About the Carbon Nanotubes Pencils

Carbon is all around us and in us. It makes up approximately 20% of the human body as part of DNA, fats, and proteins. It's found in compounds in our atmosphere, like carbon dioxide (CO_2) and methane (CH_4). It's also found in the compounds that make up fossil fuels to power our cars and cities. Because carbon atoms can arrange themselves in several distinct ways, materials made only from carbon can take on several different forms (or allotropes). Two familiar forms of pure carbon are graphite (what is in your pencil lead) and diamond. However, over the past several decades, scientists have discovered new forms of pure carbon, such as carbon nanotubes (CNTs), fullerenes (or "buckyballs"), and graphene.

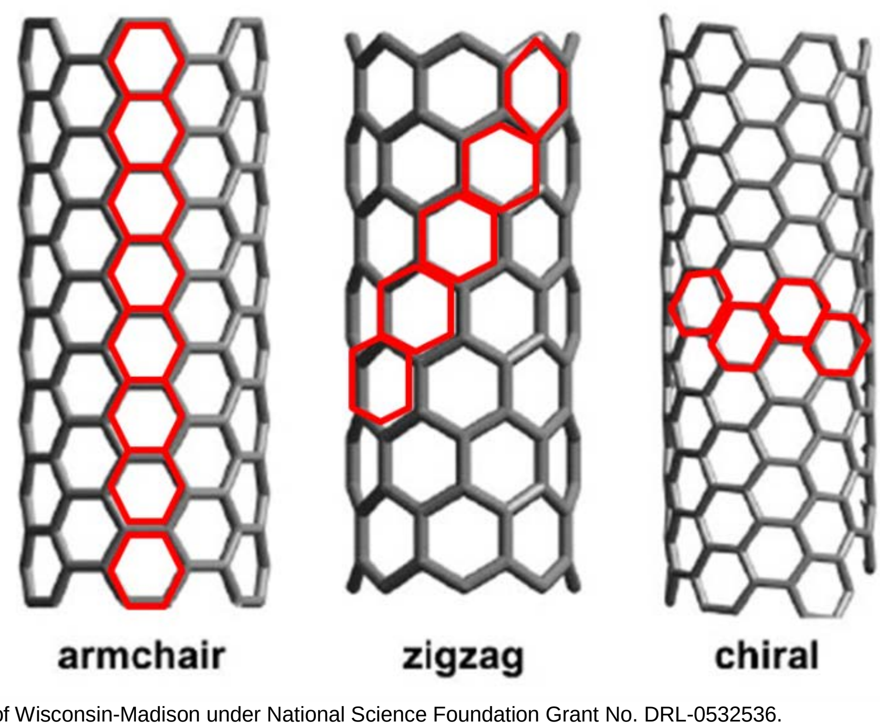
One can think of a CNT as a sheet of graphene that contains carbon atoms arranged in a hexagonal, or honey comb, pattern that is rolled up to form a tube. However, this is not how CNTs are formed. CNTs are made by growing them like a plant! This is done using heat, a carbon source (such as methane gas), and "catalyst" particles (for example, iron or nickel) that act like seeds from which nanotubes grow. These CNTs are very, very small and have a diameter of only about a nanometer (1/1,000,000,000th of a meter).

CNTs are grown in one of three types: zigzag, armchair, or chiral. The differences between the types are subtle, but by looking at the pattern of the hexagons on the tubes, you can tell the difference. These subtle changes in geometry between the three CNT types give rise to very different properties. For example, both armchair and some zigzag CNTs conduct electricity very well, better than copper; these are called metallic conductors. Chiral and some kinds of zigzag CNTs do not conduct electricity as well and are called semiconductors. CNTs are also incredibly strong. They are predicted to be 100 times stronger than steel, while only weighing 1/6th as much. This combination of lightweight strength and desirable electrical properties opens up a number of applications.

Fibers made of metallic conducting CNTs could be a lightweight, robust replacement for copper wiring. For example, the Boeing 747 has 171 miles of wiring, about the distance between New York City and Boston. By cutting the weight of those wires, one could save a lot of fuel. Modern smart phones are more powerful than super computers in the 90s because silicon-based transistors, the electrical switches enabling all modern electronics, are shrinking. This means that more transistors can fit into smaller spaces. Semiconducting CNTs may one day replace traditional transistors, allowing for even more computing power to be packed into even tinier spaces. Researchers are also using CNTs to make "smart sutures" with sensors to monitor a patient for infection after surgery. You may already own a product that contains CNTs. They've been added to boats, bicycles, goalie helmets, and baseball bats to increase strength without adding weight. CNTs aren't just making an impact on Earth; they're also helping to protect the Juno space probe from electromagnetic radiation. Can you imagine all the ways CNTs could be used in the future? The possibilities are endless.

Each one of the three pencils—maroon, blue, and black—show a different type of CNT. Can you tell which one is which?

Information on the carbon nanotube pencils is available at [www.nano.gov/CNTpencils.](http://www.nano.gov/CNTpencils)



Source: updated from NISE Network, University of Wisconsin-Madison under National Science Foundation Grant No. DRL-0532536.