Crossdisciplinary Applications of Microscopy Techniques, e.g. Physic-Life Science Interfaces

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Influence of ultraviolet radiation on spider silk - electron microscope studies

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The purpose of this work is to investigate the effects of ultraviolet radiation (UVR) on the physical properties of spider silk. Spider silk comprises protein fibroin [1], which are layers of antiparallel beta sheet assembled from the recurrent amino acid sequence; the high glycine (and, to a lesser extent, alanine) content allows for tight packing of the sheets henceforth contributing to the strength and toughness of the material. The formation of hydrogen bonds within the beta sheets and between neighbouring beta sheets in turns regulates the fine structure of the silk [2]. The final macroscopic structure of the spider silk depends on the viscosity of the protein fluid, which is regulated by the shear rate, during the spinning process [1, 2].

In this study, spider silk harvested from a conservatory was exposed to UVR at wavelength 254 nm over three different exposure times, *t* (= 10, 20 and 30 min) to determine the effects of *t* on the physical properties. Wavelength 254 nm falls within the range of wavelengths known as UVC; UVC is normally filtered out by the ozone layer so that none reaches the earth's surface. A control group (not UVR treated) was used for the purpose of comparison. Scanning electron microscopy (SEM, JEOL JSM-7600F, at 1 kV) was carried out at JEOL Asia Pte Ltd. Analysis of the SEM images from the control group revealed that spider silk featured relatively smooth texture (at low magnification; Figure 1A), with small crevices and humps (at larger magnification; Figure 1B), on the surface of the silk. However, when treated to UVR, silk dissociated into distinct fascicles, and the number of fascicles delaminated from the silk increased with increase in *t*. Figure 2A shows the distinctive (delaminated) fascicles from a UVR treated silk thread (*t* = 30 min; x5000). Further analysis at higher magnification revealed numerous small disorientated fibrils on the surface of the threads (Figure 2B). The small crevices and humps present in the control groups were noticeably absent in the UVR treated silk. Although these dramatic structural changes did not give rise to any new functional groups (as observed from the FTIR spectra; results not shown), the wavenumber of the Amide I peak decreases with increase in *t*. A decreasing wavenumber suggests an increasing number of disrupted hydrogen bond within the fibroin molecule; this lends support to the findings of a decreasing tensile strength and stiffness of the silk thread with increase in *t* ($P < 0.05$). These structure-function findings are important from an environmental perspective. Overall, the findings suggest that increase exposure time of spider thread to UVR, i.e. arising from decreases in the ozone layer, could lead to diminution of the mechanical properties, resulting in weaker and reduced stiffness, of the spider silk and this could in turn affect the foraging capability of spiders and long term adaptability in the face of the climate change. Further studies is underway to relate the molecular changes [3] underlying the structural changes seen here.

1. J. Sirichaisit, R.J. Young and F. Vollrath, Polymer 41 (2000) p. 1223
2. J.E. Trancika, J.T. Czernuszka, D.J.H. Cockayne and C. Viney, Polymer 46 (2005) p. 5225
3. S. Keten and M.J. Buehler, Applied Physics Letters (2010) 153701-1

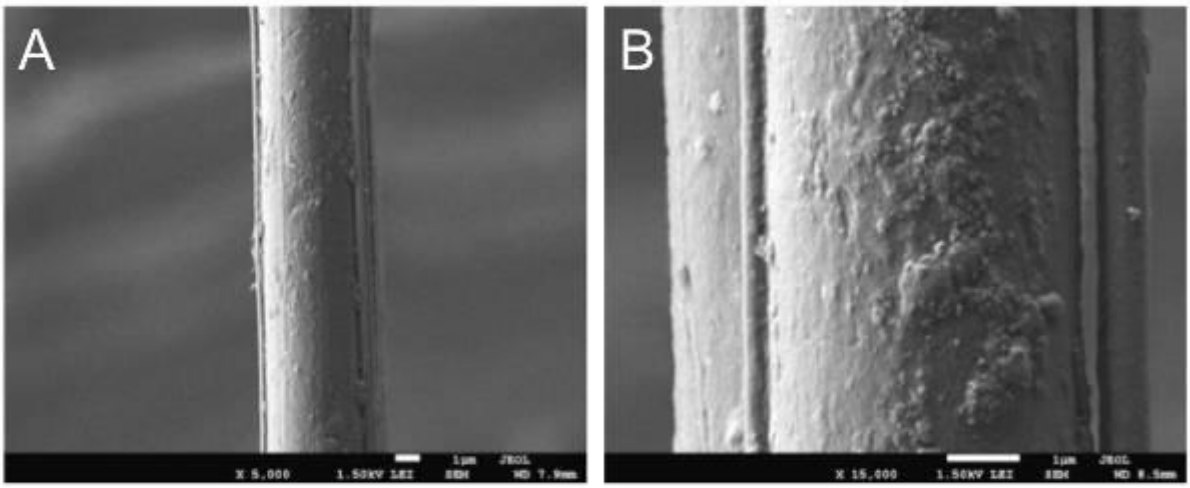

Figure 1. SEM images of spider silk (controls) at magnifications of 5000 (A) and 15000 (B); scale bars,1 □m.

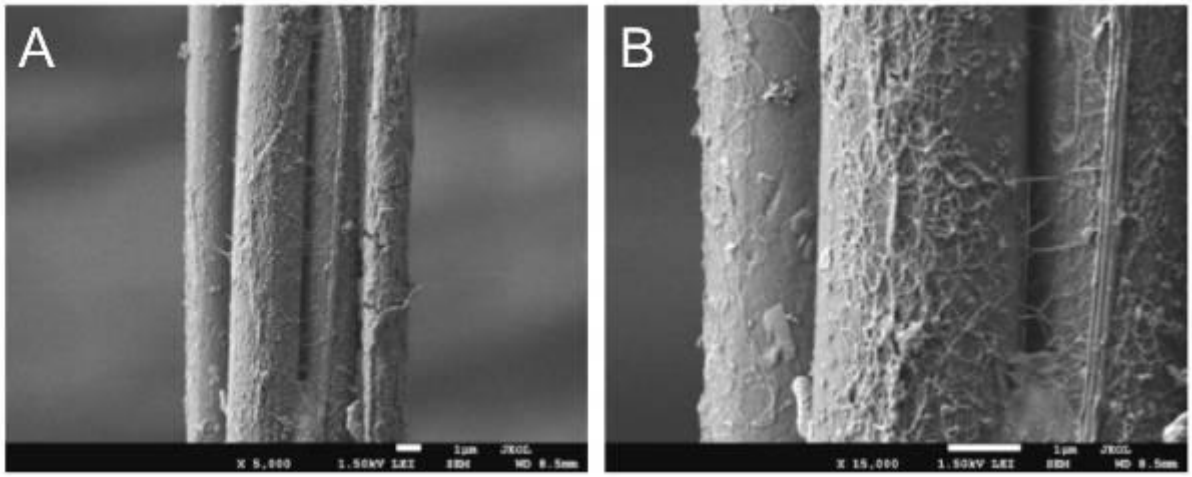

Figure 2. SEM images of spider silk (30 minutes exposure to UVR) at magnifications of 5000 (A) and 15000 (B); scale bars,1 □m.