INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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SPECIAL ISSUE FOR
INTERNATIONAL CONFERENCE ON
"INNOVATIONS IN SCIENCE & TECHNOLOGY: OPPORTUNITIES & CHALLENGES"

# SPIDER SILK - AN ANCIENT MATERIAL OF THE FUTURE

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**Accepted Date: 07/09/2016; Published Date: 24/09/2016**

**Abstract:** *Spider webs are fascinating feats of bioengineering in nature. Silk production from the abdominal silk glands is unique to spiders. In the present work, atomic force microscopy was used for determining the microscale topology and surface nanostructure of dragline silk of orb web spider Nephila pilipes. Biochemical analysis of dragline silk of Nephila pilipes was performed with the help of FTIR spectrum. The spider silk is strong, natural, biodegradable and antibacterial in nature. It can be produced pollution free. This biomaterial can be used to make a diverse range of items like bullet-proof clothing, parachutes chords, surgical threads, artificial tendons, biodegradable bottles, strings of musical instruments etc.*

**Keywords:** *Spider, Nephila pilipes, dragline silk, biomaterial.*

*PAPER-QR CODE*

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**Access Online On:**

www.ijpret.com

**How to Cite This Article:**

Sawarkar A. S., IJPRET, 2016; Volume 5 (2): 236-240

**INTRODUCTION**

Various kinds of silk producing glands in spider function as small biofactories. The most important characteristic feature of spider is their ability to produce silken threads of various kinds. Female *Nephila pilipes* constructs a huge orb web between tall trees. Many times, the prey is seen caught in the web of *Nephila pilipes* which includes grass- hopper, dragonflies, moths and even flying birds like sparrow. This indicates that, this silk can sustain any kind of force. Therefore, it has been decided to study the properties of silk from the biophysical and biochemical point of view.

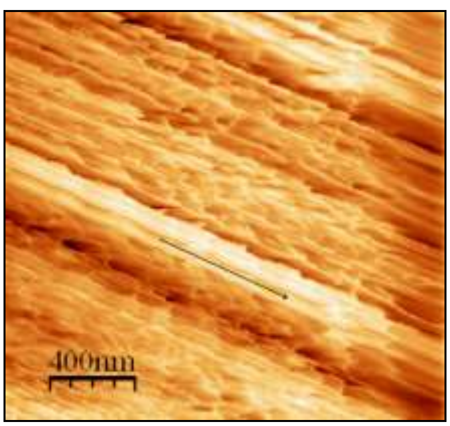
**MATERIAL AND METHODS**

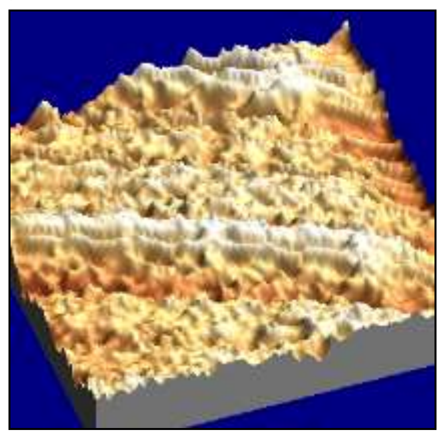
Dragline silk samples were taken from the frame thread of the orb web of *Nephila pilipes*. Atomic force microscope, Nanoscope E, model no. 245 was used for imaging silk samples. Two dimensional deflection images of dragline silk were recorded in contact mode. Image analysis was performed with WSxM Nanoscope image processing software.

Spectrum of dragline silk was obtained by using SHIMADZU Fourier Transform Infrared Spectrophotometer, Model No. 8400S in the range of 400-4000 $cm^{-1}$ at a resolution of 4 $cm^{-1}$ for 20 scans. Image analysis was performed with IRsolution software version 1.40.

**OBSERVATIONS AND RESULTS**

AFM images showed superimposed nanostructures on dragline silk surface having darker and lighter color. The arrow direction indicates the fiber axis. The nanofibrillar nature of dragline silk of *Nephila pilipes* is clearly visible (Fig. – 1. a & b).



a b

**Fig. – 1. AFM images showing topography of dragline silk of *Nephila pilipes* (scan size 2 x 2 $\mu m^2$). a. 2D image; b. 3D image .**

FTIR spectrum of dragline silk of *Nephila pilipes* showed number of well defined peaks in the range of 600-1800 $cm^{-1}$ (Fig.-2). The FTIR spectrum reveals the presence of different functional groups like C = O, C = C, N – H, C – H, C – N, $CH_3$, COOH, COH etc. These are between amino acid residues in silk peptide polymer which gives rise to well known signature in the Infrared region of the electromagnetic spectrum. The FTIR spectrum of silk showed the presence of various amino acid side chains like alanine, glycine, glutamic acid, aspartic acid, arginine, tyrosine, proline, lysine, tryptophan, serine and histidine etc. (Barth, 2000 and Zemlin, 1968)

FTIR spectrum also confirmed presence of β sheets, β turns, random coil and α helix. The peaks near 1690 $cm^{-1}$ confirms presence of β sheet structure. Whereas, the peaks in the range of 1660-1685 $cm^{-1}$ indicate presence of β turns. The absorption of IR rays at 1273 $cm^{-1}$ is associated with random coil formation. Spectra shows well defined peaks in the region of 844 to 873 $cm^{-1}$. These lower frequency wave numbers in the range of 643-967 $cm^{-1}$ shows absorption peaks for α helices.

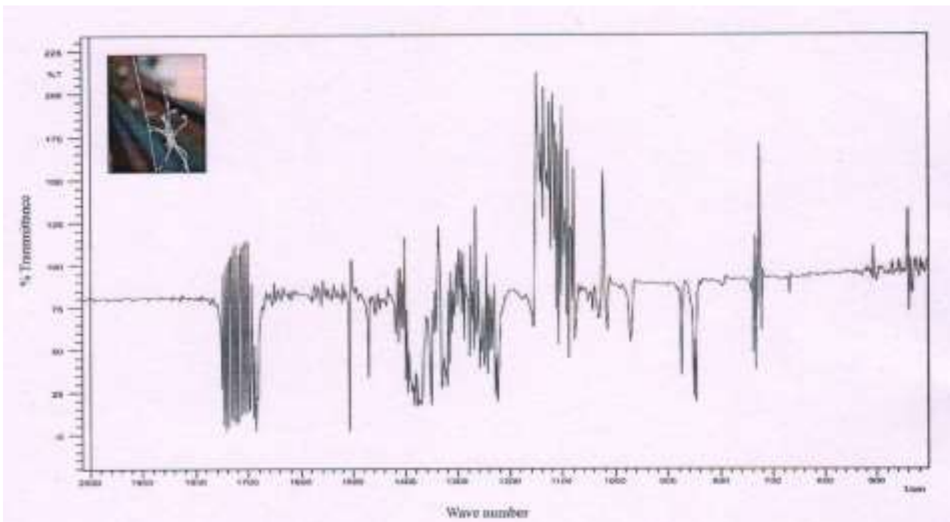



**Fig.-2. FTIR spectrum of dragline silk of *Nephila pilipes***

## DISCUSSION

AFM study confirmed the existence of well-organized bundles of nanofibrils in the dragline silk fibers. Bundles of fibrils into fibers enhance mechanical properties of silk threads. A similar multifibrillar arrangement was identified in the silk fibers of insects cocoon silk and suggested that the multifibrillar structure of silk fibers contribute to its toughness by allowing dissipation energy in the controlled propagation of cracks (Hakimi *et al.*, 2006). Each spider silk probe shows a somewhat different structure. Fibers of the same species do not necessarily exhibit the same surface features (Schäfer *et al.*, 2008). The peculiar topographical structure of spider dragline silk may be due to presence of secondary structural elements like β-sheets, β-turns, α-helices etc. These structures give semicrystalline nature to spider silk.

The FTIR spectrum showed number of peaks that are characteristics of specific types of molecular vibrations. Silk protein or spidroin largely consist of repeated sequence of amino acids. These repetitive regions of the spidroin are confined in highly organized secondary structure which is responsible for semicrystalline nature of spider silk. The FTIR spectrum of *Nephila pilipes* silk revealed the presence of majority of amino acid side chains linked in the polypeptide chains. Percentage of alanine, glycine and proline affect the degree of crystallinity, helicity or amorphous structure (Savage and Gosline, 2008) and elasticity (Liu *et al.,* 2008). Dragline silk of *Nephila pilipes* also shows antibacterial nature (Amaley *et al.,* 2014).

## CONCLUSIONS

The packing density of nanofibrills and surface roughness of dragline silk of *Nephila pilipes* indicates fact that, it is designed for extreme toughness. The primary protein structure is composed of a sequence of amino acid residue which is responsible for the defining molecular structure. The secondary protein structure like β-sheet, β-turns and α helices etc. are the key elements of this wonder fiber, responsible for its outstanding properties.

Thus, orb web spider *Nephila pilipes* produces high quality bio-material in the form of silk. Desirable properties of spider silk make it attractive for military, medical and industrial applications. Recombinant DNA technologies can be applied for large scale production of spider silk.

## ACKNOWLEDGEMENTS

Authors are thankful to University Grants Commission for granting financial assistance under minor research project. We gratefully acknowledge UGC-DAE Consortium of Scientific Research, Indore (Madhya Pradesh, India) for providing AFM facility and Central Instrumentation Cell, S. G. B. Amravati University, Amravati for providing FTIR facility.

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