The New Silk Road

*Silk's use as a fabric is well known, but these days attention is focused on using the natural silks as biomaterials. **Tetsuo Asakura**, a professor at the Tokyo University of Agriculture and Technology, and a leading researcher in the development of artificial blood vessels using silk, speaks with Takashi Sasaki.*

Production of silk is said to have begun several thousand years ago in China. Exports to places such as India, Persia and Egypt soon flourished.

Raising silk cocoons and silk reeling technology spread across the world, but the mechanism that gives silk its extremely high strength when cast from an aqueous solution remained a mystery. Tetsuo Asakura, a professor at Tokyo University of Agriculture and Technology, is working on the latest technology to unravel the mystery of this natural fiber and has become the first person in the world to clarify its molecular structure before and after spinning.

"My interest in silk stems from my research into nuclear magnetic resonance (NMR), a method of determining the molecular structure of organic compounds and proteins using a high magnetic field. Magnetic resonance imaging (MRI) devices that are used to make images of cross-sections of human bodies and other organic matter are an adaptation of this NMR technology," Professor Asakura says. "When I started my research around 1980 it was commonly understood that NMR was restricted to pure test specimens with no impure substances mixed in. My researcher colleagues told me that molecular structure analysis could be performed for specimens such as live worms or mice using NMR devices. This led me to wonder whether it could be applied to the molecular structure analysis of silk."

Elucidating the Structure of Silk

In 1981, Professor Asakura moved to the Tokyo University of Agriculture and Technology to focus his research on silkworms and silks, and quickly began a new field of research. By analyzing live silkworms using NMR, Professor Asakura thought he could identify the molecular structure of silk before spinning.

"Past research had brought an understanding that silk was a protein composed of several amino acids such as glycine, alanine and serine," Professor Asakura says. "However, we couldn't understand why the protein in a liquid state stored in the body of silkworms turned into a very strong fiber after spinning. I clarified the structure of the model compounds of silk before spinning at the atomic level together with the silk itself before spinning using new solid-state NMR equipment. In addition, I studied the detailed structure of the thin sections of silkworm spinnerets using an optical microscope to understand the structural change of silk after spinning. I performed a thorough study to determine their structure and what happened when force was applied. Having revealed these structures, I was able to understand the silk production mechanism."

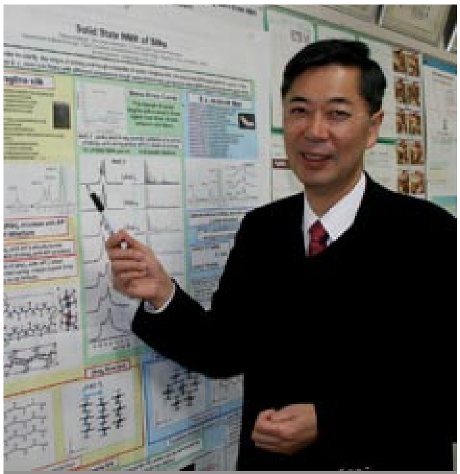
As a result of these twenty-five years of steady research, Professor Asakura in 2001 found that the silk structure before spinning is quite unique; specifically, a repeated β-turn (loose helical) structure which is quite different from other proteins and which is the key to producing a very strong fiber from the aqueous solution stored in the silkworm.

Silk Blood Vessels

The elucidation of the structure of silk makes it easier than before to improve it as a biomaterial and remarkably expands its potential. For example, raw silk can be dissolved again in an aqueous solution with a high concentration of ions and the aqueous solution can be obtained through removal of the ions by dialysis. This aqueous solution can be freeze-dried and made into a sponge form for use as a scaffold material for cartilage, corneas, bones, teeth and ears. Smooth progress in regenerating these parts has been demonstrated in animal testing.

Furthermore, a lot of attention has been paid recently to the development of thin (1.5 mm diameter) blood vessels that can be used for coronary artery bypass operations when arteriosclerosis occurs. The vessels are produced by weaving 30-micrometer-thick strands of silk around vinyl chloride tubes and then removing the tube to prepare the vessels after coating with silk gel to fill the gaps between the stitches. This coating treatment protects against leaks of blood.

Artificial blood vessels with a diameter of about 10 mm using polyester-type synthetic resin are already in practical use, but this type of artificial blood vessel clots easily if the vessels have a diameter of less than 6 mm. However, when artificial blood vessels made of silk are transplanted into mice, even after a year there is very little clogging, and a new vessel tends to form after decomposition of the silk; that is, reproduction of the vessel occurs.



TAKASHI SASAKI

Tetsuo Asakura, a professor at the Tokyo University of Agriculture and Technology

"Silk has been used for making stitches in surgical operations for many years and works well with human bodies. If it is transplanted, it is different from artificial blood vessels made of synthetic resin, which stay as is for a lifetime. It is a natural protein and so it slowly decomposes inside the body over time. In other words, it will also be possible before long to switch formed natural vessels with artificial blood vessels," Professor Asakura says.

Professor Asakura's research team is currently aiming to put artificial blood vessels to practical use within the next ten years, and research is also being carried out on larger animals such as pigs and dogs. Furthermore, through genetic modification operations, the team has successfully managed to make silkworms create silk that is strong with high cell adhesion. There is also the prospect of producing a large amount of silk for regenerative biomaterials at low cost. HJ

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