New Process Makes Spider Silk in Many Forms

The strongest fiber found in nature is a silk made by spiders known as orb weavers. Unfortunately, spiders have two flaws: They are territorial and cannibalistic, making it impossible to farm them like silkworms to produce massive quantities of silk for commercial applications.

Led by Randolph Lewis, a USTAR professor of biology in the Synthetic Biomanufacturing Center at Utah State Univ. (USU), researchers have come up with a way to make the orb weaver silk without the orb weavers. They use recombinant genetic methods to produce synthetic genes and transfer those genes to bacteria, which then produce the same proteins that the spiders use to make silk. Once purified, the proteins can be processed to make spider silk materials.

A major breakthrough that has enabled the scientists to use the proteins to produce silk materials is a method they developed to dissolve the purified proteins in a single-phase aqueous solution. Previously, expensive and potentially toxic organic solvents were required to dissolve the proteins in a process that took several hours and was only capable of dissolving half of the protein. The new process involves combining high temperature (130–150°C) and pressure (300–500 psi) with microwave irradiation — all of which help to dissolve the protein in solution. In as little as two minutes, the vast majority of the protein is solubilized. This process has been shown to work for all of the ten different spider silk proteins tested. A patent is pending on this process.

Once in solution, the proteins can be spun into fibers via two methods: standard wet spinning, which produces fibers of maximum strength and elongation; and electrospinning of an aqueous solution, which produces oriented mats. The USU team is also developing an electrospinning instrument for producing commercial quantities of multi-fiber thread.

The new process opens the door to making bio-inspired materials other than fibers from spider silk proteins. Because the protein solution is aqueous, a variety of chemicals can be added to stabilize the solution or to create functional materials such as anti-microbial or electrically conductive materials. Spider silk is well tolerated in the body, making it ideal for medical applications, and the aqueous solution of spider silk proteins allows for biomedical products that are not feasible with organic solutions.

▲ Researchers have cloned the protein used by the orb weaver spider to make a variety of materials, including the synthetic fibers shown here. They have spun silk fibers more than 1,000 m long.

So far, the USU researchers have created a wide variety of novel materials, such as films, coatings, hydrogels and lyo-gels, sponges, and adhesives, as well as materials for electrospinning and 3D printing. They are working with several companies, including the USU spin-out Araknitek Inc., to develop prototype products from the spider silk proteins. They are developing high-performance fabrics, fibers for composite materials, coatings for medical implants, glues for a variety of applications, and 3D-printed medical products.

The silk-based materials have exceptional adhesive properties, and are able to glue virtually any materials together, including difficult ones such as polytetrafluoroethylene (PTFE) and silicone, with high strength (ten times greater than many existing glues). In addition, gels made from the proteins can be doped with a variety of water-soluble compounds, including drugs such as antibiotics, growth factors, and cells. The gel density and processing parameters can be varied to alter the rate of efflux of these compounds from the gel, thus providing a controlled release and degradation rate that is crucial for medical, dental, and veterinary applications.

Coatings and films made from these proteins combine the properties of the gel and adhesive. The coatings can be sprayed onto a variety of metals, plastics, and other solid materials. The coated materials can be stretched and bent without damaging the protein coating.

USU has built a pilot-scale facility with two 500-L fermenters and purification vessels to allow for prototype development of the spider silk protein products.

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