PHYSICS UPDATE

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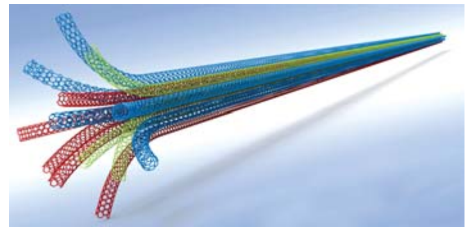
CARBON NANOTUBES SHARE THE LOAD



With a tensile strength exceeding 100 GPa, individual carbon nanotubes (CNTs) are among the strongest known materials. Realizing that ideal strength is challenging. When CNTs are fabricated in bulk, the end product is often a jumbled mass of tubes shorter than a few hundred micrometers in length and filled with structural defects and impurities. Those features reduce the nanotubes' collective strength to a small fraction of the strength of an individual CNT.

Recently Fei Wei, Rufan Zhang, and their colleagues at China's Tsinghua University developed a method to synthesize CNTs into bundles several centimeters long, with each containing up to 15 nearly defect-free CNTs. Despite the near-perfect crystalline growth, the researchers found that the CNTs in each bundle still differed in orientation and length. The larger the number of CNTs in a bundle, the further the bundle's tensile strength fell below the ideal value. That's because the load would be concentrated in just one or two CNTs instead of being evenly shared by them all.

To shore up the CNTs' collective strength, Wei and colleagues fixed one end of the bundle and then repeatedly stretched and trimmed the different CNTs at the opposite end until they had equalized the initial strain on each nanotube. (The researchers determined spectroscopically how much to trim for a uniform strain distribution.) The process thereby increased the maximum load the bundle could collectively support. Accounting for the nanotubes' cross-sectional area, the team was able to produce ultralong CNT bundles with a tensile strength of about 43 GPa. That's 5–24 times the strength of any other type of engineering fiber, including graphitic fiber, Kevlar, and steel. (Y. Bai et al., *Nat. Nanotechnol.*, 2018, doi:10.1038/s41565-018-0141-z.) —RMW

RESTORING ARTWORK WITH NANOSTRUCTURED FLUIDS

The first step in framing a watercolor, charcoal sketch, or other work on paper is to mount it on a mat by means of hinges. In the 19th century and earlier, hinges were made of paper backed with glue. By the middle of the 20th century, framers began to use the newly available pressure-sensitive tape or, to use a more familiar name, sticky tape. Old sticky tape can discolor an artwork, and if it was misapplied, disfigure it. Removing old tape is tricky. Pulling it off could damage the paper. Using a solvent to dissolve the tape risks leaving a watermark. To tackle the challenge, Nicole Bonelli of the University of Florence and her collaborators have developed an approach based on a hydrogel and nanostructured droplets. The hydrogel consists of a covalently linked polymer network that holds water. A conservator can shape a rectangular piece of the gel so that it fits exactly over the piece of sticky tape to be removed. The nanostructured droplets consist of a solvent covered with surfactant molecules. Confining the solvent in both the gel and the droplets ensures that it does not spread beyond the tape and that just the right amount is used. Lab tests demonstrated that for two types of tape used in galleries and museums today, the droplets made their way to the tape's backing and dissolved it. Among the first artworks to receive the new treatment was a 16th-century sketch that resembles one of the male figures in Michelangelo's fresco *The Last Judgment* (a detail of which is shown here). When a piece of tape at the bottom of the sketch was removed, the words "di mano di Michelangelo" ("from Michelangelo's hand") were revealed. Why would anyone conceal proof of provenance? Possibly because Michelangelo rarely signed his works, so it could have been an attempt to pass the sketch off as genuine. (N. Bonelli et al., *Proc. Natl. Acad. Sci. USA* **115**, 5932, 2018.) —CD

ATMOSPHERIC SEASONALITY FLAGS LIFE ON EXOPLANETS

Charles Keeling's measurements of atmospheric carbon dioxide atop Hawaii's Mauna Loa show that the concentration of the greenhouse gas has increased by 30% since the late 1950s. They also show a sinusoidal seasonal variation as trees and other plants in the Northern Hemisphere bloom, flourish, shed leaves, and lie dormant year after year. If an exoplanet harbors life and if its rotational axis is tilted, the composition of its atmosphere would likely vary with its seasons. Could those variations be detected by remote spectroscopy?

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To answer the question, Stephanie Olson of the University of California, Riverside, and her collaborators first identified three gases whose seasonal variations, they first thought, might serve as indicators of life: CO_2, methane, and oxygen. The researchers were pessimistic about CO_2 because its observable signatures—absorption lines around 4.3 μm and 15 μm—are likely to be saturated throughout an exoplanet's year. Methane's suitability as an indicator is diminished by the fact that a component of its seasonal variation is photochemical in origin and would occur regardless of the presence of life.

Oxygen turns out to be more promising. Like CO_2, it participates in photosynthesis. Unlike CO_2, it is not especially soluble in water, which means the presence of an ocean would not muffle variations in its atmospheric concentration. What's more, the O_2 concentration determines the ozone concentration, which can be readily measured because of absorption features in the near-UV.

For their case study, Olson and company calculated the seasonal signal of O_2 and O_3 from an Earth-like planet orbiting a Sun-like star at a period when only simple life-forms existed. Their conclusion: Seasonal, biogenic variation in O_3 could be detected by a large-aperture space telescope equipped with a UV spectrometer. (S. L. Olson et al., *Astrophys. J. Lett.* **858**, L14, 2018.) —CD PT