Semiconducting and Metallic Carbon Nanotubes

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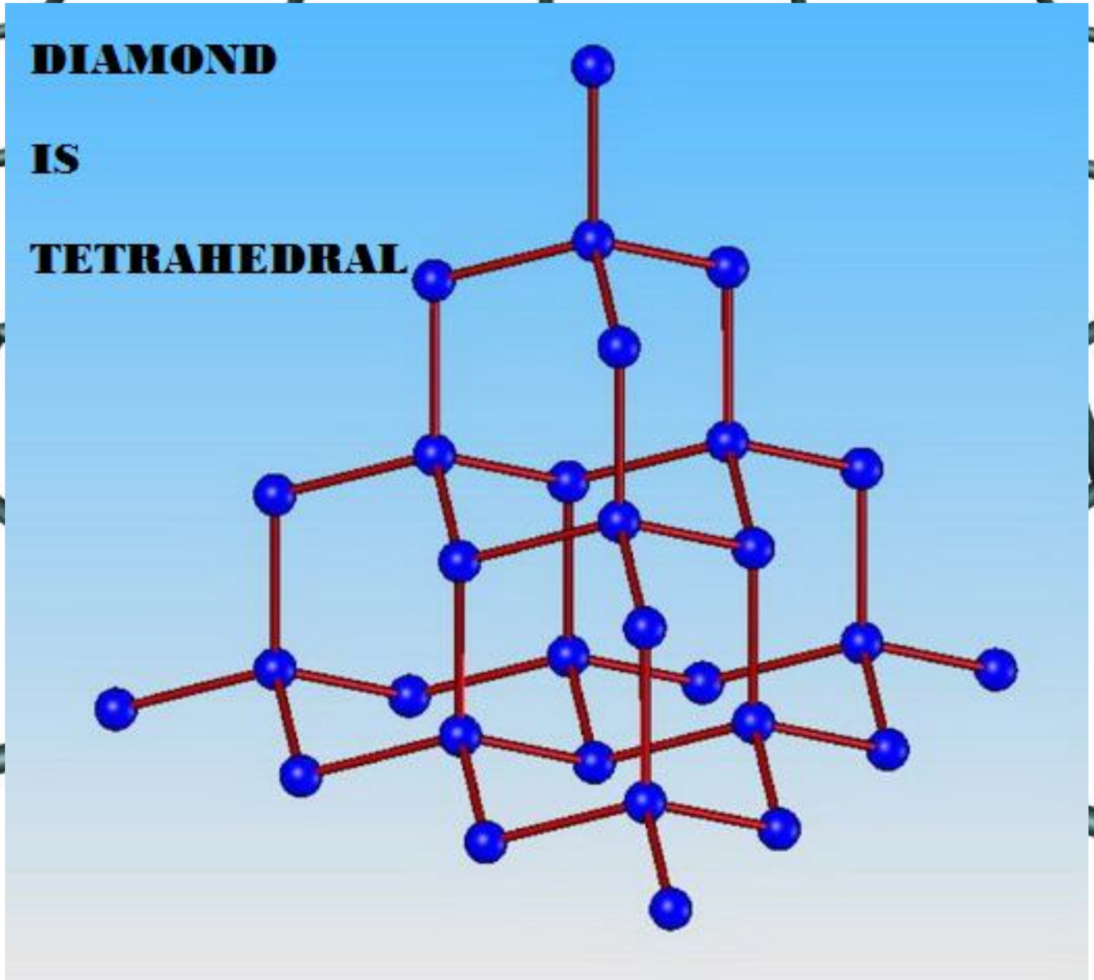
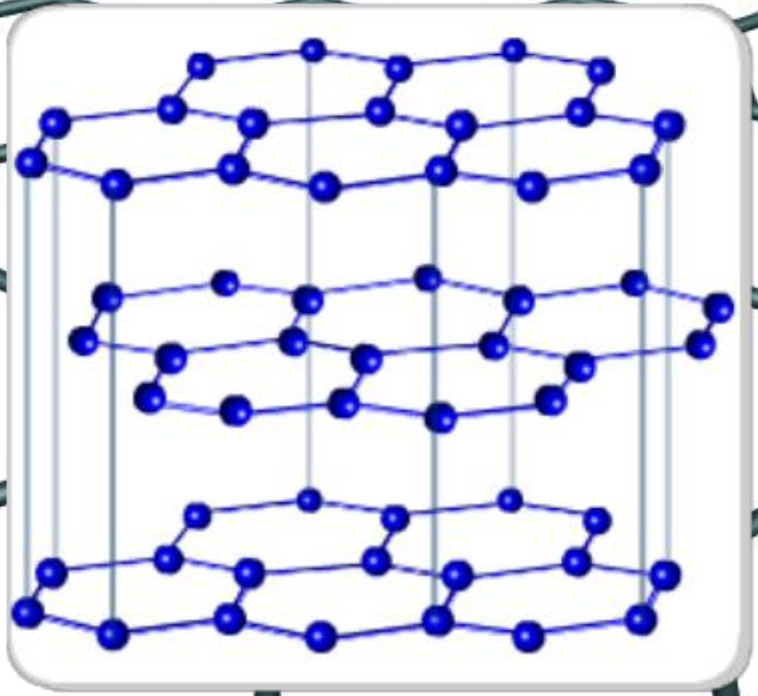
Why Carbon?

- Carbon's 4 valence electrons allow it to take many forms when bonded together with other carbon atoms

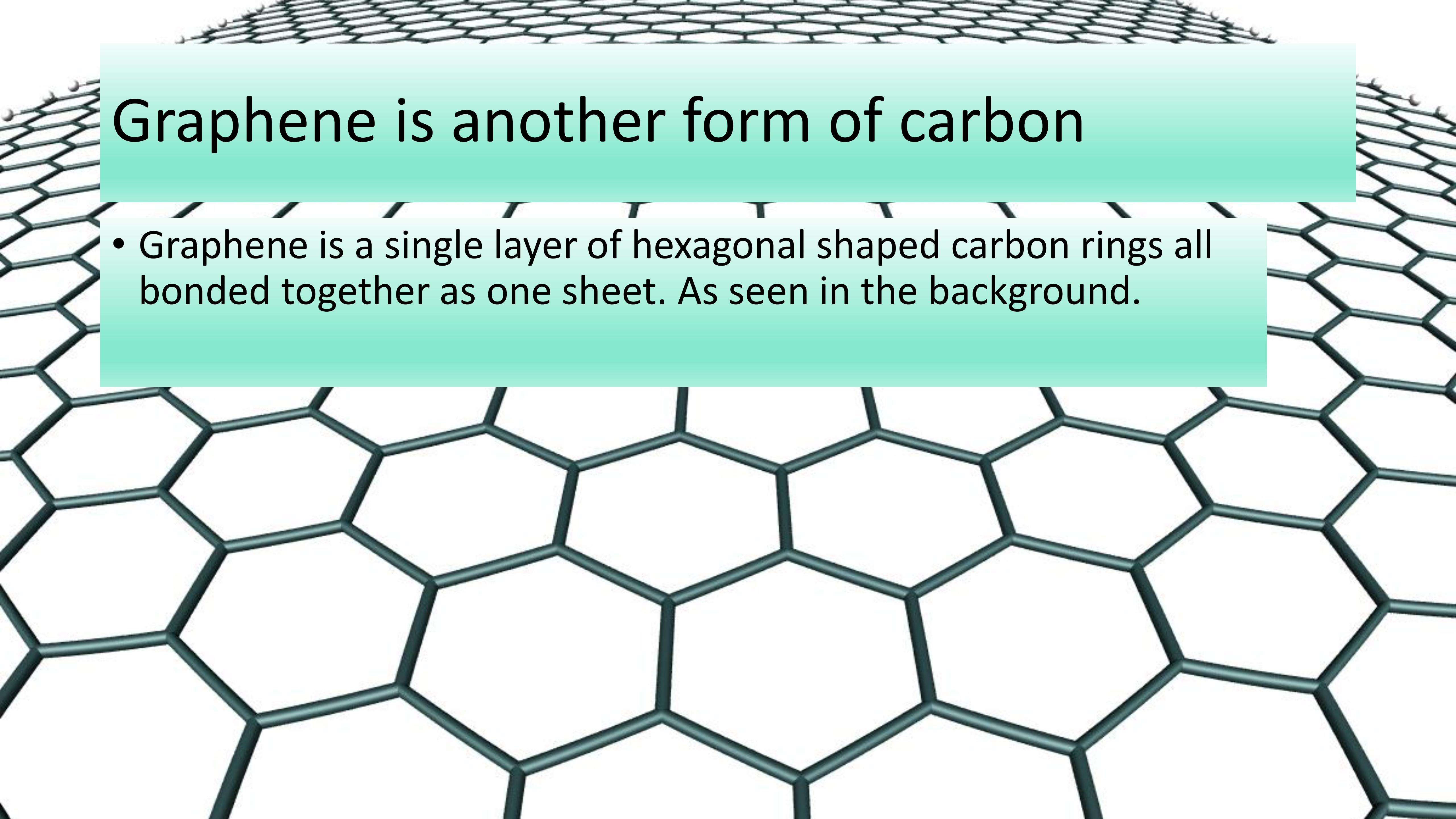


Graphite has layers of hexagonal sheets stacked on top of each other



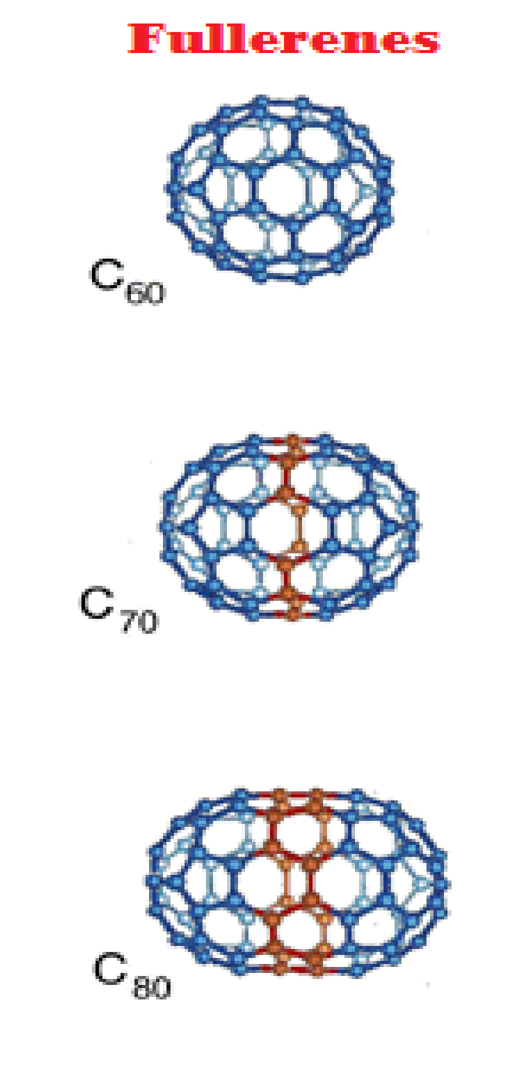
Graphene is another form of carbon

- Graphene is a single layer of hexagonal shaped carbon rings all bonded together as one sheet. As seen in the background.



What are carbon nanotubes?

- Carbon nanotubes exist as a macro-molecule of carbon, analogous to a sheet of graphite, rolled into a cylinder.
- Graphite in its molecular form looks like a sheet of chicken wire, a tessellation of hexagonal rings of carbon.(Look at the background ☺)
- When coiled, the carbon arrangement becomes exceptionally strong.
- They have the ability to be either metallic or semi-conducting depending on the twist of the tube as well as diameter.



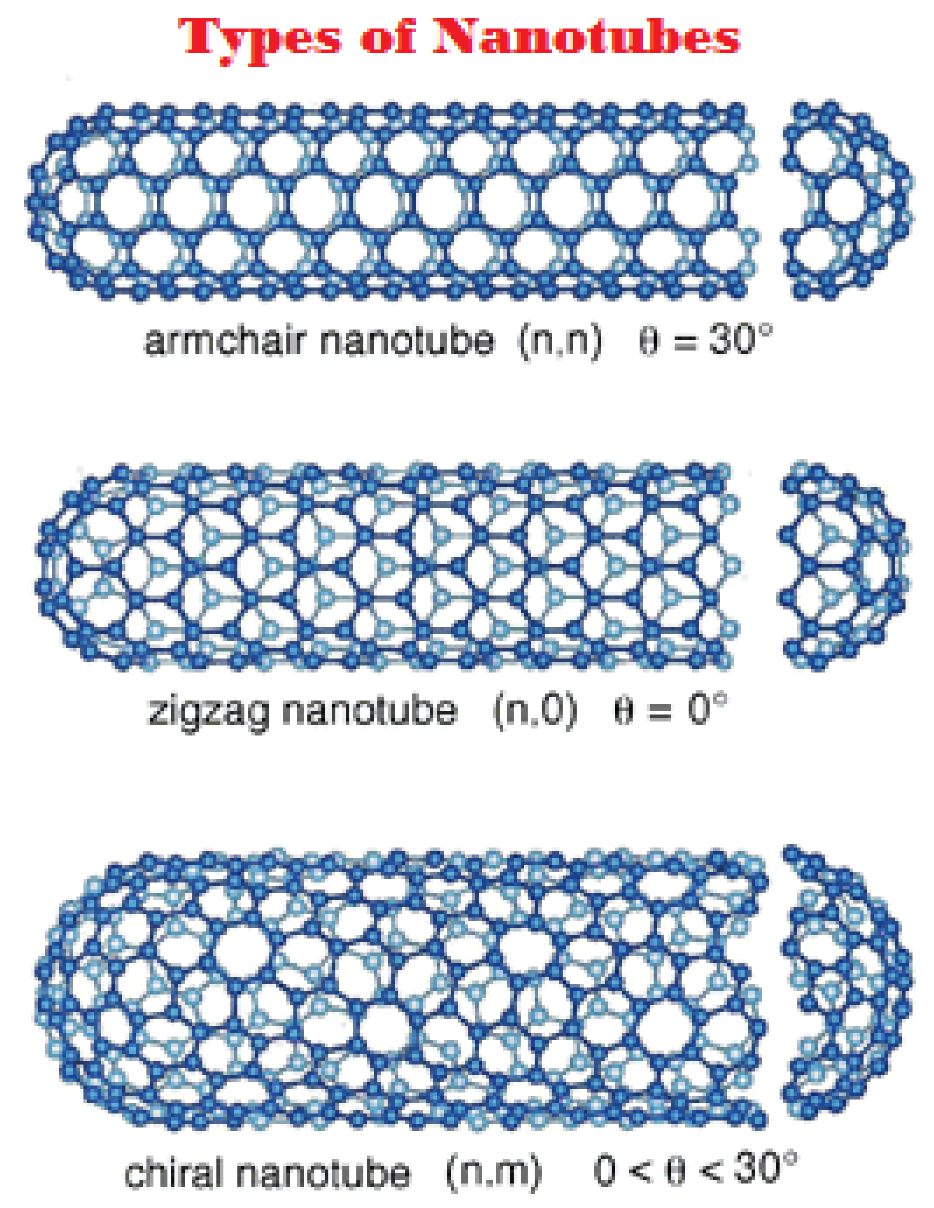
Composition

- Nanotubes are members of the fullerene structural family.
- Fullerene is any molecule composed entirely of carbon, in the form of a hollow sphere, ellipsoid, tube, and many other shapes.

Types of Nanotubes

Simply put, carbon nanotubes exist as a macro-molecule of carbon, analogous to a sheet of graphite (the pure, brittle form of carbon in your pencil lead) rolled into a cylinder. Graphite looks like a sheet of chicken wire, a tessellation of hexagonal rings of carbon. Sheets of graphite in your pencil lay stacked on top on one another, but they slide past each other and can be separated easily, which is how it is used for writing. However, when coiled, the carbon arrangement becomes very strong. In fact, nanotubes have been known to be up to one hundred times as strong as steel and almost two millimeters long! These nanotubes have a hemispherical "cap" at each end of the cylinder. They are light, flexible, thermally stabile, and are chemically inert. They have the ability to be either metallic or semi-conducting depending on the "twist" of the tube.

The diameter of a carbon nanotube and the amount of twist in its lattice determines whether it's metallic or semiconducting. Electrons in carbon nanotubes can only be at certain energy levels, just like electrons in atoms. A nanotube is metallic if the energy level that allows delocalized electrons to flow between atoms throughout the nanotube (referred to as the conduction band) is right above the energy level used by electrons attached to atoms (the valance band). In a metallic nanotube, electrons can easily move to the conduction band. A nanotube is semiconducting if the energy level of the conduction band is high enough so that there is an energy gap between it and the valance band. In this case, additional energy, such as light, is needed for an electron to jump that gap to move to the conduction band. While there is no gap between the valance and conduction bands for armchair nanotubes (which makes them metallic), an energy gap does exist between the valance and conduction bands in about two thirds of zigzag and chiral nanotubes — which makes them semiconducting.



History of the Carbon Nanotube

When	Who	Events
1970s	Harry Kroto & Dave Walton	Try to synthesize long carbon chains
Late 1980s	Scientists around the world	Buckyball was synthesized and confirmed as C60
1991	Japanese Scientist, Sumio Iijima	Discovery of multi wall carbon nanotubes
1993	S, Iijima and T, Ichihashi	Synthesis of single wall carbon nanotubes
1996	Robert F. Curl, Harry Kroto , Richard E. Smalley	Nobel Prize in Chemistry for the discovery of Buckyball
1999	Samsung	Flat Panel display prototype
2001	IBM	The first computer circuit composed of only one single carbon nanotube

Applications of Nanotubes

Cell Therapy : Modified carbon nanotubes can enter cells and deliver drugs or knock out unwanted genes. Recently, in a cross-collaboration between researchers in France and England, Alberto Bianco and Kosta Kostarelos used modified nanotubes to control the damage created by a stroke. “We have demonstrated that animals could recover their functions after a stroke thanks to the silencing of a gene following intracranial injection of siRNA complexed to carbon nanotubes,” Bianco said. ”The surprise was the efficacy of the system as we could use a very low amount of carbon nanotubes.”

Better Displays : From flat screens, to LEDs to flexible displays, nanotubes will increase your viewing pleasure and portability. These tiny pipes of carbon make excellent field emitters or conductive surfaces. They use less energy, are sturdier, and if your machine happens to heat up (which probably won’t happen because they’re amazing heat sinks as well) you’re device won’t even break down. In 2008, Samsung unveiled the first carbon nanotube ‘e-paper’ display, which needs no backlighting. Researchers at the University of Cambridge have also demonstrated a 3D hologram projected by carbon nanotube optical field emitters.

Gecko Tape : Geckos climb up smooth surfaces due to the tiny hairs on their feet exploiting the electrostatic force between themselves and the wall. Carbon nanotubes are used in a gecko-inspired tape that sticks to dry smooth surfaces when pressed against them. The tape is amazingly sturdy: Geckos cling on with over 2,000 pounds of force per square foot. The nano-tape quadruples that force. Not only may you be able to climb buildings one day like Spiderman, but you will never have to deal with annoying, sticky tape residue again.

Synthetic Muscles : They’re strong, they’re elastic, and they have amazing electrical properties. Researchers have created a carbon nanotube aerogel that expands and contracts as it converts electricity into chemical energy. Carbon nanotubes are suitable for artificial muscles since they retain their shape after being compressed thousands of times, in a similar way that soft tissue does. However, in aerogel form the tubes have an extra property: they grow denser under stress, like weight lifting does to your natural muscles. The nanotube muscle can also operate in extreme environments if need be, which could allow them to be used in space.

Biosensors a.k.a. ‘Nano-noses’ : Carbon nanotubes can be modified with protein receptors or DNA that pick up faint traces of chemical. Once the receptor interacts with the chemical, a current surges down the nanotube, identifying the target. It can be used to sniff bombs, search for toxins in the air and water, or be used to test whether someone has skin cancer by checking for a chemical called dimethylsulfone.

Spool of Nanotube fibers

Scientists at Rice University have created the first pure carbon nanotube fibers that combine many of the best features of highly conductive metal wires, strong carbon fibers and pliable textile thread.

Spool of Nanotube fibers used to wire and hold up a light

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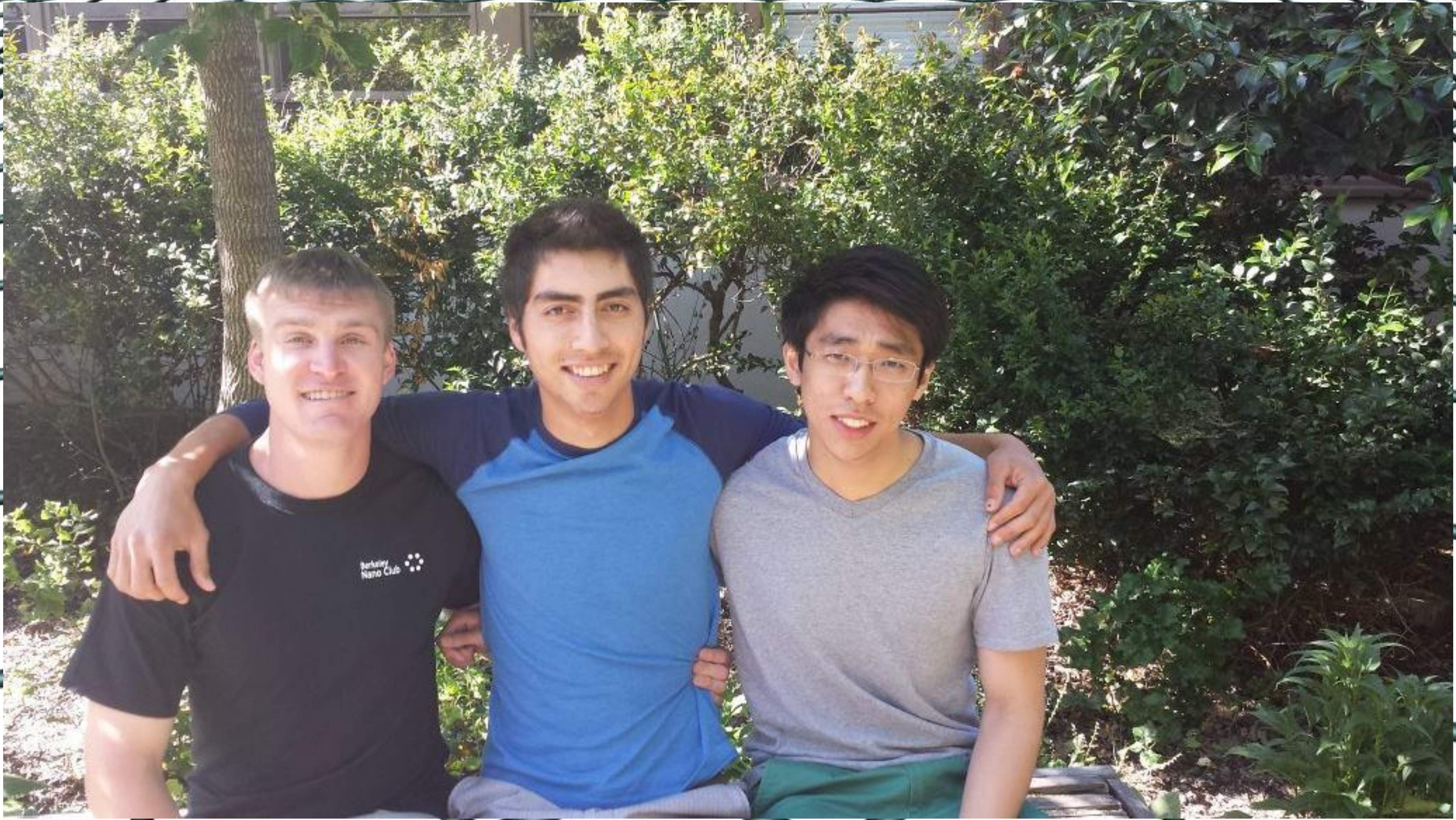
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