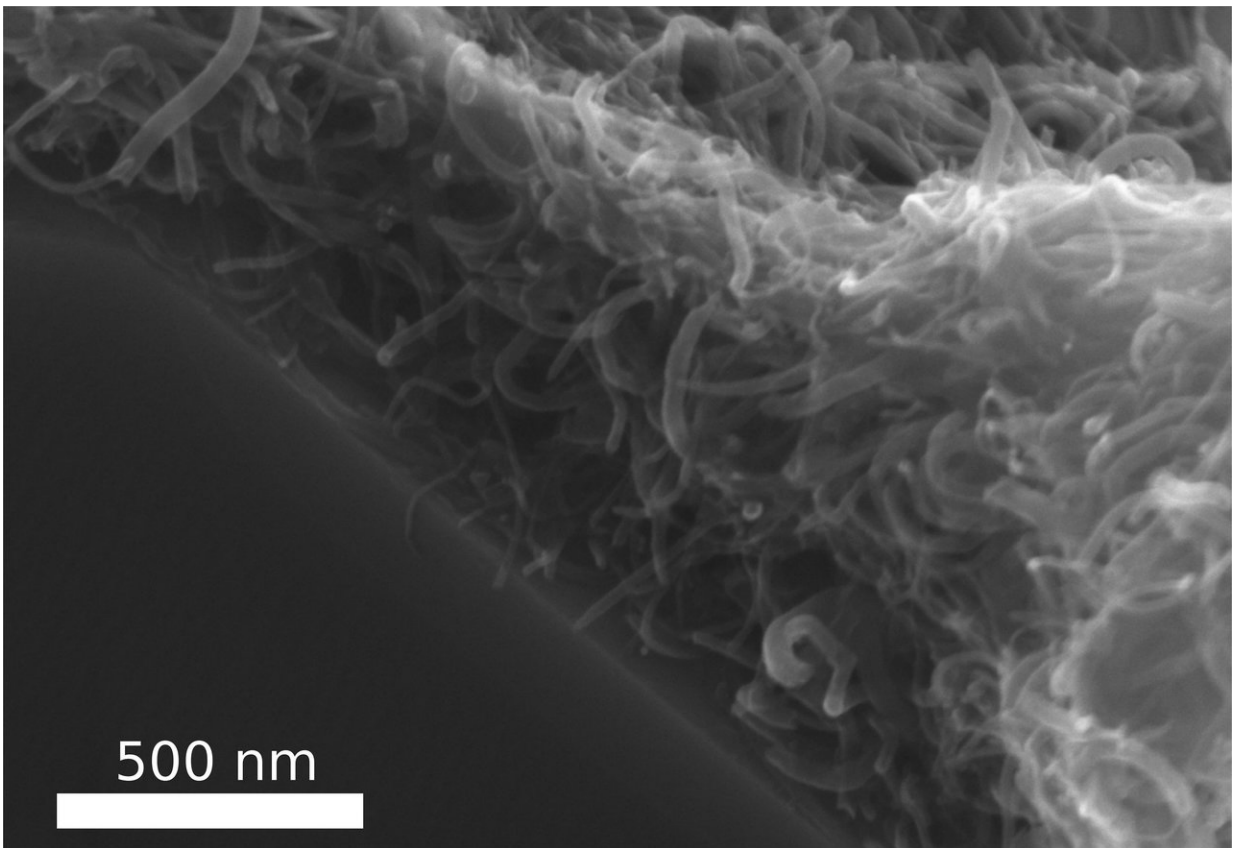


Research team develops new composite material made of carbon nanotubes

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Scientists from the Functional Nanomaterials working group at Kiel University (CAU) and the University of Trento have now developed a process to form a stable, tear-resistant layer out of tiny, thread-like carbon nanotubes (CNTs). They arrange themselves -- almost like felting. Credit: Fabian Schütt

Carbon nanotubes are extremely lightweight, electrically highly conductive, and more stable than steel. Due to their unique properties, they are ideal for numerous applications, including ultra-lightweight batteries, high-performance plastics and medical implants. However, to date, it has been difficult for science and industry to transfer the extraordinary characteristics at the nano-scale into functional industrial applications. The carbon nanotubes either cannot be combined adequately with other materials, or they lose their beneficial properties once combined. Scientists from the Functional Nanomaterials working group at Kiel University (CAU) and the University of Trento have now developed an alternative method, with which the tiny tubes can be combined with other materials so that they retain their characteristic properties. The research results have now been published in *Nature Communications*.

"Although carbon nanotubes are flexible like fibre strands, they are also very sensitive to changes," explained Professor Rainer Adelung, head of the Functional Nanomaterials working group at the CAU. "With previous attempts to chemically connect them with other [materials](#), their molecular structure also changed. This, however, made their properties deteriorate—mostly drastically."

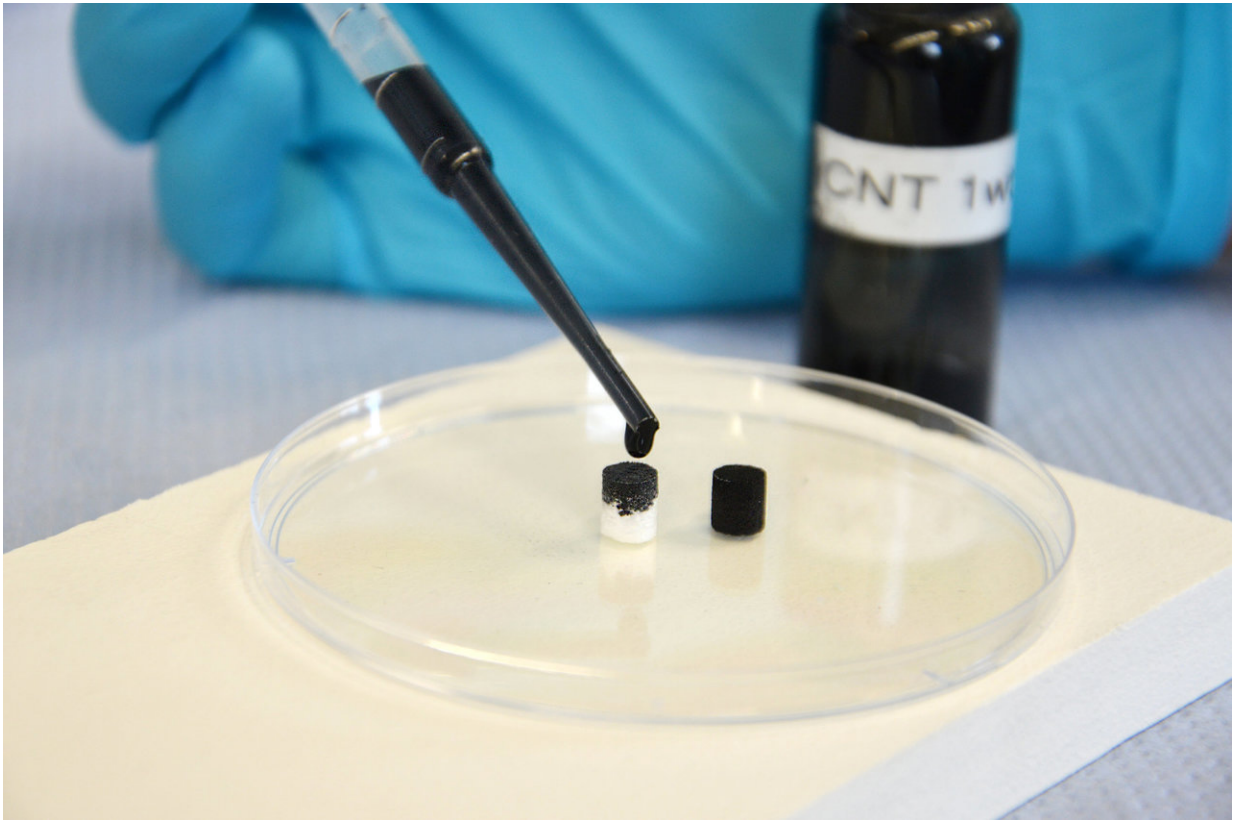
In contrast, the approach of the research team from Kiel and Trento is based on a simple wet chemical infiltration process. The CNTs are mixed with water and dripped into an extremely porous ceramic material made of zinc oxide, which absorbs the liquid like a sponge. The dripped thread-like CNTs attach themselves to the ceramic scaffolding, and automatically form a stable layer together. The ceramic scaffolding is coated with nanotubes. This has fascinating effects, both for the scaffolding as well as for the coating of nanotubes.

On the one hand, the stability of the ceramic scaffold increases so massively that it can bear 100,000 times its own weight. "With the CNT

coating, the ceramic material can hold around 7.5kg, and without it just 50g—as if we had fitted it with a close-fitting pullover made of carbon nanotubes, which provide mechanical support," said first author Fabian Schütt. "The pressure on the material is absorbed by the tensile strength of the CNT felt. Compressive forces are transformed into tensile forces."

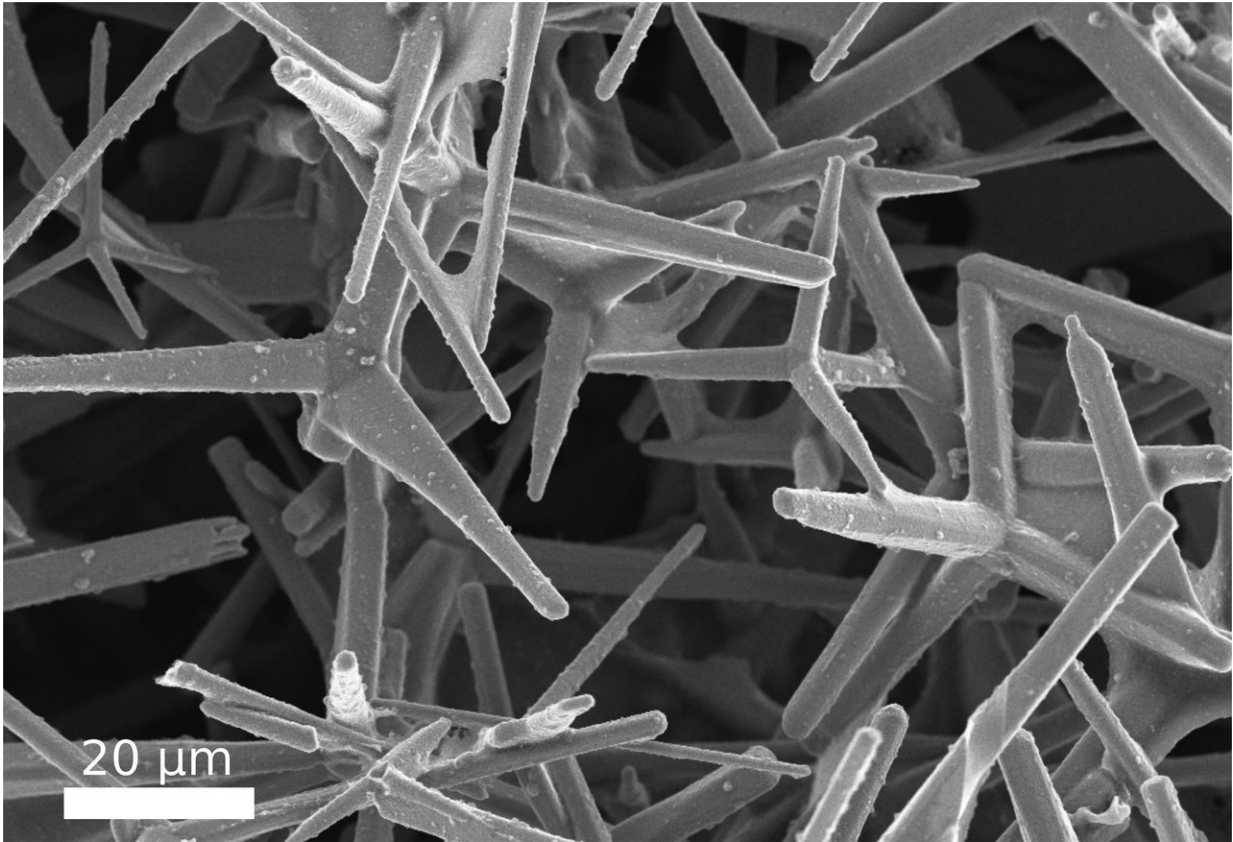
The principle is comparable with bamboo buildings that are widespread in Asia. Bamboo stems are bound so tightly with a simple rope that the lightweight material can form extremely stable scaffolding, and even entire buildings. "We do the same at the nano-scale with the CNT threads, which wrap themselves around the ceramic material—only much, much smaller," said Helge Krüger, co-author of the publication.

The materials scientists were able to demonstrate another major advantage of their process. In a second step, they dissolved the ceramic scaffolding by using a chemical etching process. All that remains is a fine 3-D network of tubes, each of which consists of a layer of tiny CNT tubes. In this way, the researchers were able to greatly increase the surface, and thus create more opportunities for reactions. "We basically pack the surface of an entire beach volleyball field into a one centimetre cube," explained Schütt. The huge hollow spaces inside the three-dimensional structure can then be filled with a polymer. As such, CNTs can be connected mechanically with plastics, without modifying their [molecular structure](#) and thus their properties. "We can specifically arrange the CNTs and manufacture an electrically conductive composite material. To do so only requires a fraction of the usual quantity of CNTs, in order to achieve the same conductivity," said Schütt.



In this simple procedure, water is mixed with the CNTs, and dripped into a white ceramic material. Like a sponge, it sucks up the black liquid. Credit: Julia Siekmann, Kiel University

Applications include battery and filter technology as a filling material for conductive plastics, implants for regenerative medicine, and sensors and electronic components at the nano-scale. The [high electrical conductivity](#) of the tear-resistant material could also be interesting for flexible electronics applications, in functional clothing or in the field of medical technology, for example. "Creating a plastic which, for example, stimulates bone or heart cells to grow is conceivable," said Adelung. Due to its simplicity, the scientists agree that the process could also be transferred to network structures made of other nanomaterials—which will further expand the range of possible applications.



The reason for this is the high porosity of the ceramic material. In the magnification, a fine network of countless 4-pronged zinc oxide particles can be seen. Due to its special structure, large open spaces are created, which the fluid seeps through. Credit: Fabian Schütt

More information: Fabian Schütt et al, Hierarchical self-entangled carbon nanotube tube networks, *Nature Communications* (2017). [DOI: 10.1038/s41467-017-01324-7](https://doi.org/10.1038/s41467-017-01324-7)

Provided by Kiel University

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