Artificial Muscle Fibers Could Serve as Cell Scaffolds

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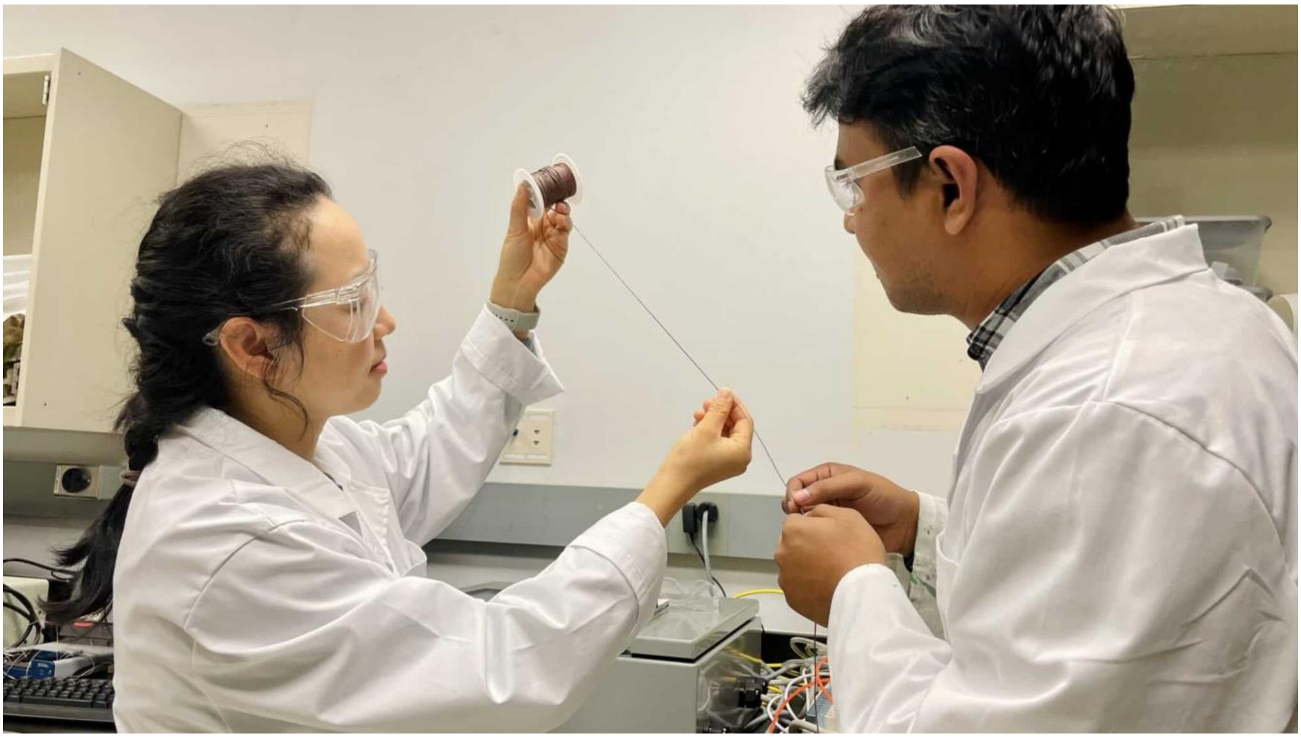
NC STATE UNIVERSITY Wilson College News

In two new studies, North Carolina State University researchers designed and tested a series of textile fibers that can change shape and generate force like a muscle. In the first study, the researchers focused on the materials' influence on the artificial muscles' strength and contraction length. The findings could help researchers tailor the fibers for different applications.

In the second, proof-of-concept study, the researchers tested their fibers as scaffolds for live cells. Their findings suggest the fibers – known as "fiber robots" – could potentially be used to develop 3D models of living, moving systems in the human body.

"We found that our fiber robot is a very suitable scaffold for the cells, and we can alter the frequency and contraction ratio to create a more suitable environment for cells," said Muh Amdadul Hoque, graduate student in textile engineering, chemistry and science at NC State. "These were proof-of concept studies; ultimately, our goal is to see if we can study these fibers as a scaffold for stem cells, or use them to develop artificial organs in future studies."



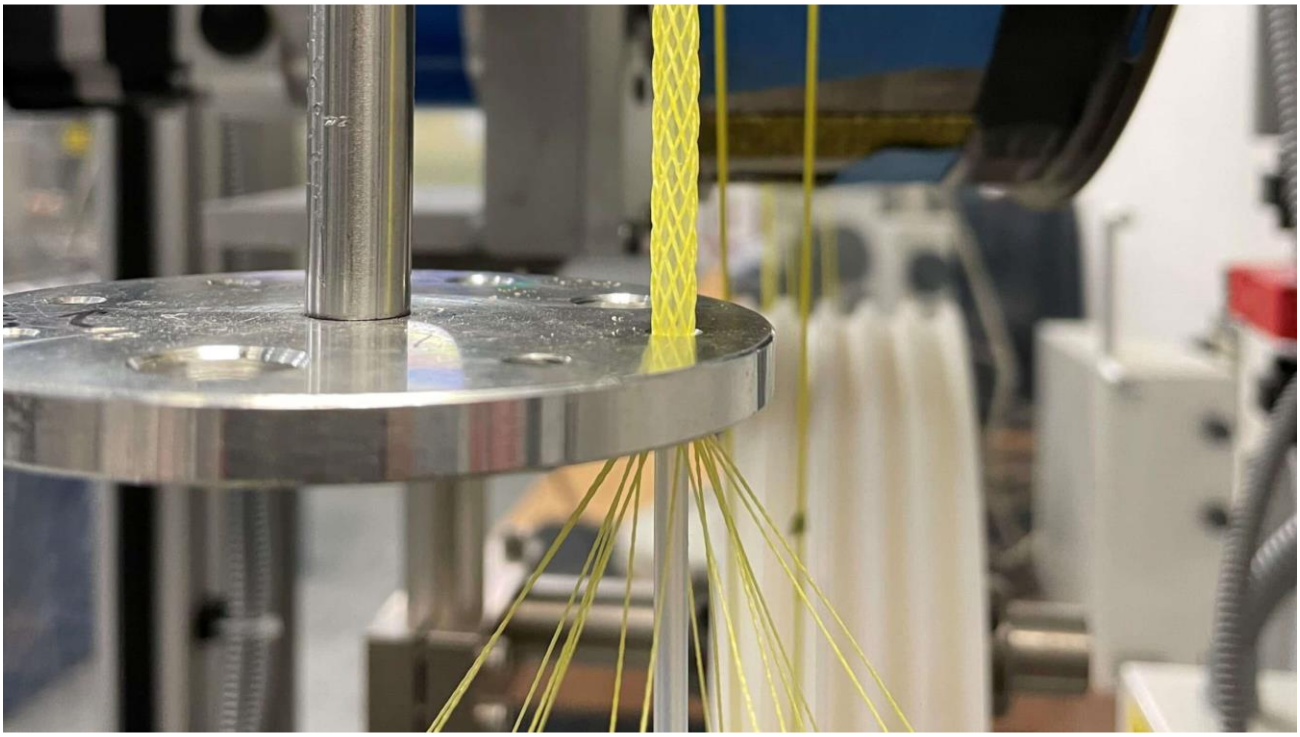
Textile researchers Xiaomeng Fang and Muh Amdadul Hoque are studying artificial muscle fibers.
Credit: Akanksha Pragya, NC State.

Researchers made the shape-changing fibers by encapsulating a balloon-like tube, made of a material similar to rubber, in a braided textile sheath. Inflating the interior balloon with an air pump makes the braided sheath expand, causing it to shorten.

The researchers measured the force and contraction rates of fibers made from different materials in order to understand the relationship between material and performance. They found that stronger, larger diameter yarns generated a stronger contraction force. In addition, they found that the material used to make the balloon impacted the magnitude of the contraction and generated force.

Xiaomeng Fang
Asst Professor

"We found that we could tailor the material properties to the required performance of the device," said Xiaomeng Fang, assistant professor of textile engineering, chemistry and science at NC State. "We also found that we can make this device small enough so we can potentially use it in fabric formation and other textile applications, including in wearables and assistive devices."



Researchers made shape-changing fibers by encapsulating a balloon-like tube in a braided textile sheath.
Credit: Muh Amdadul Hoque.

Jessica Gluck
Assistant Professor

In a follow-up study, researchers evaluated whether they could use the shape-changing fibers as a scaffold for fibroblasts, a cell type found in connective tissues that help support other tissues or organs.

"The idea with stretching is to mimic the dynamic nature of how your body moves," said Jessica Gluck, assistant professor of textile engineering, chemistry and science at NC State, and a study co-author.

They studied the cells' response to the motion of the shape-changing fibers, and to different materials used in the fibers' construction. They found the cells were able to cover and even penetrate the fiber robot's braiding sheath. However, they saw decreases in the cells' metabolic activity when the fiber robot's contraction extended beyond a certain level, compared to a device made of the same material that they kept stationary.

The researchers are interested in building on the findings to see if they could use the fibers as a 3D biological model, and to investigate whether movement would impact cell differentiation. They said their model would be an advance over other existing experimental models that have been developed to show cellular response to stretching and other motion, since they can only move in two dimensions.


Graphic: Gordon Johnson, Pixabay

"Typically, if you want to add stretch or strain on cells, you would put them onto a plastic dish, and stretch them in one or two directions," Gluck said. "In this study, we were able to show that in this 3D dynamic culture, the cells can survive for up to 72 hours.

"This is particularly useful for stem cells," Gluck added. "What we could do in the future is look at what could happen at the cellular level with mechanical stress on the cells. You could look at muscle cells and see how they're developing, or see how the mechanical action would help differentiate the cells."

The study, "Effect of Material Properties on Fiber-Shaped Pneumatic Actuators Performance" was published in *Actuators* on March 18. Emily Petersen was a co-author. The study was funded by start-up funding awarded to Fang from the Department of Textile Engineering, Chemistry and Science at NC State.

The study, "Development of a Pneumatic-Driven Fiber-Shaped Robot Scaffold for Use as a Complex 3D Dynamic Culture System" was published online in *Biomimetics* on April 21. In addition to Gluck, Hoque and Fang, co-authors included Nasif Mahmood, Kiran M. Ali, Eelya Sefat, Yihan Huang, Emily Petersen and Shane Harrington. The study was funded by the NC State Wilson College of Textiles, the Department of Textile Engineering, Chemistry and Science and the Wilson College of Textiles Research Opportunity Seed Fund Program.

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Effect of Material Properties on Fiber-Shaped Pneumatic Actuators Performance

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Abstract: Thin fiber-shaped pneumatic artificial muscle (PAM) can generate contractile motions upon stimulation, and it is well known for its good compliance, high weight-to-power ratio, resemblance to animal muscle movements, and, most importantly, the capability to be integrated into fabrics and other textile forms for wearable devices. This fiber-shaped device, based on McKibben technology, consists of an elastomeric bladder that is wrapped around by a braided sleeve, which transfers radial expansion into

longitudinal contraction due to the change in the sleeve's braiding angle while being inflated. This paper investigates the effect of material properties on fiber-shaped PAM's behavior, including the braiding yarn and bladder's dimensional and mechanical properties. A range of samples with combinations of yarn and bladder parameters were developed and characterized. A robust fabrication process verified through several calibration and control experiments of PAM was applied, which ensured a more accurate characterization of the actuators. The results demonstrate that material properties, such as yarn stiffness, yarn diameter, bladder diameter, and bladder hardness, have significant effects on PAMs' deformation strains and forces generated. The findings can serve as fundamental guidelines for the future design and development of fiber-shaped pneumatic actuators.

Development of a Pneumatic-Driven Fiber-Shaped Robot Scaffold for Use as a Complex 3D Dynamic Culture System

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Abstract: Cells can sense and respond to different kinds of continuous mechanical strain in the human body. Mechanical stimulation needs to be included within the in vitro culture system to better mimic the existing complexity of in vivo biological systems. Existing commercial dynamic culture systems are generally two-dimensional (2D) which fail to mimic the three-dimensional (3D) native microenvironment. In this study, a pneumatically driven fiber robot has been developed as a platform for 3D dynamic cell culture. The fiber robot can generate tunable contractions upon stimulation. The surface of the fiber robot is formed by a braiding structure, which provides promising surface contact and adequate space for cell culture. An in-house dynamic stimulation using the fiber robot was set up to maintain NIH3T3 cells in a controlled environment. The biocompatibility of the developed dynamic culture systems was analyzed using LIVE/DEAD™ and alamarBlue™ assays. The results showed that the dynamic culture system was able to support cell proliferation with minimal cytotoxicity similar to static cultures. However, we observed a decrease in cell viability in the case of a high strain rate in dynamic cultures. Differences in cell arrangement and proliferation were observed between braided sleeves made of different materials (nylon and ultra-high molecular weight polyethylene). In summary, a simple and cost-effective 3D dynamic culture system has been proposed, which can be easily implemented to study complex biological phenomena in vitro.