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The right recipe: Engineering research improves laser detectors, batteries

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Think of it as cooking with carbon spaghetti: A Kansas State University researcher is developing new ways to create and work with carbon nanotubes -- ultrasmall tubes that look like pieces of spaghetti or string.

These carbon nanotubes -- made of graphene, an atom-thick sheet of carbon -- have the perfect ingredients for improving laser detectors and rechargeable batteries, according to research by Gurpreet Singh, assistant professor of mechanical and nuclear engineering. Singh is working on several projects with carbon nanotubes and polymer-derived ceramic material.

One project involves new ways to cook or create a ceramic carbon nanotube material. The conventional way to make this type of material is to take a liquid polymer, pour it into a mold and heat it in an oven until the polymer forms a ceramic.

Singh's team tried a new approach. They are among the first to create their own modified liquid polymer with four ingredients: silicon, boron, carbon and nitrogen. But rather than heating this liquid polymer in an oven, they heated it in a conventional microwave -- the kind used in kitchens. They found that the microwave heats the nanotubes just as well as an oven.

"What we did is reduce the time to construct ceramic," Singh said. "If you use an oven or heater, you have to heat it for awhile. With the microwave, it is fast heating within a few minutes."

Their work -- co-authored with their university colleague William Kuhn, professor of electrical and computer engineering -- recently appeared in the journal Applied Materials *and Interfaces*, published by the American Chemical Society. Another publication involving conventional processing will appear in the *Journal of the American Ceramic Society*.

Once this ceramic carbon nanotube material is created, it has multiple applications. Singh's team is involved in a project with the Laser Radiometry Team at the National Institute of Standards and Technology, or NIST, in Boulder, Colo., which works to develop measurement methods for high-power industrial lasers for manufacturing.

Singh's team is assisting the institute in improving how laser power is measured. Currently, laser measurements involve a cone-shaped copper detector covered in carbon paint. The laser shines through the cone, is absorbed by the black paint, heats the copper cone and then heats a waterfall at the detector's back end. By measuring the rising temperature of the water, scientists can determine the energy of the laser.

The Singh team has improved this process by making the cone-shaped detector out of the ceramic carbon nanotube composite material. Because ceramic can withstand high temperatures, it protects the nanotubes, which absorb the laser light to heat the cone.

"We are checking the stability of the material," Singh said. "We are characterizing it and then sending the samples to the NIST to test."

Another project for Singh's team uses the ceramic carbon nanotube material to improve the performance of rechargeable batteries. The material addresses four ways that rechargeable batteries can be improved: having a larger storage capacity, having a longer battery life, recharging quickly and providing a lot of power in a short amount of time.

These ceramic materials can reversibly store lithium, meaning that lithium can go in and come out of it. Current rechargeable batteries use graphite to store lithium. But as the graphite wears down, a battery become less efficient and will stay charged for a shorter amount of time.

The ability to recharge quickly and provide a lot of power in a short amount of time is especially key for electric cars. Many current electric car designs take several hours to recharge and take a long time to accelerate. Scientists wanting to create a battery that can recharge in a few minutes and provide power quickly may now have a solution.

Singh's team has already seen early success with their work: Preliminary research shows that when the ceramic material is used in batteries, it doubles or triples the battery's capacity for high current. The material is also thermodynamically stabile, so it can survive longer cycles.

"It would be really nice to have one material that has high capacity, can be charged quickly and also is stable," Singh said. "With this ceramic material, it should be strong enough so that over time it does not degrade. That's the ultimate goal."

Their battery work will appear later this year in the journal *Nanomaterials and Energy*, published by the Institution of Civil Engineers. The researchers are currently charging and recharging the batteries for several cycles to understand how long the batteries made from the materials can last.

A final project from Singh's team involves the use of "nano-fingers," which are sharp tungsten needles that can probe and pick up carbon nanotubes. The researchers use these nano-fingers under an electron microscope to perform studies with individual carbon nanotubes and ceramic nanowires.

Singh's research has been supported with $57,000 from the EPSCoR program with the National Science Foundation. His research team consists of two graduate students -- Romil Bhandavat and Lamuel David, both doctoral students in mechanical engineering, India,-- and one undergraduate student, Uriel Barrera, a sophomore in mechanical engineering, Olathe.

Provided by Kansas State University

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