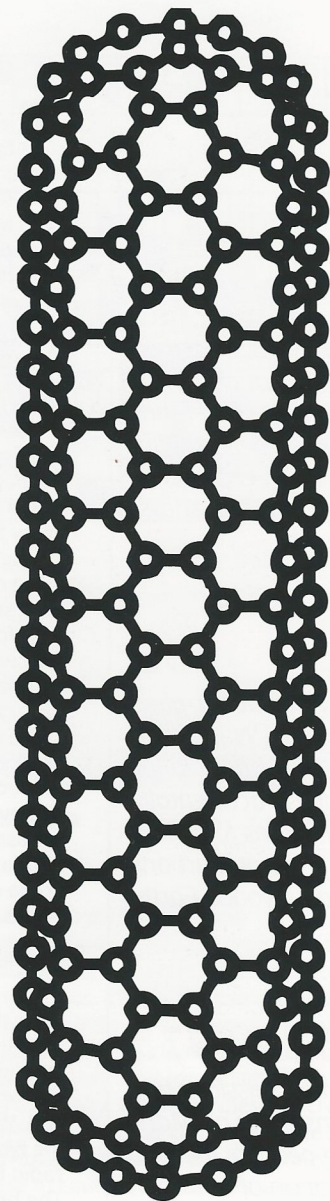


NANO-MATERIAL WITH GIGA IMPACT

BY JAMES MCCREARY

Figure 1:
A carbon
nanotube with
closed ends.¹



What material is so diverse that it has applications in everything from improving human lives to protecting the earth? Few materials are capable of both treating prolific diseases like diabetes and creating batteries that last orders of magnitude longer than industry standards. None are as thin, lightweight, and inexpensive as carbon nanotubes.

Carbon nanotubes are molecular cylinders made entirely of carbon atoms, which form a hollow tube just a few nanometers thick, as illustrated in Figure 1. For perspective, a nanometer is one ten-thousandth the width of a human hair.¹ The first multi-walled nanotubes (MWNTs) were discovered by L. V. Radushkevich and V. M. Lukyanovich of Russia in 1951.² Morinobu Endo first discovered single-walled nanotubes (SWNTs) in 1976, although the discovery is commonly attributed to Sumio Iijima at NEC of Japan in 1991.^{3,4}

Since their discovery, nanotubes have been the subject of extensive research by universities and national labs for the variety of applications in which they can be used. Carbon nanotubes have proven to be an amazing material, with properties that surpass those of existing alternatives such as platinum, stainless steel, and lithium-ion cathodes. Because of their unique structure, carbon nanotubes are revolutionizing the fields of energy, healthcare, and the environment.

ENERGY

One of the foremost applications of carbon nanotubes is in energy. Researchers at the Los Alamos National Laboratory have demonstrated that

carbon nanotubes doped with nitrogen can be used to create a chemical catalyst. The process of doping involves substitution of one type of atom for another; in this case, carbon atoms were substituted with nitrogen. The synthesized catalyst can be used in

"The synthesized catalyst can be used in lithium-air batteries which can hold a charge 10 times greater than that of a lithium-ion battery"

lithium-air batteries, which can hold a charge 10 times greater than that of a lithium-ion battery. A key parameter in the battery's operation is the Oxygen Reduction Reaction (ORR) activity, a measure of a chemical species' ability to gain electrons. The ORR activity of the nitrogen-doped material complex is not only the highest of any non-precious metal catalyst in alkaline media, but also higher than that of precious metals such as platinum.⁵

In another major development, Dr. James Tour of Rice University has created a graphene-carbon nanotube complex upon which a "forest" of vertical nanotubes can be grown. This base of graphene is a single, flat sheet of carbon atoms - essentially a carbon nanotube "unrolled." The ratio of height-to-base in this complex is equivalent to that of a

house on a standard-sized plot of land extending into space.⁶ The graphene and nanotubes are joined at their interface by heptagonal carbon rings, allowing the structure to have an enormous surface area of 2000 m² per gram and serve as a high potential storage mechanism in fast supercapacitors.⁷

HEALTHCARE

Carbon nanotubes also show immense promise in the field of healthcare. Take Michael Strano of MIT, who has developed a sensor composed of nanotubes embedded in an injectable gel that can detect several molecules. Notably, it can detect nitrous oxide, an indicator of inflammation, and blood glucose levels, which diabetics must continuously monitor. The sensors take advantage of carbon nanotubes' natural fluorescent properties; when these tubes are complexed with a molecule

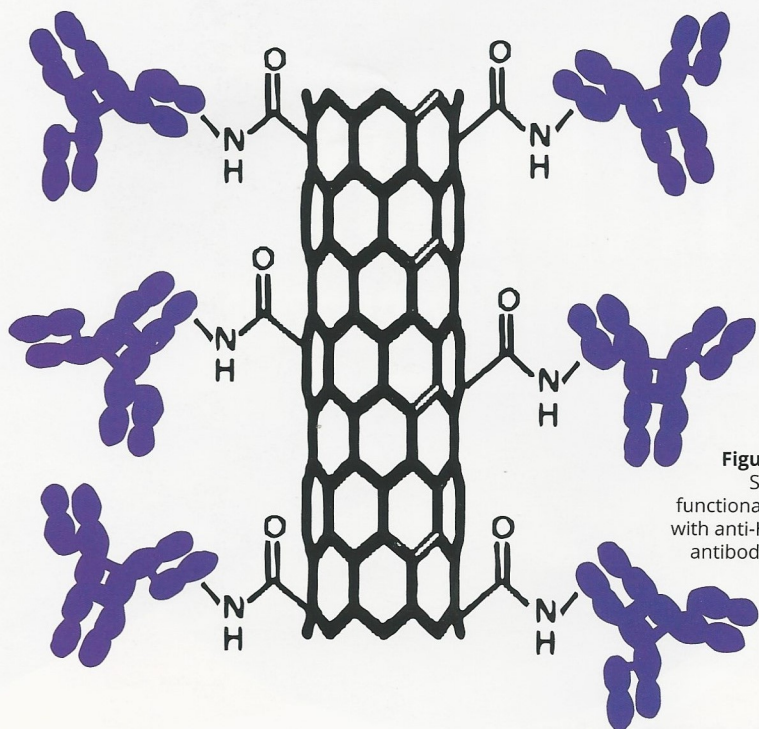


Figure 2:
SWNT
functionalized
with anti-HER2
antibodies.¹²

that then binds to a specific target, their fluorescence will increase or decrease.⁸

Perhaps the most important potential application for carbon nanotubes in healthcare lies in their cancer-fighting applications. In the human cell, there is a family of genes called HER2 that is responsible for the regulation of growth and proliferation of cells. Normal cells have two copies of this family, but 20-25% of breast cancer cells have three or more copies, resulting in quickly-growing

**"CARBON NANOTUBES
attract hydrocarbons and
repel water, absorbing
up to 100 times their
weight in oil"**

tumor cells. Approximately 40,000 U.S. women are diagnosed every year with this type of breast cancer. Fortunately, Huixin He of Rutgers University and Yan Xiao of the National Institute of Standards and Technology have found that they can attach an anti-HER2 antibody to carbon nanotubes to kill these cells, as shown in Figure 2. Once inserted into the body, a near-infrared light at a wavelength of 785 nm can be reflected off the antibody-nanotube complex, indicating where tumor cells are present. The wavelength then increases to 808 nm, at which point the nanotubes absorb the light and vibrate to

release enough heat to kill any attached HER2 tumor cells. This process has shown a near 100% success rate and leaves normal cells unharmed.⁹

ENVIRONMENT

Carbon nanotube technology also has environmental applications. Hui Ying Yang from Singapore has developed a water-purification membrane made of plasma-treated carbon nanotubes which can be integrated into portable, rechargeable, and inexpensive purification devices the size of a teapot. These new purifications devices are ideal for developing countries and remote locations, where large industrial purification plants would be too energy- and labor-intensive. Unlike other portable devices, this rechargeable device utilizes a membrane system that does not require a continuous power source, does not rely on thermal processes or reverse osmosis, and can filter for organic contaminants found in brine water - the most common water supply in these developing and rural areas.¹⁰

Oil spills may no longer be such devastating natural disasters either. Bobby Sumpter of the Oak Ridge National Laboratory demonstrated that doping carbon nanotubes with boron atoms alters the curvature of the tubes. Forty-five degree angles form, leading to a sponge-like structure of nanotubes. As these tubes are made of carbon, they attract hydrocarbons and repel water due to their hydrophobic properties, allowing the tubes to absorb up to 100 times their weight in oil. Additionally, these tubes can be reused, as burning or squeezing them

was shown to cause no damage. Sumpter and his team used an iron catalyst in the growth process of the carbon nanotubes, enabling a magnet to easily control or remove the tubes from an oil cleanup scenario.¹¹

Carbon nanotubes provide an incredible opportunity to impact areas of great importance to human life - energy, healthcare, and environmental protection. The results of carbon nanotube research in these areas demonstrate the remarkable properties of this versatile and effective material. Further studies may soon lead to their everyday appearance in our lives, whether in purifying water, fighting cancer, or even making the earth a better, cleaner place for everyone. Big impacts can certainly come in small packages.

WORKS CITED:

- [1] Nanocyl. Carbon Nanotubes. <http://www.nanocyl.com/CNT-Expertise-Centre/Carbon-Nanotubes> (accessed Sep 12, 2015).
- [2] Monthieux, M.; Kuznetsov, V. Guest Editorial: Who should be given the credit for the discovery of carbon nanotubes? Carbon 44. [Online] 2006. 1621. <http://nanotube.msu.edu/HSS/2006/1/2006-1.pdf> (accessed Nov 15, 2015)
- [3] Ecklund, P.; et al. Ugliengo, P. In International Assessment of Carbon Nanotube Manufacturing and Applications, Proceedings of the World Technology Evaluation Center, Inc. Baltimore, MD, June, 2007.
- [4] Nanogloss. The History of Carbon Nanotubes - Who Invented the Nanotube? <http://nanogloss.com/nanotubes/the-history-of-carbon-nanotubes-who-invented-the-nanotube/#axzz3mtharE9D> (accessed Sep 14, 2015).
- [5] Understanding Nano. Economical non-precious-metal catalyst capitalizes on carbon nanotubes. <http://www.understandingnano.com/catalyst-nitrogen-carbon-nanotubes.html> (accessed Sep 17, 2015).
- [6] Understanding Nano. James' bond: A graphene/nanotube hybrid. <http://www.understandingnano.com/graphene-nanotube-electrode.html> (accessed Sep 19, 2015).
- [7] Yan, Z. et al. ACS Nano. Toward the Synthesis of Wafer-Scale Single-Crystal Graphene on Copper Foils 2012, 6 (10), 9110-9117.
- [8] Understanding Nano. New implantable sensor paves way to long-term monitoring. <http://www.understandingnano.com/carbon-nanotubes-implant-sensor.html> (accessed Sep 20, 2015).
- [9] Understanding Nano. Combining Nanotubes and Antibodies for Breast Cancer 'Search and Destroy' Missions. <http://www.understandingnano.com/nanomedicine-nanotubes-breast-cancer.html> (accessed Sep 22, 2015).
- [10] Understanding Nano. Plasma-treated nano filters help purify world water supply. <http://www.understandingnano.com/nanotube-membranes-water-purification.html> (accessed Sep 24, 2015).
- [11] Sumpter, B. et al. Covalently bonded three-dimensional carbon nanotube solids via boron induced nanojunctions. Nature [Online] 2012, doi: 10.1038/srep00363. <http://www.nature.com/articles/srep00363> (accessed Mar 06, 2016).
- [12] Huixin, H. et al. Anti-HER2 IgY antibody-functionalized single-walled carbon nanotubes for detection and selective destruction of breast cancer cells. BMC Cancer 2009, 9, 351.

DESIGN BY Kris Sheng, Vidya Giri

VOLUME 9, 2016

Catalyst

RICE UNDERGRADUATE SCIENCE RESEARCH JOURNAL



OVERFISHING + MEGAFIRES

ALSO IN THIS ISSUE:

Stem Cell Treatment for Bone Regeneration
How Bionic Eyes are Changing the Way We See the World
Nano-Material With Giga Impact