Orb web spider silks: how their optics affects potential visibility

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Orb web spider silks – how their optics affects potential visibility

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ABSTRACT

Certain spider silks, as used in aerial orb webs, are high quality optical micro-fibers with widths of 1 to a few microns and a refractive index of ~1.55. It has been reported that such silks have reduced relative reflectance in the ultra-violet and violet, as compared to the rest of the visible light spectrum with implications for their visibility to insect vision. Relative reflectance as a function of wavelength gives no insight into the fraction of the intensity of light that falls on a spider silk that will be backscattered/reflected into a solid angle such that it might result in it being visible to an oncoming insect, for example. We will report comparative results from measurements of the radial silks of four orb web weaving spider species. These species evolved at different times and/or to exploit different biological habits. One species is nocturnal. Combining the results of photoreflectance measurements and optical surface profiling studies shows how the geometry of the spider silks may have evolved to reduce the scattered/reflected light from the radial silk of certain species. The properties of certain spider silks as an optical material with low UV absorption also emerge from this study.

Keywords: micro-optical fiber, spider silk, light scattering, photoreflectance, optical surface profiling

INTRODUCTION & DISCUSSION

The mechanical properties of spider silk, particularly dragline and radial spider silk of certain orb web spiders, has been studied for decades. As drawn, spider silk is a fascinating nanocomposite protein polymer with large values for its strength and toughness. The significance of its optical properties has been less considered. Research in the past decade has shown certain such silks to be high optical quality micro-fibers. It has been a challenging to research the experimental methods to measure its refractive index and absorption of such micro-optical fibers. Photos of the webs of two Phonognatha graeffei (leaf curling) spiders are shown in fig. 1 as examples of aerial orb webs.

In contemplating why evolution might drive spider silk to be high optical quality micro-fibers, visibility of the web is a key factor of importance. The sense of sight is common across the animal kingdom. It relies on detecting, imaging, and processing light reflected and scattered from surrounding surfaces using a biological, optical visual system. From an evolutionary perspective there is a complex interplay as plants and animals evolve, in parallel and interdependently, to achieve combinations of being seen and evading being seen within the backdrop of a specific physical environment with its evolving biota. Sight is only one of the senses that animals use to sense their surroundings, but it is the one of relevance to our consideration of the “reflectance”/scattering properties and geometrical form of the radial silks. This has been done for four spider species. Each species comes from a different genera. Prior studies of the silks of Argiope keyserlingi (St Andrew’s cross spider) and Plebs eburnus have shown the radial silks to be well approximated by double cylinders. Microscopy studies have supported this as well. It was tempting to assume, given the bio-chemico-physical process by which the initially liquid silk dope is drawn, that all silks would be expected to have a circular cross-section. This has been tested for the radial silk of Eriophora transmarina, the garden orb weaver, a nocturnal spider; Nephila plumipes, the golden orb weaver spider; Argiope keyserlingi; and Phonognatha graeffei, the leaf curling spider; by optical surface profiling of the silks using an interferometric microscope. Only two of the species studied, A. keyserlingi; and P. graeffei, are found to have cylindrical dragline silk. The flatter profile of the others, combined with a larger physical width, leads to a greater visibility. The implications for the effective reflected/scattered signal will be further discussed along with those of the spectral form of the photoreflectance spectrum.

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FIGURE 1. Natural webs of *Phonognatha graeffei*. The visibility of the capture spiral of the web on the left is enhanced by dew drops nucleating on the capture droplets. The web on the right (with enlargement of a small area in the inset) also has visibility enhanced by early morning dew but to a lesser extent than the web on the left. Note that the radial silks are not enhanced and are less visible. The curled leaf and part of the spider can be seen in both photographs.

REFERENCES