

MONTGOMERY COLLEGE STUDENT JOURNAL OF SCIENCE & MATHEMATICS
Volume 3 June 2005

Composite Materials

by

Michael Beltowski

Under the supervision of: Nevert Tahmazian

Composite Materials

by

Michael Beltowski

Composite materials by definition are items or products made up of more than one substance. These materials have been around for years and have many everyday uses. With every passing day they are refined and new uses found for them. This paper will touch on the chemistry and engineering of composites, their uses, and their future.

There are many composites that are used in everyday life. Some common ones are fiberglass, carbon fiber, and concrete. Being composite materials they are obviously made from multiple substances. Most composites are made from a filler material and some sort of solidifying material. Independently each part of a composite has its weaknesses, but together they compliment each other to make a strong product.

The two main composites this paper will discuss are fiberglass and carbon fiber. They are both used as a lightweight structural material. These particular composites are made from combining a fibrous material and either an epoxy resin or other thermosetting material. The fibers can either be spun together to make stranded cord, woven to make cloth, or left loose. Each type has its specific uses and advantages. Stranded carbon fiber cord is used as a high tensile strength cable in aviation. Woven cloth is probably the most common, being produced in mono-directional and bi-directional. Cloth is primarily used for molding shapes. Loose fibers are used for reinforcing various forms of plastics.

Fiberglass can be found in everything from insulation in a house, to ammunition shells and gas tanks. It is made up of just what its name implies, glass fibers. Fiberglass was

first developed by Owens-Corning in the mid 1930's, and is made by forcing a jet of air through molten glass. A few years later they developed a woven cloth that turned out to be flame retardant. When mixed with a polyester resin, whose formula was stolen from the Germans during WWII, created a lightweight rigid composite. Fiberglass withstands high heats without any structural degradation. The biggest advantage of fiberglass is that it is relatively light and is very cheap to produce. Of all the lightweight composite materials, fiberglass is the least expensive and most common.

Carbon fiber on the other hand is more expensive and less common. Carbon fiber is made from a polymer, called polyacrylonitrile, which is a form of graphite. Graphite is a form of pure carbon. The basic idea behind the production of carbon fiber is that polyacrylonitrile must be heated. The polymer is cooked several times at various temperatures that cause the polymer to alter its chemical structure. The process is long and complicated, releasing various gases to leave almost pure carbon. The carbon atoms are arranged into big sheets of hexagonal rings. These sheets resemble a chicken wire pattern.

These ribbon-like sheets pack together to form polymeric fibers. A polymeric fiber is a polymer whose chains are stretched out straight and are lined up next to each other, all along the same axis. These fibers can then be spun into threads or woven together. Since carbon fibers are arranged in crystals they have a very high tensile strength but also have a very low compressional strength. As a result of this carbon fiber is only strong in one direction, the direction in which the crystals are oriented. When stress is applied at a ninety-degree angle to the crystals direction they tend to break. This fact is what makes carbon fiber cloth the most used one. The cloth is a bi-directional weave, which eliminates the ability to place stress at a ninety-degree angle to the fiber. In order to strengthen the fibers, thermosetting materials are used, such as resins. Resins are two part epoxies. They surround the fiber and harden, reinforcing the fiber as well as using the fibers as a form of reinforcement.

The actual scientific process is a lot more complicated; scientists aren't exactly sure what happens during the process or even the temperatures at which the changes take place. When the polyacrylonitrile is cooked, the heat causes the cyano repeat units to form cycles. It is cooked again at a higher temperature, ~700 Celsius, this causes the hydrogen atoms to break free and the polymer to form a chain of fused pyridine rings. Next, it is cooked again at lower temperature, ~400-600 Celsius, which allows adjacent chains to bond together, creating a ribbon like substance. It is cooked one last time, at ~1300 Celsius, causing the release of nitrogen gas and allowing the ribbons to join together. When the process is complete what is left is almost pure carbon in the graphite form. (Figure 1)

The strength of materials, including composites, is measured in various ways. The three main measurements of strength are tensile, compressional, and flexural. Tensile strength is the amount of stress that can be applied to stretch a material before it breaks.

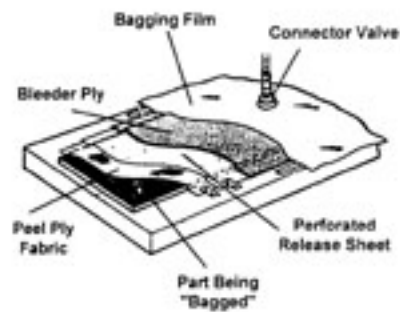
Compressional strength is measured by calculating the amount of stress that is needed to crush a material. Flexural strength is the amount of stress a material can take while bending before it breaks. All of these measurements involve stress. Stress is simply the amount of force applied divided by the area that it is applied to, and is usually measured in Newtons per square centimeter or pounds per square inch. Fibrous materials have a very high tensile strength in the direction of the crystals as well as a very good flexural strength. However, they lack compressional strength. Structural steel has a tensile strength of 400 MPa(Mega-Pascals), whereas carbon fiber has a tensile strength of 3.5 GPa(Giga-Pascals). Each GPa is equal to 1,000 MPa, which is an enormous difference.

Carbon fiber however has one major drawback, cost. It costs roughly about thirty dollars a square yard for just the carbon fiber cloth. That fact is the main reason why carbon fiber is only used in specialized situations. It is used mostly in aviation and aerospace technology, where lightweight materials are worth the extra cost. Lightweight planes reduce the amount of jet fuel required to keep them airborne. There are many uses for carbon fiber but until the production process becomes cheaper it will remain a rarity.

Composites aren't the easiest materials to work with. Even though carbon fiber is more rare it is just as easy to work with as fiberglass. Both can be worked with by hand, or produced by a process called vacuum bagging. Most commercially produced products are done through vacuum bagging. Fiberglass is easier to work with by hand. Normally fiberglass is covered with either paint or a colored gel coat, which is a hard plastic like coating. Carbon fiber, on the other hand, is normally finished with a clear gel coat because people like the look of the carbon weave. Vacuum bagging adds to the cost of the final product, due to the one time use of bagging materials. On average, production costs for a square yard of fiberglass is about fifteen dollars as compared to roughly one hundred dollars for carbon fiber.

Vacuum bagging is the main process used to produce carbon fiber products. It is just what the name implies, a bag with the air sucked out. When working with a mold it is necessary to vacuum bag for best results. First a mold is placed on a flat surface inside a bag that can be made airtight. Then a release

layer is placed over that. Next comes a bleeder ply, which allows any excess resin to wick away from the carbon fiber cloth, then comes the actual resin impregnated cloth. On top of that is another bleeder ply and release layer. The bag is then sealed and the air sucked out of it. By removing the air from the bag it presses the carbon fiber layer down around the mold while removing any bubbles and smoothing excess resin. The result is a high quality finished product.



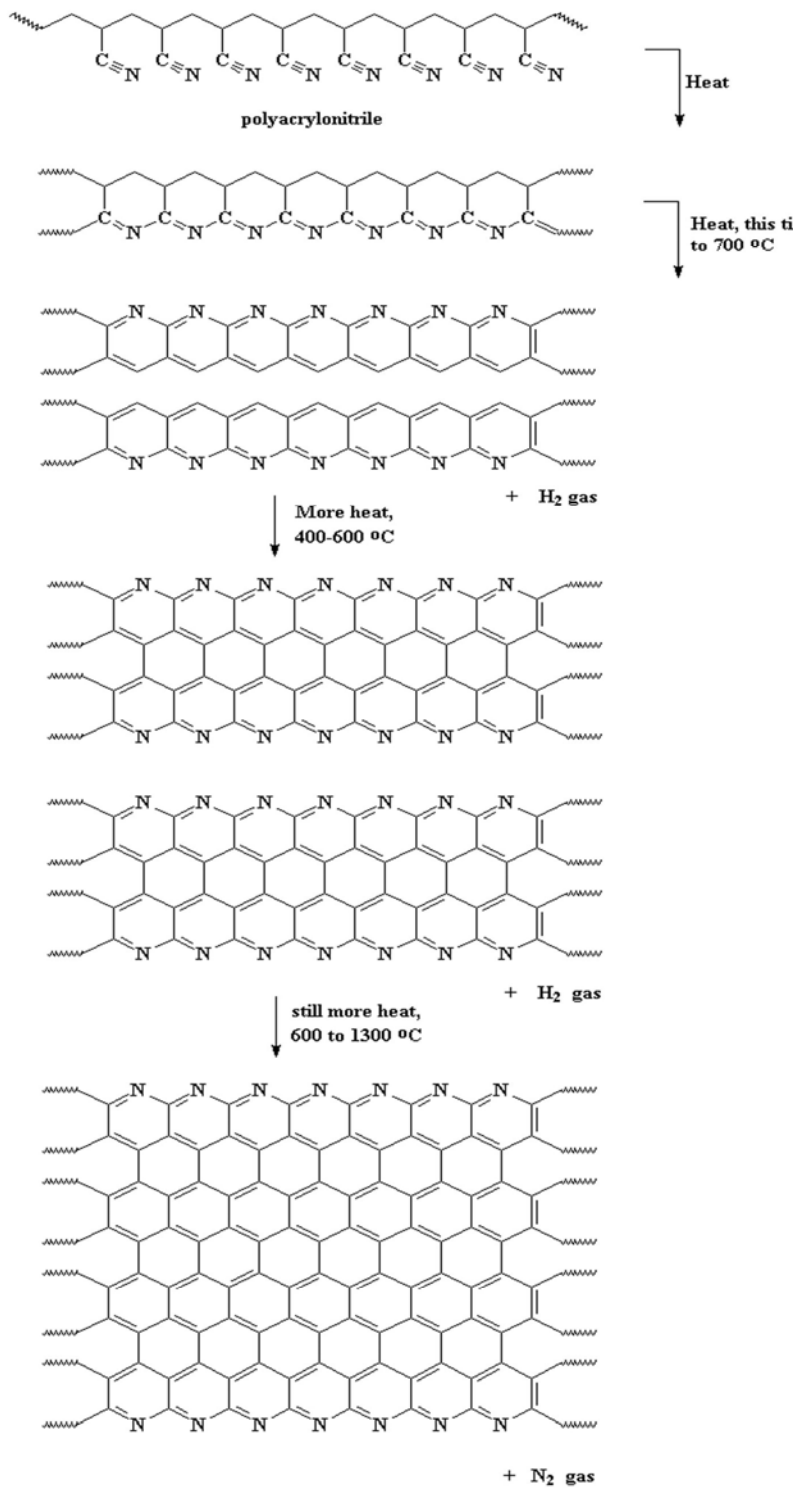
Carbon fiber cloth is only the thickness of a piece of paper. Its tensile strength is tremendous, but it is still flexible. For any practical purposes it needs to be made thicker and stronger. This can be done by putting many layers together, but that would take a large amount of cloth and raise the cost that much more. To reduce the amount of cloth

used, as well as keep the weight down, either a high density foam or thin aluminum honeycomb is sandwiched between two layers of the cloth. Carbon fiber can be used for just about anything. It can be made into tubes, angles, and any other shape needed. In some applications where the product doesn't need to be super light, fiberglass is used to add layers to the carbon fiber. Fiberglass cloth is twice as thick as carbon fiber cloth.

In the future composites will replace metals. New composites are being developed every day. In the future it is possible for carbon fiber to be the new fiberglass. As technology improves, production costs will come down making carbon fiber more common.

Currently, carbon fiber is used in very few everyday items. Exotic and race cars are now starting to incorporate carbon fiber in their chassis and body panels. The Boeing 7E7 Dreamliner uses carbon fiber in much of the structural aspects of the plane, reducing the amount of fuel needed by over twenty percent. Given the properties and advantages of carbon fiber, there is no doubt that technological advances in the area of composites, especially cost effective production will revolutionize the future.

Figure 1



Bibliography

1. Carbon Fiber. <http://www.psrc.usm.edu/macrog/carfib.htm>
2. Vince Kelly's Carbon Fiber Homepage.
<http://www.geocities.com/CapeCanaveral/1320/>
3. The History Of Fiberglass.
<http://www.psrc.usm.edu/macrog/mpm/composit/fiber/fibeglas/history.htm>
4. Tensile Strength. http://en.wikipedia.org/wiki/Tensile_strength
5. All Atoms Web Site.
<http://web1.caryacademy.org/chemistry/rushin/StudentProjects/CompoundWebSites/2002/CarbonFiber/default.htm>
6. Buckyballs, Diamond, and Graphite.
<http://www.chem.wisc.edu/~newtrad/CurrRef/BDGTopic/BDGtext/BDGGraph.html>