FAST BREAKING PAPERS - 2009

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Liming Dai talks with *ScienceWatch.com* and answers a few questions about this month's Fast Breaking Paper in the field of Materials Science. The author has also sent along images of their work.

Article Title: Gecko-foot-mimetic aligned single-walled carbon nanotube dry adhesives with unique electrical and thermal properties
Authors: Qu, L;Dai, L
Journal: ADVAN MATER
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SW: Why do you think your paper is highly cited?

In our paper, we demonstrated that vertically-aligned single-walled carbon nanotube arrays can be used for a successful synthetic approach to mimic gecko foot-hairs to develop advanced dry adhesives with fairly reversible semiconducting behaviors under load and provide an excellent thermal resistance, due to the unique thermal and electric properties intrinsically associated with single-walled carbon nanotubes.

Such multifunctional aligned single-walled carbon nanotube dry adhesives are about three times stickier than natural gecko feet and will offer options for many novel applications of carbon nanotubes. Many researchers are looking into novel applications for carbon nanotubes and multifunctionalities for gecko-foot-mimetic dry adhesives. Our paper provides a unique combination which should lead to new directions in both fields.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

Understanding that sample purity and quality are important in order to ensure strong adhesion for carbon nanotube dry adhesive, we used a combined method of plasma-enhanced chemical vapor deposition and fast heating for the syntheses of vertically-aligned single-walled carbon nanotube arrays with a high purity and graphitization degree.

The small nanotube diameter, together with a pure p -p conjugated carbon surface, allowed vertically-aligned single-walled carbon nanotube arrays to have an intimate contact and an enhanced adhesion force along the substrate surface in respect to their multiwalled counterparts previously studied as gecko-foot-mimetic dry adhesives.

SW: Would you summarize the significance of your paper in layman's terms?

The secret behind the gecko's ability to scurry up walls and cling to ceilings lies in the forest of microscopic hairs on the underside of its foot. Under a microscope, vertically-aligned carbon nanotubes look a lot like the tiny, sticky hairs on the gecko's feet. This finding has prompted several research groups to develop gecko-foot-mimetic dry adhesives based on vertically-aligned multiwalled carbon nanotubes.

In our research, we used tailor-made vertically-aligned single-walled carbon nanotube arrays to mimic gecko feet. Better than the natural gecko foot and its multiwalled counterpart, this new single-walled carbon nanotube dry adhesive is nearly three times stickier than natural gecko feet, with additional thermal and electrical management capabilities.

This discovery could lead to various applications, ranging from low-tech fridge magnets to holding together electronics or even holding together the parts of an airplane. For instance, rather than soldering components into electronic devices, these parts could be easily held together by using the new adhesive.

Computers and laptops could also be made to disperse heat from their circuits without the need for additional heat sinkers. As a dry adhesive, carbon nanotube material would also have many uses in space, where there's a vacuum and traditional kinds of adhesives dry out. They can also be used to create wall/rock climbing robots, super-grip tires, and to provide rapid repairs for various systems.

Figure 1: +details

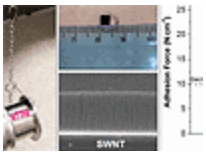

Figure 2:

Figure 3:

SW: How did you become involved in this research, and were there any problems along the way?

My group has been working on the growth and microfabrication of vertically-aligned carbon nanotubes for a long time. Although the formation of an aligned/micropatterned multiwalled carbon nanotube array has been known about for some years, the synthesis of a vertically-aligned single-walled carbon nanotube array is a fairly recent development.

Soon after the first paper on the growth of vertically-aligned single-walled carbon nanotubes from Sumio Iijima's group at the Japan Science and Technology Agency (JST/SORST) appeared in 2004, we, along with several other groups, successfully produced vertically-aligned single-walled carbon nanotube arrays. The use of our high-quality vertically-aligned single-walled carbon nanotube arrays to mimic the gecko foot-hairs turned out to be very successful with the first set of adhesion data obtained in early 2006.

SW: Where do you see your research leading in the future?

"The secret behind the gecko's ability to scurry up walls and cling to ceilings lies in the forest of microscopic hairs on the underside of its foot."

Further research on functionalization of these carbon nanotube "gecko feet" should lead to a wide range of multifunctional smart (e.g., photo-sensitive, temperature-responsive, or optoelectronically active) dry adhesives, attractive for diverse potential applications. The possibilities for practical uses of these vertically-aligned single-walled carbon nanotube dry adhesives has not yet been fully exploited, largely because it is still a challenge to synthesize high-quality vertically-aligned single-walled carbon nanotube arrays on a large-scale and in a cost-effective manner.

Overcoming this challenge should facilitate the research and development of vertically-aligned single-walled carbon nanotube dry adhesives with enhanced multifunctional performance. This, in turn, would then allow for a large-scale preparation of vertically-aligned single-walled carbon nanotube dry adhesives that could be repeatedly used in a variety of practical applications.

SW: Do you foresee any social or political implications for your research?

Our results indicated that only 150 pieces of these small single-walled carbon nanotube arrays, each one measuring only 4×4 square millimeters, with a total contact area of about 5×5 square centimeters, which is much smaller than the palm of your hand, would be needed to collectively hold a person weighing about 70 kg.

Apart from their potential applications as dry adhesives in electronics and aerospace vehicles, therefore, these vertically-aligned carbon nanotubes might find possible uses for climbing robots just like Spider-Man. Continued research efforts in this exciting field should affect the lives of everyone and, in the longer term, also influence many industrial sectors around the world.

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Keywords: carbon nanotube arrays, mimic gecko foot-hairs, single-walled, dry adhesive, graphitization degree, conjugated carbon surface, vertically-aligned multiwalled, aligned/micropatterned, JST/SORST.

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