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الجمعية المصرية لعلوم وتكنولوجيا النسيج

Nanotechnology to Improve the Performance of Silk Fabric

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Abstract

Silk is one of the oldest materials known to humans and has been used extensively in a wide range of situations. The fiber-like proteins that insects emit are referred to as "silk." The fact that proteins in aqueous solutions are employed by insects to produce silk fibers is intriguing, but the fibers also cause the proteins to crystallize and become intractable. Currently, several research organizations across the globe are attempting to create advancements in this area. Nanomaterials are widely employed as catalysts, in the textile industry, electronics, cosmetic goods, food packaging, industrial purification processes including water purification, and in the area of medicine as drug delivery systems. Due to the range of products it may be used to make, particularly in the production of high-end commercial goods like wrinkle-free textiles, nanotechnology has consequently emerged as a very popular sector.

Keywords: nanotechnology, metal nanoparticles, and silk fabric.

Introduction

Silk is a unique natural polymer that serves a vital purpose in our society. Every year, one hundred billion dollars are spent on silk-based products. Silk threads from the Bombyx mori silkworm have laid the groundwork for a millennium-old textile industry with a thriving business. More than 120 000 tonnes of silk are produced worldwide, with China, India, and Japan having the most economic clout. Even though spider silk threads are far more enticing due to their superior intrinsic mechanical properties, they have yet to be commercialized. Insects create silk proteins in several ways, but each species can only produce one kind. A single spider, on the other hand, can manufacture up to eight different types of silk thread. [1-4]

Insects build up proteins (25–30% proteins) in their glands to create fibers that have a viscosity close to 3.5 million times that of water. Due to the material's high viscosity, insects can extrude continuous fibers. A protein droplet is ejected onto a substrate, and the solution is subsequently pulled and drawn away from the substrate to create fibers.

Typically, the major protein fibroin is found in two filaments that are joined together by the protein sericin to form silk fibers. Heavy fibroin (200–350 kDa), light fibroin (25–30 kDa), and glycoprotein P25 (25 kDa) are the three types of fibroin that are found in fibers. In a 6:6:1 ratio, the heavy chain fibroin is joined to the light chain fibroin by disulfide bonds and to P25 by hydrophobic contacts.

The majority of silks have large concentrations of the non-essential amino acids glycine, alanine, and serine, preventing insects from eating these proteins as food. [5-8]

Insects that produce silk have been divided into 23 different categories based on the type of silk gland, molecular structure, and evolutionary relationship.

The most prevalent type of silk on the market is known as mulberry silk and is produced by the bug Bombyx mori. Univoltine insects, as opposed to multivoltine ones, which produce several cocoons during their life cycle, are the most common source of B. mori silk. Currently, the annual global production of silk is at 1.5 million tonnes. Even though approximately 60 countries are said to manufacture silk, China and India account for more than 90% of the world's total silk output.[9]

Silk's physical characteristics

- The fabric often ranges in shade from grey to dark brown, and the raw silk is a neutral cream color.

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- The silk fiber appears to be non-slippery, smoother, and shinier in appearance. [10]
- Although less elastic, it appears to be a lightweight, flexible, reasonably absorbent, and breathable cloth.
- The sericin proteins in silk function as a "glue" to unite the two fibroin filaments to create the silk yarn[11]. Because it is hydrophobic by nature, this fiber weakens when exposed to intense sunlight and loses 20% of its strength when it becomes wet.[12]
- It feels chilly to the touch and is a bad conductor of electricity.
- Unwashed silk chiffon contracts by up to 8% as a result of fiber macrostructure relaxation.[13]

Silk's chemical composition

- Silk fabric withstands weak acids, contracts in medium acids, and dissolves in strong acids.[14]
- Silk will suffer some minor harm from the weak alkali and dissolve in the strong base.[15]
- In the organic solvent, it becomes insoluble and vulnerable to fungus attacks.
- Due to peptide bond breakage brought on by ultraviolet light, the fabric experiences polymer degradation on its surface, which causes silk to fade or yellow.[13, 16]
- silk fiber contains 70%–80% silk fibroin and 20%–30% sericin.

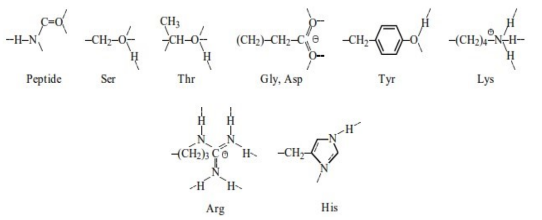

Fig. 1. The chemical composition of silk fiber.

Nanotechnology

Nanotechnology finds its use in a broad spectrum of fields primarily due to the versatility of its applications. Richard Feynman, a Nobel winner, first proposed the concept of nanotechnology, but it wasn't until Norio Taniguchi created the phrase "nanotechnology" in 1974 that it attracted widespread notice. Nanomaterials, nanoparticles, nanorods, nanocrystals, and nanoribbons are all used in nanotechnology. [17-20]

Currently, many research institutes all over the world are working to develop innovations in this field. Nanomaterials have found their use in the fields of medicine as vehicles of drug delivery, in the textile industry, in electronics, in cosmetic products, in food packaging, in industrial and purification processes like water purification, and are also widely used as catalysts, etc. Nanotechnology has thus proven to be quite a sought-after field due to its variety of applications, especially in the creation of high-end commercial goods like wrinkle-free textiles.[21, 22]

The use of nanotechnology on silk

Silica (SiO2) Nanoparticles

- Silk intermolecular bonds are brittle and break readily, which causes the molecular chains to create new hydrogen bonds with one another, which causes wrinkles in silk garments. Cross-linking agents and finishing agents are utilized to address this problem because they maintain the links between the chains, which increases wrinkle resistance.
- A study by Li-Zhi Gao et al. found that coating silk fabrics with nano-silica (nano SiO2) and using a silane coupling agent (KH570) resulted in the development of wrinkle-resistant and UV-protective qualities.
- Nano-silica particles are regarded as superior finishing agents because of their high specific surface area, chemical inertness, thermal stability, and favorable mechanical characteristics.
- Multiple hydroxyl groups found in nano-silica can establish hydrogen bonds, improving the resilience of silk materials to wrinkles.
- The WRA of silk treated with nano-SiO2 and KH570 was discovered to be 270.6 degrees, an increase of 16.5% above the sample treated with water.
- It is possible that the crosslinking of nano-SiO2 and silk fibers will retain the silk molecular chains in place and limit their relative mobility, significantly enhancing wrinkle-resistant qualities. [22, 23]

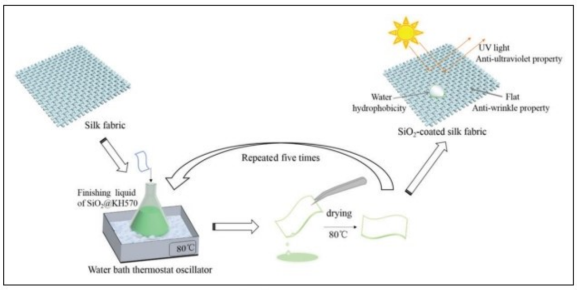

Fig. 2. Diagram of the procedure of coating nano-SiO2 on the silk fabric surface

2- carbon nanomaterial

The electrical and mechanical characteristics of silk fibroin fiber may be enhanced by treatment with graphite, graphene, or carbon nanotubes. By reducing GO with sodium disulfide. transformed silk fibroin fiber with decreased graphene. Its surface resistance was as low as 3.24 k cm-1.[24]

In a thermoplastic polyurethane (TPU) matrix, Narayanan et al. created a dispersion of liquid exfoliated graphite (EG), nanographite (NG), carbon nanotube (CNT), and carbon nanofiber (CNF), and applied it to silk fibroin fiber. The conductivity of the modified fiber was up to 11 S/m.[25]

The fabrication of sheath-core-structured single-fiber strain sensors employing ultrafine graphite flakes as the sheath and silk fibroin fiber as the core was accomplished. using a simple dry Meyer rod coating procedure. The sensors had exceptional stability, great sensitivity, and little hysteresis.

The silk fibroin fiber can be altered with metal nanoparticles, inorganic nanoparticles, or carbon nanomaterials to give it specific qualities, however, this can also lead to drawbacks including poor adhesion, self-accumulation, and durability. It is worthwhile to alter silk fibroin fiber by introducing functional groups for additional covalent fusion.[26, 27]

3- radiative cooling by nano (Al2O3)

Due to its protein content, natural silk naturally exhibits strong absorption in the ultraviolet (UV) region 22. It is therefore fundamentally impossible for it to achieve a net cooling power or sub ambient temperature when exposed to sunlight during the daytime because of its total reflectivity in the sunlight wavelength range (0.3-2.5 m), which is only 86%

Therefore, it would be desired to develop methods that boost silk's reflectivity in the UV wavelength region without adversely compromising its thermal emission qualities to create silk-based materials for sub ambient daytime radiative cooling. Additionally, the processing must maintain its great wearability. Consequently, for the following reasons, first, the method shouldn't eliminate silk's intrinsic hierarchical structure and distinctive components, as these are directly tied to its optical qualities.

Second, properties such as moisture transportation and air permeability are essential to the comfort of fabrics and therefore should not be sacrificed. In addition, the sub ambient daytime radiative cooling properties after treatment need to be durable, even after wearing, twisting, and washing. Also, the treatment process should be scalable and compatible with large-scale fabric manufacturing techniques.[28]

Silk's UV reflectivity could be raised by adding tAl2O3 nanoparticles. Particle sizes between 250 and 350 nm can produce substantial UV wavelength scattering. However, because the particle sizes are significantly smaller than the thermal wavelength, adding such nanoparticles to silk does not change its excellent emissivity and low reflectivity in the MIR wavelength region, which is crucial for thermal emission. As a result, Al2O3 nanoparticles about 300 nm in size [29, 30] were to maintain the silk's inherent characteristics while adhering the Al_2O_3 particles to the material. As a low-cost, high-throughput method, To join the Al_2O_3 particles to silk, tetra butyl titanate (TT) was employed as the coupling agent.

The hydroxy groups on the surface of Al_2O_3 can create hydrogen bonds with TT, and it also lessens the aggregation of Al_2O_3 particles. TT can simultaneously create potent covalent connections with the silk's amino acids. [31]

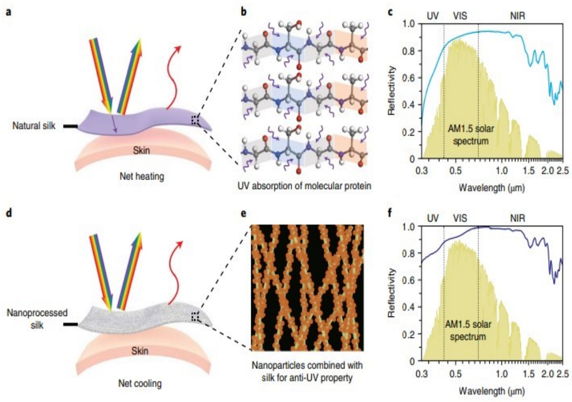

Fig. 3. Subambient daytime radiative cooling design for nano processed silk

Nanoprocessed silk can achieve a temperature of about 3.5°C below ambient in the daytime and, when covering simulated skin, can achieve a reduction of skin temperature of about 8 °C under sunlight, with similar comfort and wearability to natural silk. This is accomplished through molecular bonding design strategy and scalable dip-coating methods. Because of the sub ambient radiative cooling impact created by sunlight, the skin will have a similar cooling effect when in touch with this nano processed silk, if not a greater one than when skin is exposed to ambient temperature directly.[32]

4- **gold nano (AUNCs)**

By chemically covering the surface of the natural silk fiber with luminescent AuNCs via a redox reaction between the protein-based silk and an Au salt precursor, we show that luminescent silk may be easily manufactured by nanotechnology in situ. Due to their excellent qualities, such as their subnanometer size, high fluorescence quantum yield (QY), good biocompatibility and photostability, and simplicity of preparation, luminescent metal nanoclusters—new rising stars in nanotechnology—have recently attracted increasing attention.

Our findings suggest that the luminous golden silk exhibits good in vitro biosafety whether exposed to cells or prolonged contact with animal skin. It also has a strong and steady red fluorescence with an absolute QY of about 8%. In addition, golden silk has even better mechanical characteristics than immaculate silk, including a higher breaking strength and elongation rate at break as well as a greater capacity to block UV rays. We go on to show that this photoluminescent silk is a great choice for anti-counterfeiting by taking advantage of these benefits.

performed an experiment synthesis of golden silk through a typical synthesis, an aqueous solution containing 0.143 mm of hydrogen tetrachloroaurate (III) hydrate (HAuCl4•3H2O) and 10 mg of silk was mixed with vigorous magnetic stirring for 10 min. Then, 10 minutes were spent stirring 70 mm of sodium hydroxide (NaOH, Aldrich). This mixture was incubated for 45 minutes at 80 °C. After bringing to room temperature, store.

the Proved indicates that the resultant golden silk possesses excellent optical properties, including a relatively long-wavelength fluorescence (red), a high QY (8%), a long fluorescence lifetime (322 ns), and high photostability. Furthermore, its biosafety is as high as that of pristine silk.[33]

Conflicts of interest

There are no conflicts to declare

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There is no fund to declare

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تقنية النانو لتحسين أداء النسيج الحريري

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الملخص

الحرير هو واحد من أقدم المواد المعروفة للبشر وقد استخدم على نطاق واسع في مجموعة واسعة من الحالات. يشار إلى البروتينات الشبيهة بالألياف التي تنبعث منها الحشرات باسم "الحرير". حقيقة أن البروتينات في المحاليل المائية تستخدمها الحشرات لإنتاج ألياف الحرير أمر مثير للاهتمام ، لكن الألياف تتسبب أيضا في تبلور البروتينات وتصبح مستعصية. حاليا ، تحاول العديد من المنظمات البحثية في جميع أنحاء العالم خلق تقدم في هذا المجال. تستخدم المواد النانوية على نطاق واسع كمحفزات ، في صناعة النسيج ، في الإلكترونيات ، في مستحضرات التجميل ، في تغليف المواد الغذائية ، في عمليات التنقية الصناعية بما في ذلك تنقية المياه ، وفي مجال الطب كأنظمة توصيل الأدوية. نظرا لمجموعة المنتجات التي يمكن استخدامها لصنعها ، لا سيما في إنتاج السلع التجارية الراقية مثل المنسوجات الخالية من التجاعيد ، فقد برزت تقنية النانو بالتالي كقطاع شائع للغاية.

الكلمات المفتاحية: تقنية النانو والجسيمات النانوية المعدنية والنسيج الحريري.