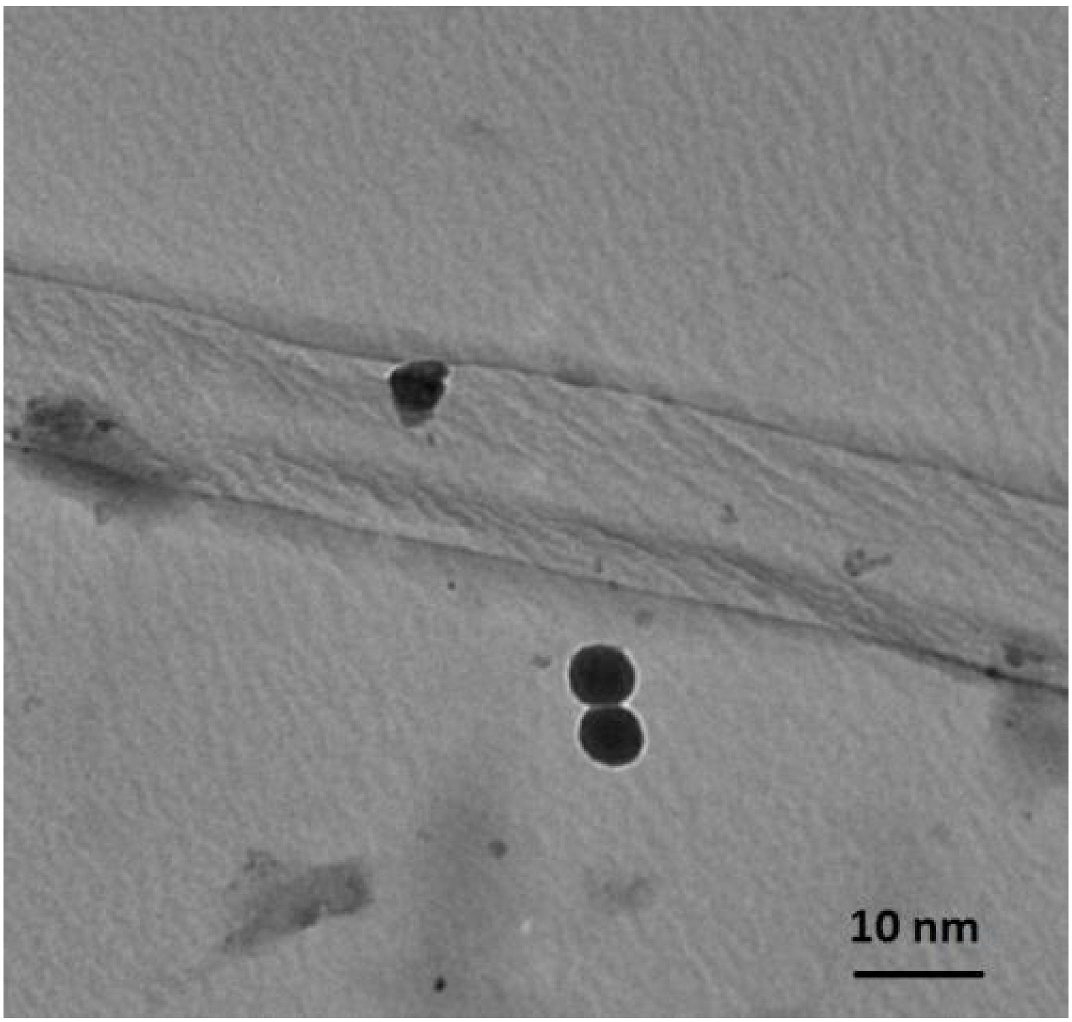
PHYS ORG

Novel plastic could spur new green energy applications, 'artificial muscles'

March 26 2015



Carbon nanotubes (one shown above) and 'buckyball' clusters (dark spots) are incorporated in a new material to boost its electricity-generating properties. Credit: Voit lab

A plastic used in filters and tubing has an unusual trait: It can produce electricity when pulled or pressed. This ability has been used in small ways, but now researchers are coaxing fibers of the material to make even more electricity for a wider range of applications from green energy to "artificial muscles." They will report progress on a novel form of this plastic at the 249th National Meeting & Exposition of the American Chemical Society (ACS).

ACS, the world's largest scientific society, is holding the meeting here through Thursday. It features nearly 11,000 presentations on a wide range of science topics.

"For the past couple of years, we've been doing a lot of work with a material called PVDF—polyvinylidene fluoride," explains Walter Voit, Ph.D., of the University of Texas at Dallas (UT Dallas). "If we produce it under precise conditions, we can make it piezoelectric, which means if I stretch it, it generates electricity. Or I can put electricity onto the surface of the material and make it change shape."

PVDF and other materials with similar traits have already made their way into modern technology in the form of pressure sensors in touchpads and tilt sensors in electronics, for example. But their potential, if their piezoelectric properties get a significant boost, could go far beyond these first-generation applications.

In collaboration with Shashank Priya, Ph.D., at Virginia Polytechnic Institute and State University, Voit has already made new progress toward this goal. They have led efforts to develop "soft" polymer-based, energy-harvesting materials as part of the Center for Energy Harvesting Materials and Systems, a National Science Foundation (NSF) program focused on the development of energy-capture and motion-control technologies.

Cary Baur, a doctoral student in Voit's lab, has figured out a way to incorporate organic nanostructures known as "buckyballs" and single-walled carbon nanotubes into PVDF fibers to double its piezoelectric performance. Buckyballs are tiny spheres made out of carbon atoms. They and their cylindrical relatives have interesting properties that scientists are harnessing in a variety of ways.

In the case of Voit's materials, the carbon nanostructures even out and increase the overall strength of the electrical field. As a result, the PVDF-carbon hybrids are the best piezoelectric composites that have been reported to date in the scientific literature, Voit says.

To turn these yarn-like structures into artificial muscles—a catch-all name for materials that can contract or relax in response to an electric current or temperature—Voit needs to make them more powerful. One approach for accomplishing this was developed by a UT Dallas colleague. Ray Baughman, Ph.D., took a bundle of nylon fibers about the width of ten strands of human hair and wound them into a long, tight coil, just like an old-fashioned telephone cord but on a much smaller scale. That structure could contract by nearly 50 percent when heated and lift about 16 pounds.

"The effect is similar to twisting a rubber band," Voit says. "If you pull on it when it's coiled, you get a lot more strain on the rubber band than if it's just straight."

Voit is looking to create a similar effect for his PVDF-carbon fibers, which are far better piezoelectric materials than nylon and would contract in response to an electric current. "We have to coil it," he says. "We have to have the right piezoelectric properties after it's in that complex shape. That's the real secret sauce that we think we can pull off. Ultimately, it could be used to build synthetic muscles that could make prosthetic limbs more life-like."

Another potential use for Voit's materials that has attracted commercial interest is for energy harvesting, he says. Boeing, which funded some of his research, is interested in using the energy generated from airplane passengers as they sit, get up and adjust in their seats to power some of the plane's functions such as overhead lights in cabins. Voit says this would allow the airline to eliminate some cables, which can add significantly to the weight of their jets, and save on fuel.

"Now we're finding ways to make this more processable at larger scales to enable larger energy harvesting apparatuses and practical artificial muscles," Voit says.

More information: Piezoelectric polymer composites: From energy harvesting to artificial muscles, 249th National Meeting & Exposition of the American Chemical Society (ACS).

Abstract
We have demonstrated that the piezoelectric performance of polyvinylidene fluoride (PVDF) can be doubled through the controlled incorporation of carbon nanomaterials. Specifically, PVDF composites containing carbon fullerenes (C60) and single walled nanotubes (SWNT) are fabricated over a range of compositions and optimized for their Young's modulus, dielectric constant, and d31 piezoelectric coefficient. Thermally stimulated current measurements show a large increase in internal charge and polarization in the composites over pure PVDF. The electromechanical coupling coefficients (k31) at optimal loading levels are found to be 1.84 and 2 times greater than pure PVDF for the PVDF-C60 and PVDF-SWNT composites, respectively. Such property-enhanced nanocomposites bring significant advances to electromechanical systems employed for structural sensing, energy scavenging, sonar, and biomedical devices. In this work, we employ PVDF-C60 composites (the highest piezoelectric value of any polymer composite) in a yarn structure to produce large-displacement, electrically

driven artificial muscles. Polymer composite fibers of 1 mm in diameter are drawn through core shell extrusion, with a soft metal conductive core that acts as an inner electrode. Fibers are gold coated and twisted into a yarn-like structure. Through extensive twisting, tight coils are formed in the structure which, upon applying a voltage between the inner and outer electrodes of the yarn, expands and contracts across the length and the width of the structure. Torsional strain allows for the coils to be "unravelled" which greatly increases the elongation of the muscles. Alternately, the application of long strains enable this material to be a long-stroke energy harvesting device. Many piezoelectric energy harvesting material are only able to endure small strains before undergoing catastrophic degradation. The development of large strain energy harvesters presents manifold applications where large deformations/movements are anticipated.

Provided by American Chemical Society