

# Silk Fibroin Sponge Sheet for Skin Care

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## 1 Abstract

Silk yarn has been used as fabric on account of inimitable shininess and texture, and also as surgical suture on account of high strength and bio-compatibility. By using fibroin protein that is the main constituent of silk, the utilization as the film, the powder, and the sponge is considered<sup>1)</sup>. There were some reports how to form the sponge, but the strength of the sponge was insufficient. Therefore, the sponge has not been implemented yet<sup>2)</sup>. We have examined how to make the high-strength sponge, and have succeeded in getting the sheet form of the high-strength sponge using the fibroin protein<sup>3)</sup>. We propose our sponge sheet as skin care materials, because our developed sponge sheet maintains the good feeling of silk itself, and has the high water absorbency, the high water holding property, and the high adherence.

## 2 Key Points of the Development Product

- This development product comprising natural silk fibroin offers a uniquely soft and tender touch.
- Safety tests, including for cytotoxicity, skin sensitization and human patch were successfully conducted and a high level of biological safety was also confirmed.
- Skin care material with superior performance in terms of water absorption, retention, skin adherence and transparency compared to nonwoven cotton fabric frequently used in items such as face masks can be offered.

## 3 Development Background

We started developing the sponge sheet for skin care by focusing on silk fibroin as a bio-derived material, produced by the silk worm, as part of work to develop life science-related products compatible with changing consumer behavior of recent years in areas such as the environment, safety and health. Figure 1 shows various product forms produced from raw material fibroin. In this report, we specifically focus on sponge among these product forms.

Collagen has been known as a sponge which can be formed from protein but lacks strength as a skin care material. Silk fibroin sponges outperform collagen in strength terms but are not good enough for use as a skin care material. We improved the sponge manufacturing technology developed by the National Institute of Agrobiological Sciences<sup>1)</sup>, and developed a high-strength sponge which was suitable as a skin care material.

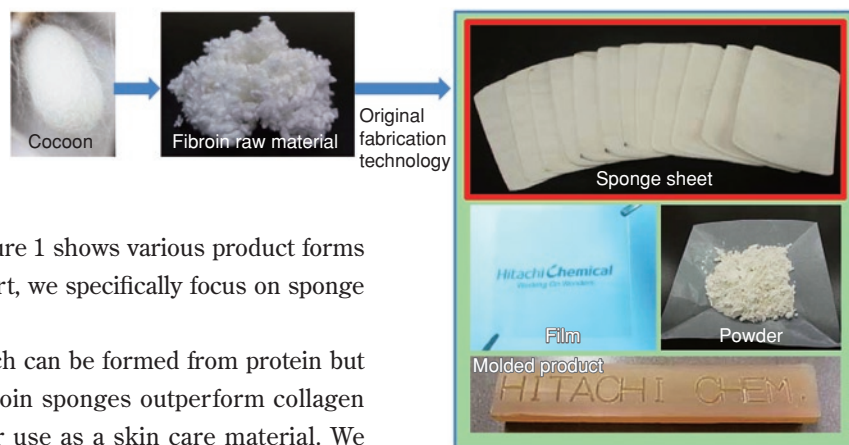


Figure 1 Various fibroin product forms

## 4 Technical Content

Table 1 shows the characteristics of the fibroin sponge sheet, while Figure 2 shows an SEM image of the fibroin sponge sheet. Structural components such as void size and content, and mechanical properties such as tensile modulus and compressive hardness are controllable at will within the ranges described in Table 1.

The characteristics required for skin care material were evaluated against cotton spun-lace nonwoven fabric (hereinafter referred to as nonwoven fabric), which is often used for face mask material, as a control material. Under microscopic observations of sponge sheet and nonwoven fabrics, the surface of the sponge sheet looks smooth without fluff in comparison to nonwoven fabric, which means the sponge sheet can offer a tender touch due to differences in surface structure. Figure 3 shows the water

absorption rate per own weight after water was absorbed in the sponge sheet and nonwoven fabric for 5 minutes. The sponge sheet absorbed approx. 15 times its weight in water at an absorption rate approx. double that of nonwoven fabric. We assume that this difference was attributable to material and structural differences. Figure 4 shows the measurement results of the stress required for releasing wet sponge sheets and nonwoven fabric after they touched the skin. It shows that the adherence strength of sponge sheets is higher than nonwoven fabric by approx. 1.8 times. This result also shows that sponge sheets have better concave/convex skin surface tracking capability than nonwoven fabrics. Figure 5 shows the measurement results of the water dripping ratio when a wet sponge sheet and nonwoven fabric are held in the air for 30 seconds. These results indicate scope to comfortably wear a wet sponge sheet face mask without dripping skin lotions, for example, when a sponge sheet is used as a face mask base material. Figure 6 shows the color differences between a wet sponge sheet vs. the standard Japanese skin color plate and wet nonwoven fabric vs. standard Japanese skin color plate, while both the wet sponge sheet and wet nonwoven fabric are placed on the standard Japanese skin color plate. The smaller the color difference, the more transparent it appears. The greater the color difference, the more opaque it becomes. In conclusion, this result indicates that the wet sponge sheet can deliver a more transparent feeling than wet nonwoven fabric, and can reduce feelings of discomfort while wearing a wet face mask.

Table 1 Characteristics of the fibroin sponge sheet

Item	Characteristics
25%Compressive hardness	2-400 kPa
Tensile modulus	0.01 kPa-10 MPa
Void size	1-300 $\mu\text{m}$
Void content	50-98% by volume
Heat resistance	150°C or more
Solvent resistance	Stable

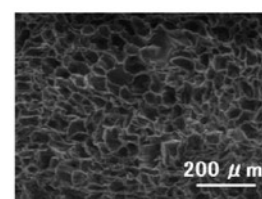


Figure 2 SEM image of the fibroin sponge sheet

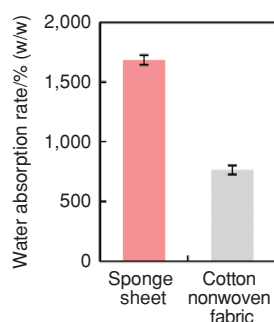


Figure 3 Comparison of the water absorption ratio between the fibroin sponge sheet and the nonwoven cotton fabric

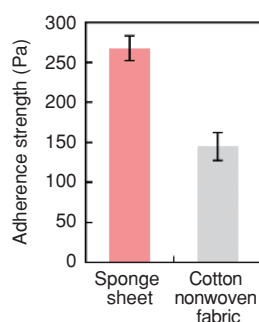


Figure 4 Comparison of the adherence strength to the skin between the fibroin sponge sheet and the nonwoven cotton fabric

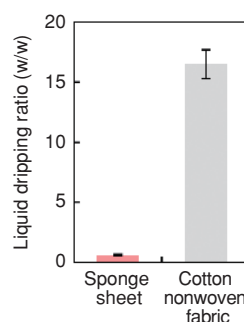


Figure 5 Comparison of the liquid sagging ratio between the fibroin sponge sheet and the nonwoven cotton fabric

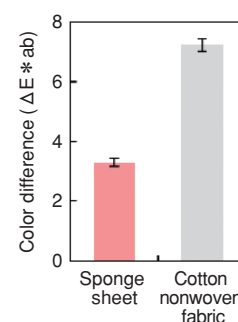


Figure 6 Comparison of the color difference between the fibroin sponge sheet and the nonwoven cotton fabric, compared to the skin color

Figure 7 shows a sponge sheet punched in a face mask sheet. Since any kind of shape can be easily punched out with the Thomson blade, the sponge sheet has various uses.



Figure 7 Facemask made from the fibroin sponge sheet

## 5 Future Business Development

Applications for medical use, including wound dressing, hemostatic material, sustained release dosage form and tissue engineering scaffold material.

### [References]

- 1) Yasushi Tamada: Silk as Natural Bio-based Polymer, BIO INDUSTRY, Vol. 24, pp. 5-10 (2007)
- 2) For example, Norihiko Minoura, Masuhiro Tsukada: Silk Fibroin Porous Body, JP-A-Hei-1-118544, 1987
- 3) Naosuke Sumi and four other colleagues: Proceedings of the Lecture about the 18th Polymer Materials Forum, The Society of Polymer Science, Japan, 2009, p. 201.