Spider and silkworm silk: From the nanometer scale to the macroscopic properties

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Silks are high performance fibers spun by arthopods for a wide range of biological functions, including the protection of the offspring and the capture of preys [1]. Most efforts in the field have been devoted to the study of the silk produced by silkworms (*Bombyx mori*) and that spun from the major ampullate gland (MAS) of the orb-weaving spiders. It has been found that both silks share some similarities in terms of sequence and of organization at the molecular scale. Silkworm silk presents the repeated motif –GAGAGS- that has been shown to form β–nanocrystallites responsible for the mechanical stability of the fiber. This role is played by polyalanine motifs (A_n; n=5-8) in MAS [2]. However, there is a very limited knowledge of the microstructural structural organization of both silks at higher scales ranging from the nanometer to the micrometer.

In this work we present recent advances in the characterization of silk fibers by atomic force microscopy. Silkworm silk (*Bombyx mori*) and spider MAS (*Argiope trifasciata*) have been studied. MAS fibers were observed both in the state of minimum alignment of the chains with respect to the macroscopic axis (maximum supercontracted fiber, MS) and in the state of maximum alignment (forcibly silked fiber, FS) [3]. Silk fibers have been embedded in resin and ultramicrotomed in the longitudinal direction.

Both silkworm and spider silk show a common nanoglobular organization. Silkworm silk nanoglobules are anisotropic with a longitudinal dimension of 23 ± 6 nm and a transverse dimension of 16 ± 4 nm. In contrast, spider silk nanoglobules are isotropic, and their size increase from the MS state (10 ± 2 nm, maximum size 18 nm) to the FS state (13 ± 4 nm, maximum size 21 nm). At larger scales, it has been found that silkworm silk nanoglobules show a loose alignment with the macroscopic axis of the fiber, no such an organization at the micrometer scale has been observed in spider MAS either in MS or in FS state.

The microstructural differences between silkworm and spider silk can be related to their biological functions. Silkworm silk is designed to protect the pupa during its metamorphosis [4], so that a stiff material is required to prevent possible predators from reaching the worm. In contrast, MAS is designed to absorb and dissipate large amounts of mechanical energy [5], in order to fulfil its biological functions either in the web or as a safety line for the spider. The increase in size of the nanoglobules due to the stretching of the fiber, which is supposed to proceed by the formation of new β-nanocrystallites, is a likely mechanism that accounts for both requirements.

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