Breakthrough Achievement by Chinese Scientists on Mechanism of Spider Silk's Water Collection

A Chinese research group, led by Jiang Lei who is a chemist at the Institute of Chemistry, Chinese Academy of Sciences (CAS) and also a CAS academician, made a breakthrough achievement on the mechanism of spider silk's water collection. This significant work was published on Nature on Feb. 4 2010 (Nature 2010, 463, 640-643) with a cover story. The research revealed the directional water collection on wetted spider silk, based on the research of bio-surface special wettability (published on Nature, 2004, 432, 36; Adv. Mater. 2002, 14, 1857-1860) and the investigation on water-collection of natural bio-surface in the recent years. They observed in detail water collective behavior at micro-region of natural spider silk by optical microscope, and found that tens of micrometer-size drops move from one micro-region to another on spider silk, displaying distinctly the directionality of drop movement, and thereby revealed at micro- and nano-level the mechanism of "multi-cooperative effect" in driving drops responsible for water collection.

The study revealed that when the dry capture silk of cribellate spider (Uloborus Walckenaerius) was placed in fog, the puff of dry capture silk, composed of nanofibrils (Fig. 1) could be changed into alternative spindle-knot and slight joint between spindle-knots (Fig.2-3). Interestingly, the spindle-knot forms the freedom nanofibrils structure (Fig. 3c), and the joint forms the aligned nanofibrils structure (Fig.3e), in which the different structures between spindle-knot and joint would induce the surface energy gradient. In addition, the curvature gradient formed due to geometry of spindle-knot induces the difference in Laplace pressure (Fig.4). Two gradients acted cooperatively on micrometer-size drops, making a continuous condensing-drop collection and transportation from the joint to the spindle-knot. Spider silk achieved this task on effective condensing-drop collection and stable hang of larger water drops, displaying a strong ability of water collection. Inspired by this finding, the group designed artificial fibres that mimic the structural features of silk and exhibit its directional water collecting ability (Fig. 5).

This achievement will be hopeful to solve the bottle-neck problem of small drop in driving. For instance, in previous research, people found that when surface energy gradient or difference in Laplace pressure was designed on a surface, respectively, the drops in size of hundreds of micrometer moved easily, while a drop moved difficultly when its size is below 200 mm mostly due to the contact angle hysteresis. Jiang's finding introduces a new approach to small size drop movement through understanding the mechanism of water collection on spider silk and further biomimetic researches.

This finding will inspire scientists to design the novel smart surfaces that can control the fluid in microfluidics, fiber-netty materials on a large scale for water collection in air and fog, serving for the needs at the places with the lack of water resource. The research finding will be of help in designing smart catalysts that realize the reaction of different chemical matter through fast gathering together due to effect of microstructure, and also the filtering materials used in the process of industry machining and so on.

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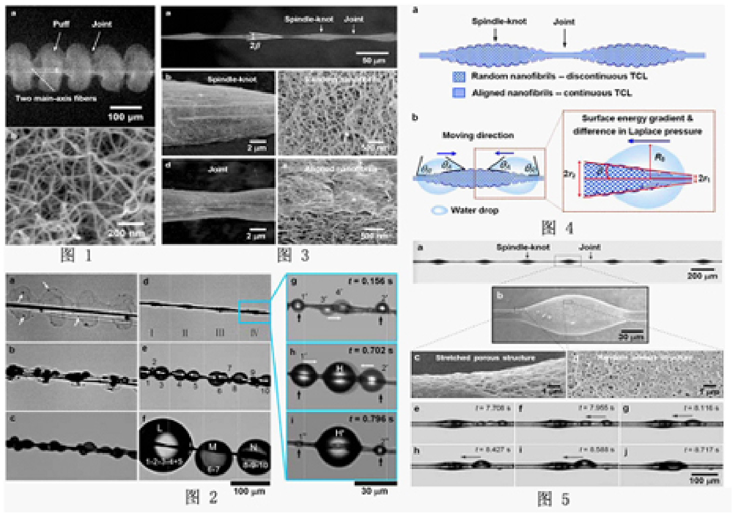


(Left) Cover caption：Caught in the web -- the structural flip that allows spiders' silk to collect water

(Right) Fig. 1 Dry capture silk of spider, a) Composed of puff and joint, along two-main-axis fibers; b) Puff is composed of nanofibrils.

Fig. 2 Silk structure is changed when water condensed on silk, puff becomes “spindle-knot” (a-d) and directional water collection of condensed drops (e-f); g-i）Directional movement of condensed drop on single spindle-knot.

Fig. 3 Microstructure on silk, b-c) Spindle-knot has freedom porous nanofibrils structure; d-e) Joint has aligned nanofibrils structure.

Fig. 4 Illustration of mechanism for condensed drop direction movement, a) Freedom nanofibrils structure forms the discontinuous three phase contact line (TCL) and aligned nanofibrils structure forms continuous TCL; b) Surface energy gradient and difference in Laplace pressure drive cooperatively the drop move directionally.

Fig. 5 The directional movement of drop was realized by fabricating the structure similar to that of spider silk.

The work was highlighted by worldwide medias as follows：

http://www.nature.com/news/2010/100203/full/news.2010.47.html

http://news.bbc.co.uk/2/hi/science/nature/8496559.stm

http://www.mrs.org/s_mrs/sec.asp?CID=1920&DID=84063

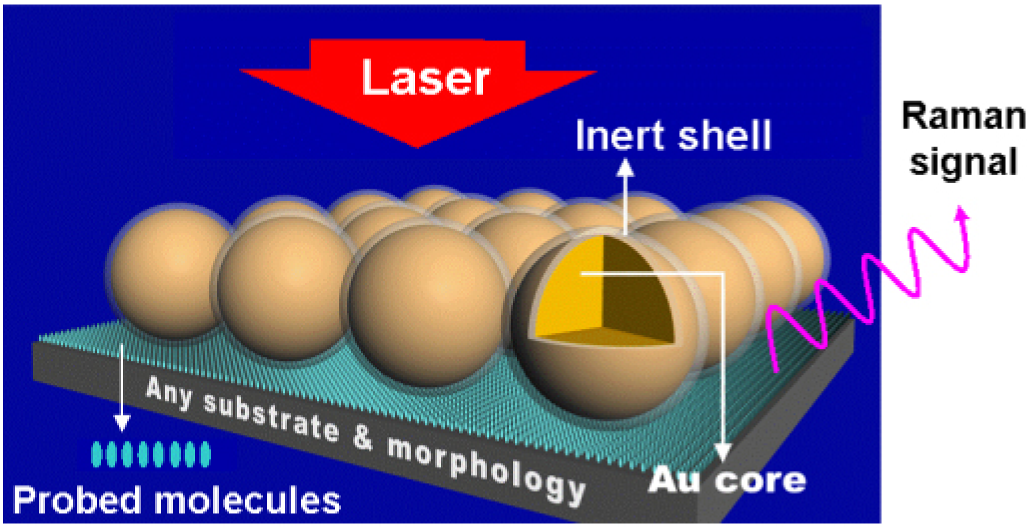
http://Physicsworld.com

http://www.physorg.com

http://www.rsc.org/chemistryworld/News/2010/February/03021003.asp

http://www.infox.ru/themes/science/, and so on.

Shell-isolated Nanoparticle-enhanced Raman Spectroscopy



A research team composed of Tian Zhongqun’s group (State Key Laboratory of Physical Chemistry of Solid Surfaces and College of Chemistry and Chemical Engineering, Xiamen University, Xiamen, China) and Wang Zhonglin’s group (School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, USA) has established a shell-isolated nanoparticle-enhanced Raman spectroscopy (SHINERS), which has broken the long-standing limitations of SERS and obtained high quality Raman spectra for the first time on various molecules adsorbed at Pt and Au single-crystal surfaces with different facets in an electrochemical environment. They have used the three-dimensional finite-difference time-domain (3D-FDTD) method to simulate the related enhancement, and the calculated results are in good agreement with experimental data. The concept of shell-isolated-nanoparticle enhancement may also be applicable to more general spectroscopy such as infrared spectroscopy, sum frequency generation and fluorescence, etc. They have further studied the species on Si wafer, the components of cell walls and pesticide residues on orange fruit, and the results show that SHINERS can be widely applied in probing surface composition, adsorption and processes of diverse objects and morphologies. Recently, this work was published on Nature, and another paper introducing its scientific and practical significance was also published in the same issue.

The research has been carried out for five years under the support by the National Natural Science Foundation of China.

Significant Progress in the Research on Mechanics-Dimension Effect

Yu Qian， a postgraduate of Micro-Nano-Scale Materials Behavior Research Center of the State Key Laboratory of Mechanical Behavior of Metal Materials, Xi'an Jiaotong University， with the cooperation with Prof. Li Ju of Pennsylvania University of USA, Dr. Huang Xiaoxu of Raith National Laboratory of Denmark, conducted an in-depth research on twinning deformation behavior in the small-scale metal single crystal materials and its influence on the mechanical properties of the materials. The research revealed that the dimensions of single crystal can bring significant influence onto the deformation behavior and mechanical properties of twinning crystal. The research was carried out under the guidance of Prof. Sun Jun, Prof. Xiao Lin, Prof. Ma En and Prof Shan Zhi Wei, who are in the same research center and the result has been published in Nature on January 21. Reviewers were very impressed by the pioneering work. They said that the author has made significant progress in the research on the mechanical-dimension effect.

The research plays a very important role in systematically investigating the small-scale mechanical behavior of materials. The achievement will be of much help in the property evaluation and design for microelectronic components and micro-electromechanical systems, in particular for the micro-nano processing by means of the intensive crystal-dimension effect.

The research has receives financial support from the National Natural Science Fund、 "973" project, and the first batch of Innovation & Talents Projects of the State Foreign Experts Bureau / Ministry of Education, respectively

Two Types of Melanosomes Found by Chinese and Foreign Scientists in Early Birds and Hairy Dinosaurs

An article entitled "Melanosome fossils and the colors of Cretaceous dinosaurs and birds" was published in the recent issue of the UK academic journal *Nature*, introducing two types of Melanosomes found in birds and dinosaurs with hair in Jehol Biota in China. As another significant achievement in the study of ancient birds and dinosaurs, the results provide reasonable evidences for inferring the "colorful" appearances of early birds and dinosaurs might have. Meanwhile, the research result also provides new evidence for scientific recovery of the colors of palaeobios, origin of feathers and birds, and the systematic relationship between birds and dinosaurs.

Some important progresses have been obtained in the international research of the colors of palaeobios in the past two years. In 2008, a Yale University research group comprised of paleontologists and ornithologists, for the first time, found melanosomes containing true melanin in Early Cretaceous feather fossils discovered in Brazil. They found many structures containing melanin in the fossils in their research, such as birds' eyes, fish's eyes, and the hair of mammals.

The research team also conducted an investigation into German Eocene bird feathers in 2009, and discovered the true melanin again, further confirming that the feather color information could be saved in the fossils.

The melanosomes found in ancient birds and dinosaur skin derivatives presented the first demonstration that a number of ancient birds and hairy dinosaurs living in 125 million years ago enjoyed a common colorful basis. Scientists have discovered two types of melanosomes in these fossils, i.e. true melanin and brown melanin, with the latter being first found in fossils.

In addition, the research methods and approaches have been improved in this study. In the past, the morphological research on feathers and other skin derivatives was mainly conducted by means of human eyes and optical microscopes at the level of cell and tissue. But the present study conducted a pioneer investigation into the internal cellular structures, melanosomes, of more than 125 million years ago mainly through electron microscopic and spectroscopic techniques, laying a sound foundation for the future paleontological study on cellular and subcellular structures at the micrometer level, providing a new means to ancient environment and taphonomy research at the micrometer level, and promoting the integration between paleobiology and modern biology that would bring about a growth momentum in new scientific disciplines.

Supported by the National Natural Science Foundation of China, Ministry of Science and Technology of China, Chinese Academy of Sciences, the UK Natural Environment Research Council, and the UK Royal Society, the research was jointly completed by scientists from the United Kingdom, Ireland and China. Chinese scientists included Zhang Fucheng, Zhou Zhonghe, Xu Xing and Wang Xiaolin from the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences.