# TURNING PLASTIC BAGS INTO CARBON NANOTUBES

I was surprised to learn recently that plastic bags can be turned into a new material called carbon nanotubes. Prior to this, all I had heard about plastic bags was about the environmental threat that they potentially pose, either by accumulating in wildlife or clogging landfills with slow-to-break-down waste. Many recycling techniques have been developed to reduce plastic bag waste, but there were very few ways to convert it into a new technologies–until a recent study on carbon nanotubes came on the scene.


As I write these words, thousands of plastic bags are being used around the world. And unfortunately, only a small fraction of those are recycled. The rest is piling up in the environment. From a pile of plastic bags to new technologies… WHAT?!

Carbon nanotube technology is rapidly growing to become an integral part of our lives due to nanotubes' unique mechanical and electrical properties. You can already find them in many pieces of sports equipment, such as tennis racquets, hockey sticks, and golf balls, since they make materials much lighter in weight and more resistant to damage. What is more, carbon nanotubes are a promising material for lithium-ion batteries and solar cells. But how is it possible to produce these fancy high-technology materials from trashed grocery bags?

To understand this, let's first look at what carbon nanotubes are. Carbon nanotubes are composed entirely of a single element – carbon. So they are nothing but a form of carbon, just like diamond or graphite—two other materials that are made entirely of the element carbon, and that differ only in the way those carbon atoms are arranged.

Now, imagine a sheet of carbon atoms arranged in a hexagonal pattern, just like in the cross-section of a honeycomb, but on a much smaller scale.

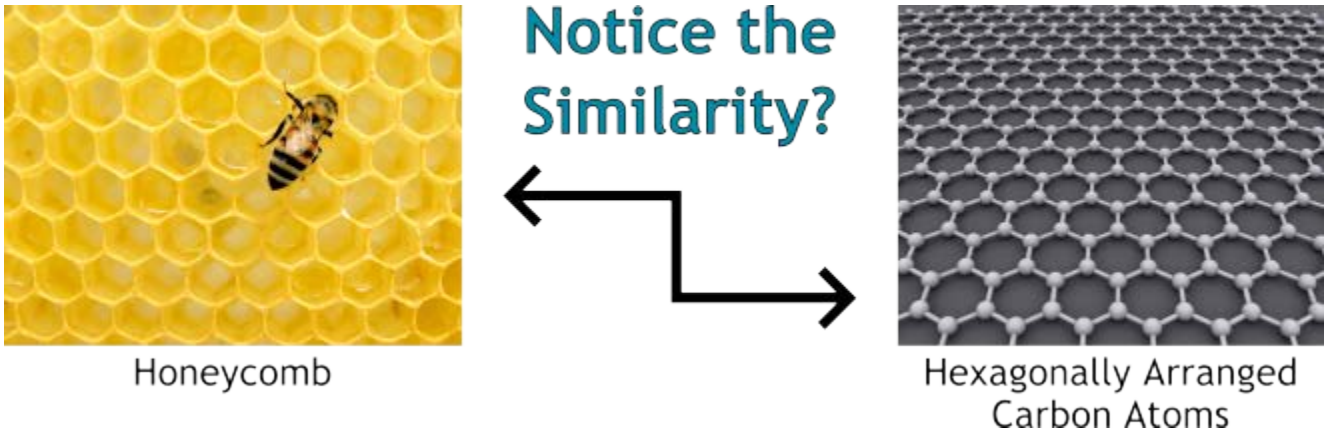
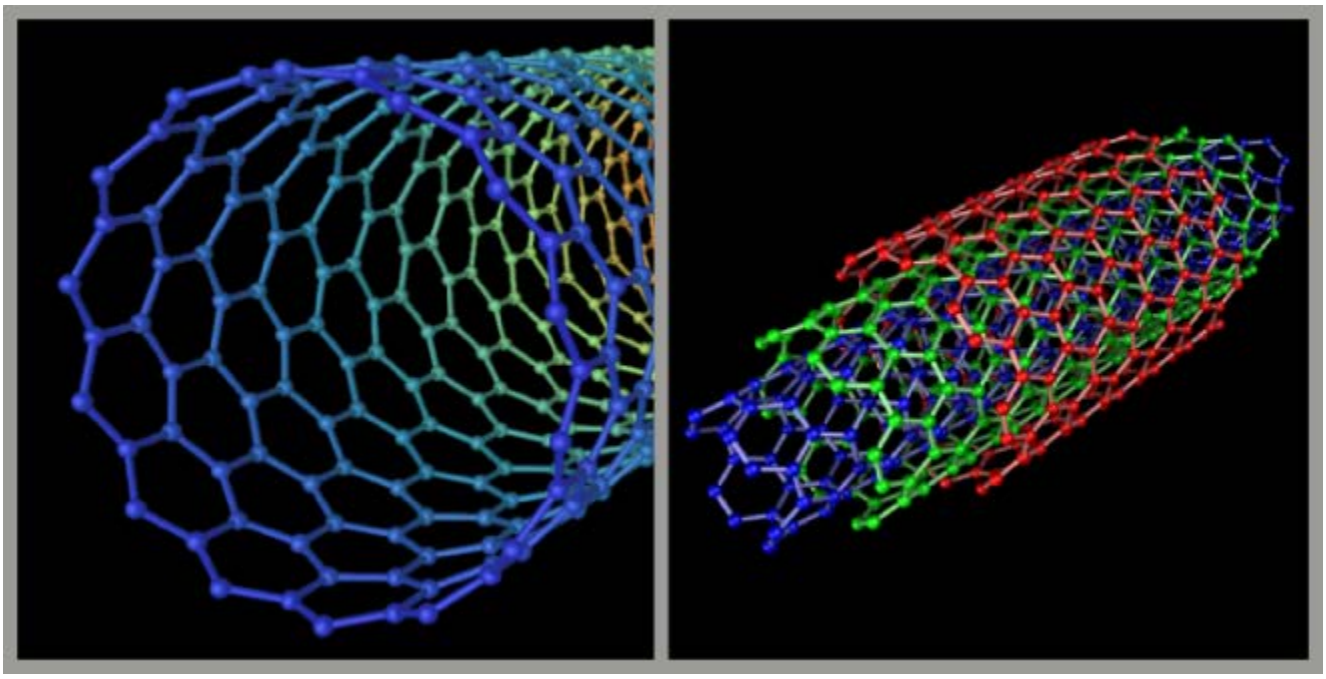



Image adapted from Source1 (Texas Photographer, Matthew T Rader) and Source2.

If we pile up several of these one-atom-thick carbon sheets, we will end up with the material in our pencils, which is graphite. On the other hand, if we take a single sheet and roll it into a nano-sized cylinder, we will obtain a carbon nanotube. The strong interactions between atoms in these coiled structures is what makes carbon nanotubes stronger than many materials, even stronger than steel!* These interesting materials may feature different properties according to the way we roll them. They can appear as single tubes (Single-Walled Nanotubes) as well as nested tubes (Multi-walled Nanotubes), one inside another.

The former is more flexible, whereas the latter has high thermal stability to keep it from melting like ice cream! But both structures are still pure carbon.



Single-walled and multi-walled carbon nanotubes. Image Source1 and Source2.

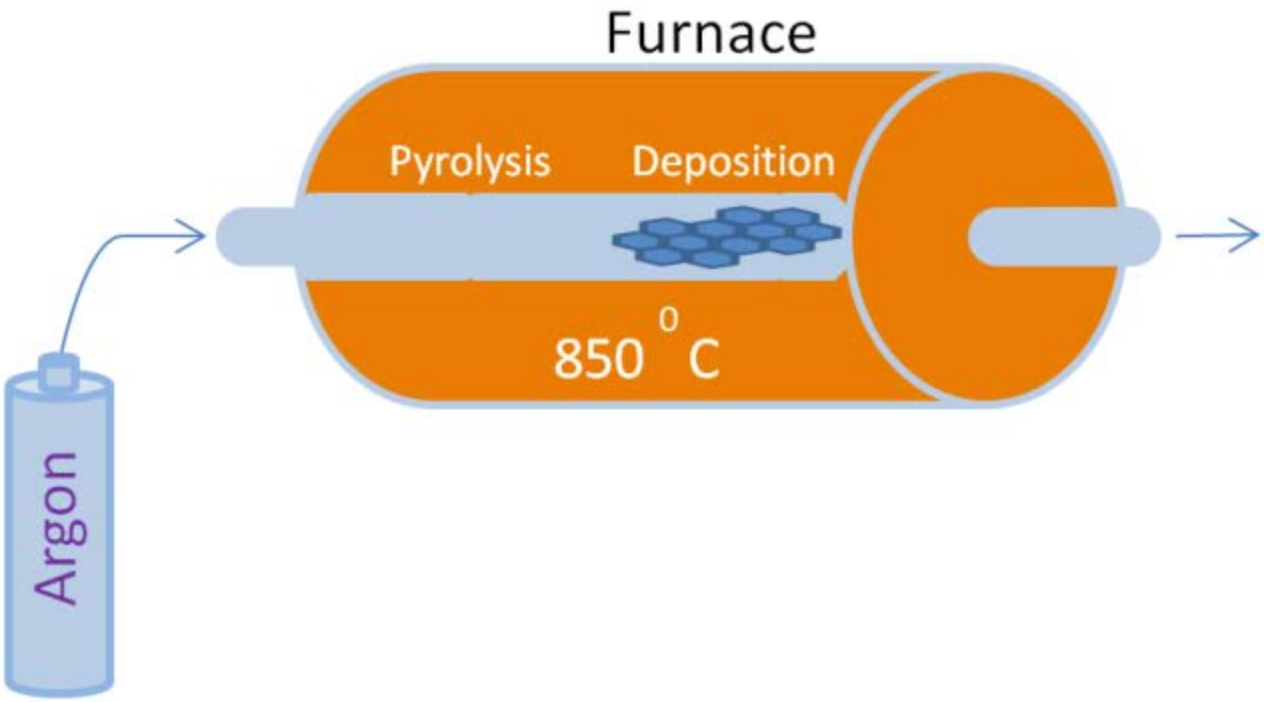
Now that we roughly know what carbon nanotubes are, how are they related to plastic bags? Most plastic bags – the ones that make shopping much easier, the ones that we use to take our croissants home – are made of low density polyethylene. Polyethylene is a chain of carbon atoms, along with hydrogen atoms that are bonded to the carbon chain links.

A cartoon of one small segment of a polyethylene chain. The black spheres are carbon atoms, the grey spheres are hydrogen atoms.

As most of the weight of polyethylene comes from carbon atoms, and carbon nanotubes are composed solely of carbon, the prospect of transforming plastic into carbon nanotubes is hopefully becoming more imaginable in your mind. Scientists are using plastic bags as the carbon source of the nanotubes! This is what science is all about, imagination and making connections.

Let’s take a closer look at how Australian scientists made this happen.

Heat, as a form of energy, makes changes in the system on the molecular and atomic level. When we heat coal in air, it burns to form carbon dioxide and water. However, burning occurs when there is oxygen present. Let’s say we heat carbon in such an environment that there is no oxygen… Can a process other than burning occur?




Chemical Vapor Deposition Instrument

It turns out there is a scientific instrument that can do just that! Chemical Vapor Deposition instruments have a furnace that flushes oxygen away by blowing argon gas through. This oxygen-free furnace kept at very high temperatures is where the entire nanotube formation process occurs. Initially, the cleaned plastic bags are heated up to 850 $^{o}$C. Remember there is no oxygen, so the polymer breaks down and releases carbon atoms – rather than burning. Then, the carbon atoms travel to the build-up section where scientists have placed special membranes with hexagonally arranged cylindrical pores. Carbon atoms fit within these hexagons and grow within the pores. With these membranes, carbon nanotubes can be formed in any shape and size (of course as much as the chemistry allows). Depending on the time spent in the furnace, the tubes can grow up to a few centimeters long. This may sound short to you, but for tubes whose walls are only one atom thick, this is incredibly long! In the final step of the process, the scientists perform a chemical carving procedure known as etching, to remove the hexagonal membranes and release free carbon nanotubes.

Out of plastic bags, carbon nanotubes are now ready to be engineered into tennis racquets and a whole variety of emerging technologies.

Although it wouldn’t be practical to transform all the waste plastic bags worldwide into nanotubes, it is really exciting to see this creative approach to waste reduction that produces an exciting new technology. Not to mention that this process makes tubes of pure carbon that can be as small as 1 nanometer in diameter. This is 100,000 times smaller than the average human hair diameter!

Source : http://sustainable-nano.com/2014/03/04/turning-plastic-bags-into-carbon-nanotubes/