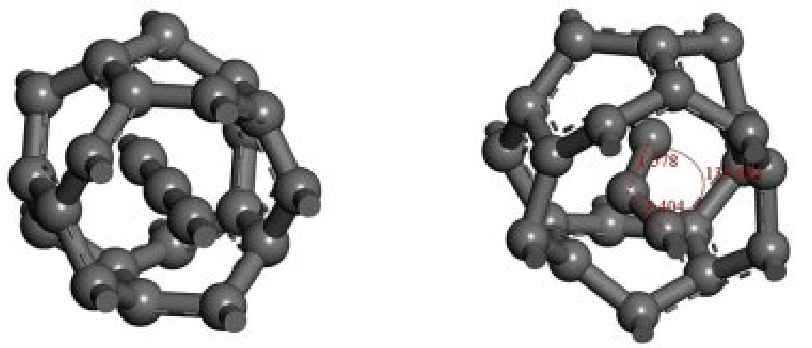
Physicists found the temperature at which carbon nanotubes become superconductors

December 19 2017



Before geometric optimization

After geometric optimization

Fig. 6. The (5,0) carbon composite (one repeated unit is shown) is made by inserting a linear carbon chain into a (5,0) SWCNT. The LHS shows the input atomic coordinates of the repeated unit, while the RHS displays the repeated unit after geometric optimization. The composites are arranged to form a regular array in which they are laterally separated by 1.7 nm. (A colour version of this figure can be viewed online.)

The geometric structure 'a carbon chain in a tube' before and after optimization. Credit: Chi Ho Wong

Scientists from Ural Federal University (UrFU) together with their colleagues from Lomonosov Moscow State University, have discovered a mathematical method to calculate the temperature at which single-walled carbon nanotubes became superconductors and developed a way to increase it, thus opening new prospects for superconductive materials application. The work was published in *Carbon* journal.

Superconducting materials that are able to conduct electricity without resistance are used in cyclotrons, magnetic trains, power lines and super-sensitive magnetometers (devices used to measure the Earth's magnetic field). Still, the main issue with superconductivity is that it is expressed at temperatures slightly above absolute zero (-273°C). If a material is superconductive around -70°C, it is aiming at a record. The leader among all materials is hydrogen sulfide frozen under incredible pressure—it becomes a superconductor at -70°C.

"Room temperature superconductivity is the dream of humanity. For example, your mobile phone would not need to recharge anymore, and electricity can run forever," says Dr. Chi Ho Wong, a postdoc of Ural Federal University and a co-author of the work.

The ability of carbon to form flat, one-atom-thick graphene sheets (separate graphite layers) has attracted the attention of scientists. Rolling such a sheet to make a tube produces another interesting structure—a single-walled carbon nanotube (SWCNT). These structures are highly tensile, refract light in an unusual manner, and may be used in many areas from electronics to biomedicine. Atoms inserted in the walls of such tubes may change their properties, including conductivity. It may depend on the orientation of hexagons that form the carbon layer, on the filling of the tube, or on additionally inserted or attached atoms of other elements.

Single-walled carbon nanotubes are actively studied as prospective superconductors. However, their diameter equals only 4 angstroms (four-tenths of a nanometer), therefore they are close to 1-D materials. At temperatures close to absolute zero, so-called Cooper pairs of electrons form within them. In the absence of curvature, Cooper pairs do not form, and no superconductivity is observed.

"Our task was to change the 1-D structure in order to increase the temperature of superconductive transition," says Anatoly Zatsepin, the head of a scientific research laboratory at Institute of Physics and Technology, UrFU. "It turned out that if you pile SWCNTs up, Cooper pairs stabilize, and a superconductor is formed." Still, even such piles require quite low temperatures to exhibit superconductive properties—only 15 degrees above absolute zero.

Physicists found a solution for this issue. They added a one-atom-wide carbon "wire" inside an SWCNT. The chain itself does not form bonds with the atoms of the tube, but it makes the tube change its own geometry and flex.

When the team from UrFU changed the shape of the internal carbon chain from straight to zigzag-like, they managed to increase the temperature of superconductivity transition by 45 degrees. To achieve the best effect, the angles of zigzags were mathematically calculated, and the predictions proved to be correct.

More information: C.H. Wong et al, Superconductivity in ultra-thin carbon nanotubes and carbyne-nanotube composites: An ab-initio approach, *Carbon* (2017). DOI: 10.1016/j.carbon.2017.09.077

Provided by Ural Federal University

Citation: Physicists found the temperature at which carbon nanotubes become superconductors (2017, December 19) retrieved 23 April 2024 from https://phys.org/news/2017-12-physicists-temperature-carbon-nanotubes-superconductors.html