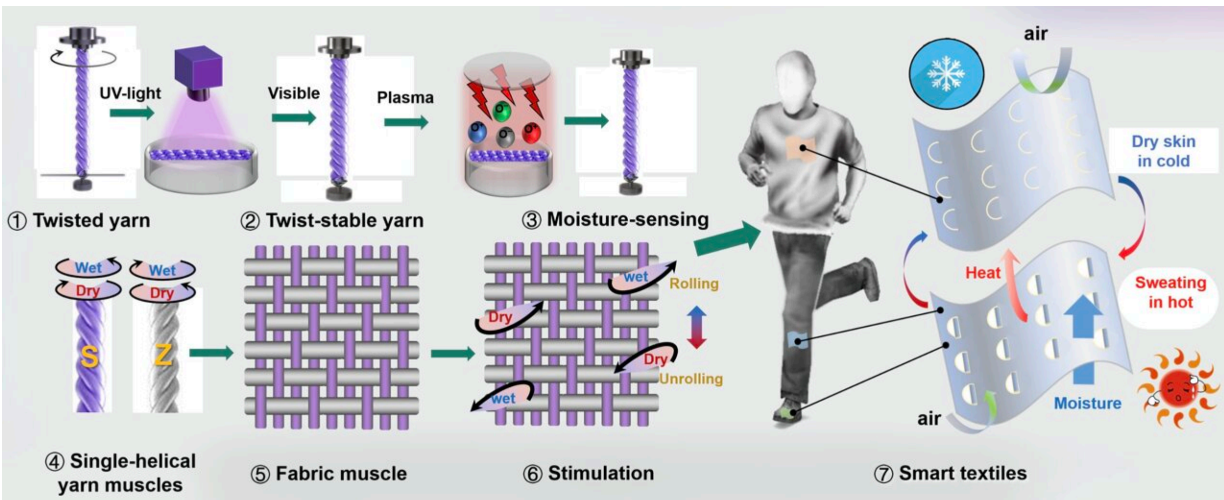
New adaptive artificial muscles made of a single-helical woolen yarn

August 8 2022, by Ingrid Fadelli



An illustration of the team's hierarchical construction of free-standing woolen yarn artificial muscles for humidity-responsive smart textiles. Credit: Peng et al.

In recent years, material scientists have designed a wide range of innovative materials that could be used to create new technologies, including soft robots, controllers and smart textiles. These materials include artificial muscles, structures that resemble biological muscles in shape and that could improve the movements of robots or enable the creation of clothing that adapts to different environmental conditions.

As part of an ongoing project focused on textile-based soft actuators, a team of researchers at Jiangnan University in China recently developed new artificial muscles based on free-standing, single-helical woolen yarn. Their artificial muscles, introduced in a paper published in *Smart Materials and Structures*, could be used to easily and affordably produce twisted actuators that can detect and respond to humidity in their environment.

"We are trying to design flexible and versatile actuators by leveraging the hierarchical structure design of textiles, ranging from microscales (e.g., molecular chains and aggregation structures) to macroscales (e.g., fiber morphology and textile architectures)," Fengxin Sun, one of the researchers who carried out the study, told Tech Xplore. "Realizing a yarn-based artificial muscle with free-standing and single-helical architecture via eco-friendly and easy-fabrication manufacturing process is still challenging."

The primary objective of the recent work by Sun and his colleagues was to overcome some of the common challenges faced when designing artificial muscles based on yarn (i.e., spun thread). Most notably, past studies have showed that reliably twisting yarn to create free-standing artificial muscle structures without using harmful chemicals or processes is far from an easy task.

The researchers at Jiangnan University, however, were able to identify an eco-friendly treatment strategy for the reliable production of single-helical yarn-based muscle. Their fabrication method is based on a combination of UV illumination and plasma etching, a plasma processing technique often used to produce integrated circuits.

This processing technique can limit the dissipation of energy from the woolen fibers, thus enhancing the artificial muscles' actuation performance. In addition, it is effective, scalable and easy to implement, thus it could be ideal for fabricating these muscle-like structures on an industrial level.

"The woolen yarn artificial muscles we created display reversibly torsional actuation when alternatively exposed to wet and dry environments," Sun explained. "The yarn muscles display an impressive torsional actuation upon wetting, as a result of the amplified hygroscopic expansion of the highly twisted wools. The solidified helical morphology in the wools resulting from the reformed disulfide networks endows the woolen yarns with a 'shape memory effect.'"

Due to the unique design and fabrication approach used by the researchers, the yarn that makes up their artificial muscle structure can recover its original helical shape after it is dried, without requiring the integration of an external spring. In initial tests, the single-helical yarn-based muscles exhibited reversible and moisture-sensing actuation, as well as a high moisture-actuating performance with lower energy dissipation.

Remarkably, the fabrication process employed by Sun and his colleagues is also eco-friendly, as it does not require any chemical and toxic additives. As their artificial muscles are made of wool, which is inherently biodegradable and renewable, they could be used to create more sustainable technologies and smart textiles.

"Single-helical structures are generally considered unstable and prone to untwist without external torsional tethering, but we here harness the inside-tether effect of reformed disulfide bridges in the helical structure state of wools to stabilize the inserted twists in yarn muscles via UV-light illumination and autoxidation," Sun said. "Such strategy is completely eco-friendly and greatly improves the actuation performance of woolen yarn muscles."

In the future, the recent work by this team of researchers could inspire the development of new yarn-based actuators and artificial muscles for robots that can be produced sustainably, at reasonable costs and on a large-scale. In addition, the single-helical woolen yarn they produced could be used to create comfortable, breathable, nontoxic and skin-friendly textiles for smart clothing, smart camping gear and other smart textile products.

"In the next stage of our research, we will explore the route towards the Industrial fabrication of our artificial muscles, to realize their mass-production and promote technological innovation towards the commercial application of the yarn muscles in smart textiles," Sun added. "Imaging a shirt, the yarn can adapt to different weather conditions by switching the air holds on the fabric intelligently, that would be fascinating. We hope this kind of clothes will become available in our daily life at a low cost."

More information: Yangyang Peng et al, Free-standing single-helical woolen yarn artificial muscles with robust and trainable humidity-sensing actuation by eco-friendly treatment strategies, *Smart Materials and Structures* (2022). DOI: 10.1088/1361-665X/ac7fca