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MATERIAL SELECTION FOR CAR BODIES

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INTRODUCTION

Materials for car bodies in today's time of efficiency are an interesting challenge. The industry needs a lightweight, strong, easily manufactured, and cheap material to do the job. Lightweight materials can improve efficiency by a big margin if enough weight is removed. "The EPA says that for every 100lbs fuel economy can be increased by 1-2%" according to Autoblog.com.[1] If a material can provide enough strength without adding weight engineers can find a way to get more efficiency out of vehicles. Finding a material that is strong, lightweight, easily manufactured and low cost would allow car manufactures to build cars with lower emissions helping the planet as well as making it economically viable for the average human to afford.

MATERIAL SELECTION

We have chosen Carbon Fiber as our material choice. It may not be as cheap and easily manufactured as steel, but it is extremely lightweight and strong. Zoltek a carbon fiber producing company states "the strongest carbon fibers are ten times stronger than steel and eight times that of aluminum, not to mention much lighter than both materials, 5 and 1.5 times respectively. Additionally, their fatigue properties are superior to all known metallic structures".[2] This allows engineers a lot of freedom in how to design a car without worrying about a huge weight penalty for the same stiffness. Carbon fiber costs about $44/kg to produce, mostly from its production costs. According to the Oak Ridge National Laboratory, if the cost can be reduced to about $11/kg it can see widespread use in making car bodies. Its competition includes steel and aluminum. Steel costs $2.2/kg and aluminum cost $1.76/kg to produce. Problems with those are that steel is about 20% heavier, and aluminum has 1/3 the tensile strength carbon fiber has. The application of carbon fibers in cars is becoming more and more common as the material has reduced in cost and companies are investing more in manufacturing plants for production.

The lightest weighing cars in the world are Formula 1 cars. The cars have a minimum weight of 702kg or 1548lb with a driver and the body is made of carbon fiber. Compare that to the average vehicle weight right now of 2900lbs which are made of Aluminum mostly now. F1 cars are under extreme loads constantly and can handle tremendous impacts without injuring the driver. The potential for carbon fiber use in cars has already been proven.

As engineers we need to find a way to make it economically viable to produce family cars with carbon fiber as a major component to reduce weight while being safe still. This weight reduction alone has huge potential in efficiency not only for just car body production, but for other areas of the car.

STRUCTURE

Carbon Fiber is theoretically 100 percent carbon atoms. In reality there will always be trace elements. This carbon atom structure is bonded using covalent bonds as most carbon atoms are bonding with other carbon atoms. Modern carbon fiber is made using a precursor polymer then carbonizing it. The precursor polyacrylonitrile (PAN) is used for most modern carbon fiber[3]. The repeating unit for PAN is C_3H_3N. The carbonization process causes the bonds to break and allowing the just the carbon atoms to bond together creating the super strong covalent carbon bonds to form into hexagonal graphite ribbons. These ribbons have weak Van der Waals bonds between the layers. Carbon fibers however get their strength from the folding of these ribbons and interlocking of them. Carbon Fibers are note however graphite, as graphite is just carbon in a hexagonal lattice. Carbon fibers are an amorphous due to having no long-range order.

MIT graphics of these bonds

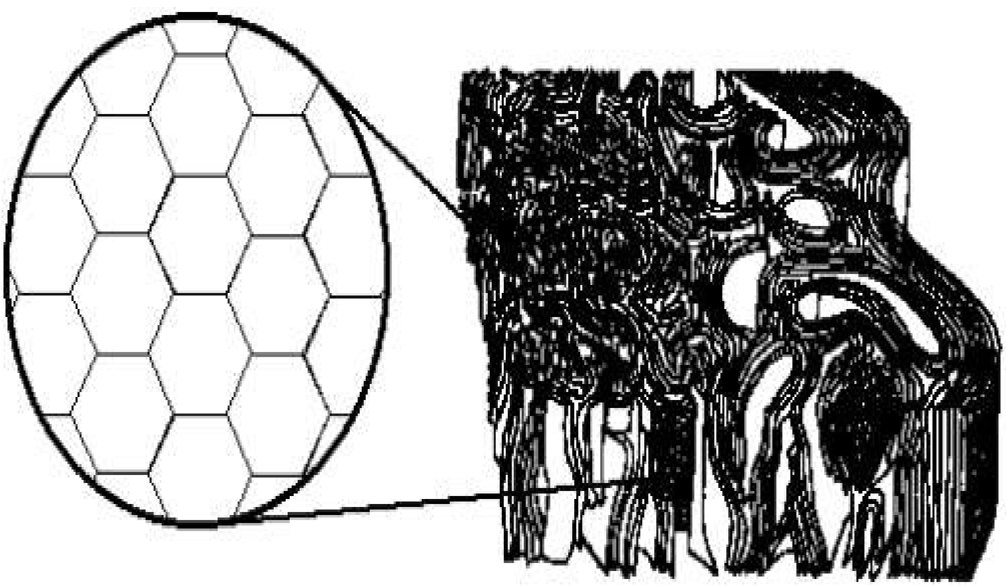


Image above shows folding of hexagonal graphite layers.

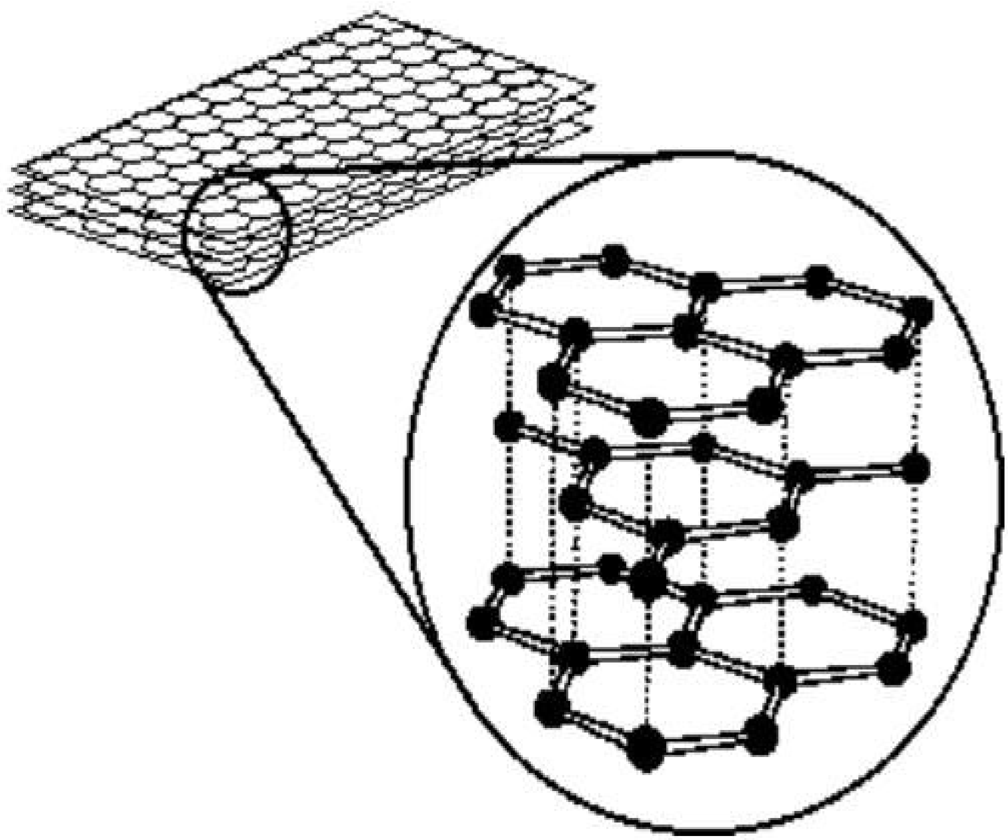
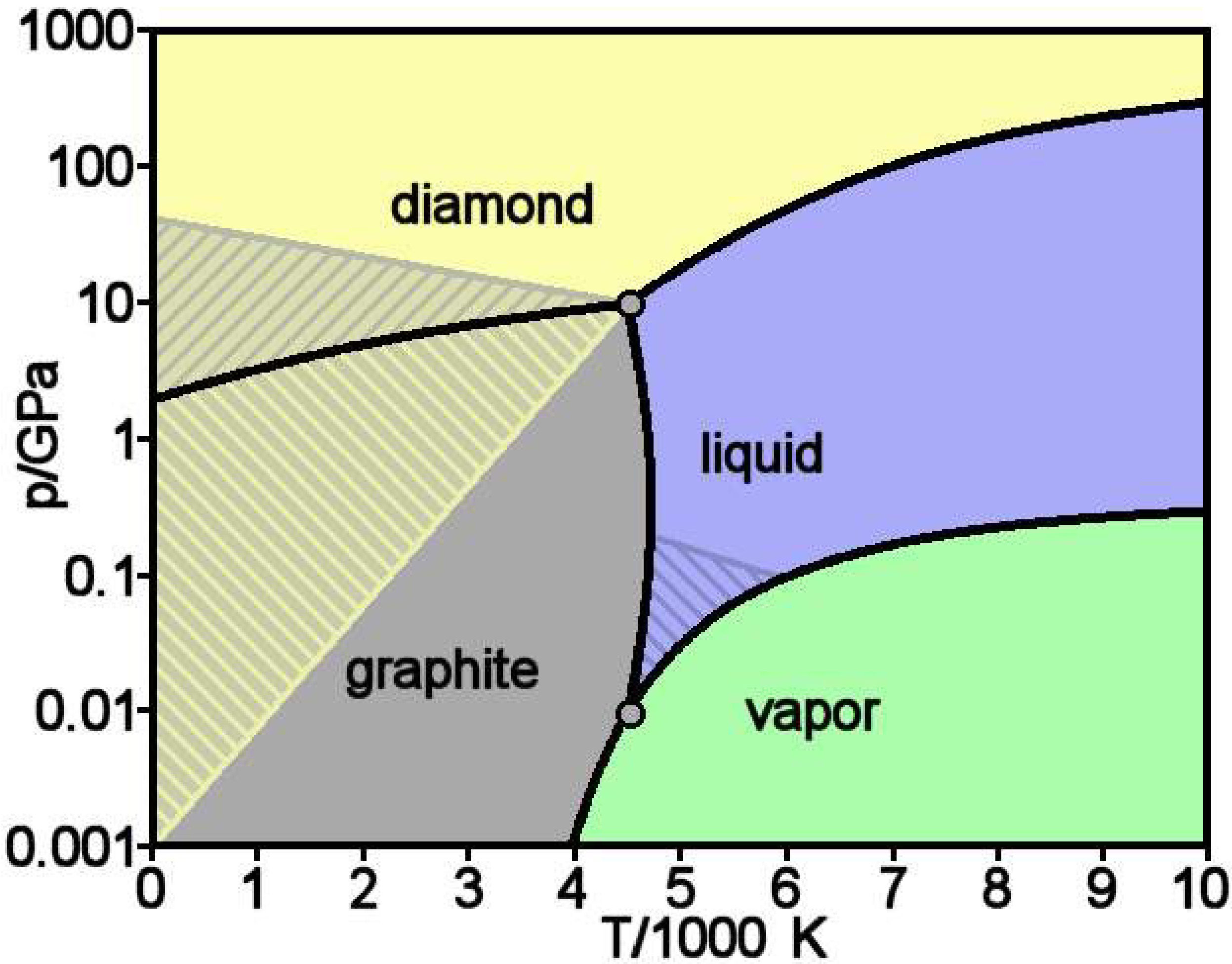


Image above shows the hexagonal graphite layers.

PHASE DIAGRAM

The carbon phase diagram is a relatively simple one compared to an Iron-Carbon phase diagram.



At high temperatures and pressures diamonds form. Where it becomes interesting is the graphite and diamond regions. These regions are metastable regions. This means there is state of the material that is not at its lowest energy but not having enough energy to transform into the different phase. Most carbon fibers are carbonized at 1500-2500°C and .0001 GPa. This puts carbon fibers well into the graphite range of carbon. The triple point of carbon is at about 4300K and .01 GPa.

PREDICTIONS

- Microstructure

The microstructure of carbon fibers because it is a polymer is probably a network due to its high strength. The Carbon-Carbon covalent bonds want to be fulfilled so you would expect carbon fiber to have a strong network of bonds holding everything together. Carbon fiber's diffusion follows Fick's law, when absorbing liquid. The diffusion coefficient for carbon fiber at 323K is 1.76×10^8.

- Mechanical Properties

The mechanical properties of carbon fibers would expect to have high tensile strength due to the orientation of the fibers. Carbon fibers are also highly conductive of electricity due to the easy path electrons can take through the carbon matrix. The heat expansion would also be relatively small due to the amount of energy it would take for the atoms to want to expand out of the strong covalent bonds they are in. Young's Modulus for Carbon Fiber is 150 GPa. Yield strength is 3.5 Gpa.

Comparison between Carbon Fiber and competitors

Material	Young's Modulus(GPa)	Tensile Strength(MPa)	Density g/cc
Carbon Fiber	120	2250	1.57
Alloy Steel	205	1275	7.85
Aluminum	71.7	570	2.81

- Strengthening Mechanisms

Some strengthen mechanisms you could possible do is to weave the fibers in different directions. This would be grain refinement making it harder for dislocations to travel before hitting a "grain boundary" in a sense. Another possible scenario is to weave a metal fiber into the carbon weave, such as titanium. Carbonizing at different temperatures and leaving some of the Nitrogen in the material from PAN, may also act like a solid solution making dislocations harder to move throughout the fiber.

IMPACT ON SOCIETY

The impact on Society could be huge. Efficiency is a key point to reducing our greenhouse gas impact on the world. As mentioned before for every 100lbs loss we could reduce emissions by 1-2%. If we could reduce an SUVs weight from 6000lbs to 4500 while maintaining all the strength of an Aluminum-alloy, you could decrease the amount of fuel used by 15-30% theoretically. Imagine the impact that would have over thousands of cars. Weight of the body would not be the only factors. You could reduce the motor size to get even more efficient as you aren't having to move the same amount of mass as before. The application of carbon fiber is becoming more and more into the practical world, from once an exotic material and only used for high end race cars to now use in hockey sticks and modern sports cars. There are so many possibilities for carbon fiber to impact the automotive industry that we are starting to see to now. As the race for efficiency and weight reduction dominate the industry, Carbon Fiber is an answer.

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