see 1 above) or other material with a similar chemical structure (referred to as the precursor), the threads are passed over many rollers to become a large course that looks like a giant sheet (see left). In the early stages, gases implant chemicals and through a series of heat treatments in oxygen free environments, reactions force the chemicals that are not carbon to dissipate. As the threads cool, they form a series of long, tightly bonded carbon crystals aligned with the length of the fiber.



Raw PAN fibers start the process in a giant white sheet on rollers.

The fiber threads are then ready for Pre-Treatment, which is like applying a primer. The surface is slightly oxidized either with a gas treatment or an electrolytic bath to roughen it and improve its ability to bond to the resin (see 2 above).

This is the step that makes "pre-preg" carbon fiber stronger than a simple cloth + epoxy method and is the reason why "pre-preg" is the preferred product for industry standard production.

Fibers produced for a weave will have a further treatment to make them more pliable and resist cracking.

Liquid resin (a heat-activated epoxy is applied and spread thoroughly before the final product is rolled up – ready to go.

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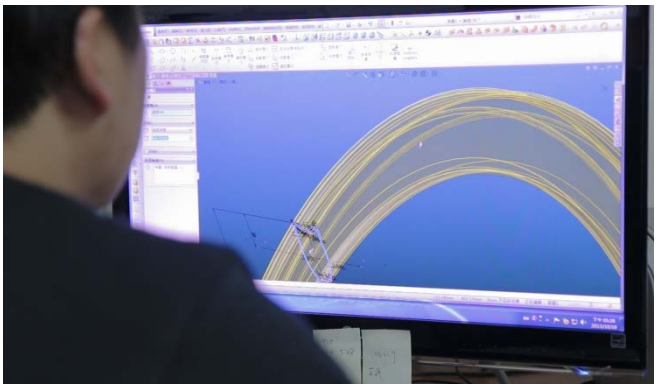
CAD engineers will prepare an extensive layout plan in layers, with each layer calculated for maximum strength against expected stresses. Considerations include unidirectional vs woven, weave count, thickness and flexibility of fiber and the direction of the fibers for the finished product of each individual piece. This is then turned into a set of operating procedures for the cutting department and the layup department.



The finished product is cured in a mold with air bladders to generate pressure to squeeze the layers together and eliminate as much resin as possible. The strength comes from the fiber: less resin means stronger and lighter.

Pro-Lite uses special high-pressure bladders which allow higher pressures.

The completed product is checked, cleaned, heat-hardened, painted or clear-coated and then it's on its way to your door.

Watch a behind-the-scenes look at our production in the Birth of a Carbon Wheel video here: http://www.youtube.com/embed/x_Us6eEyPfc