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Spiber, Inc

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The eleven-year-old company Spiber Inc. of Tsuruoka City, Yamagata Prefecture, Japan, is the pioneer and global leader of the synthetic protein materials industry, and one of the first companies that has demonstrated capabilities to produce synthetic proteins fibers in an industrial scale, according to Kazuhide Sekiyama, Spiber's Representative Director and co-Founder. While not yet profitable, it almost certainly will be incredibly so within a few years. I visited Spiber on November 8, 2018.

The basic objective of Spiber is to develop and produce industrial protein materials such as fibroin, a protein that is the chief constituent of silk and spider webs. This is an extraordinary company, not only for its new products and potential, but also, so far as I know, for its unique salary-setting system.

For over a century petrochemicals have been widely adopted as the feedstock for cheap, high-performance materials. However, production is energy-intensive, and the world's fossil fuels are ultimately in limited supply. Spiber believes that protein materials such as it produces will eventually compete effectively with existing materials in a wide range of applications, from apparel, to auto parts, to airplane components.

Spider silk is the world's toughest known material by weight, as much as 340 times tougher than high-tensile steel, even tougher than Kevlar. Carbon fiber is strong but not flexible; under high-speed impact it is brittle and breaks. Spider silk can be more flexible than nylon. These features have long attracted attempts to produce spider silk. But that has been elusive.

The insight of Spiber's founders was to make *synthetic* spider silk based on the proteins that make up spider silk, rather than to grow or make spider silk directly. That is not straight-forward. There are at least 40,000 species of spiders known, and it is said that there is at least as many that have yet to be discovered. Each spider produces up to seven types of silk for various uses. Identifying and isolating the specific properties of difficult spider silks is a virtually limitless research area.

Spiber has established a technology to manipulate sequences of amino acids and genes for synthesis of spider silk. It developed a proprietary technology for high-efficiency fermentation and spinning in the production process. Spiber now has produced this material, with the trademark QMONOS, a play on the Japanese word for spider web. (The company's name is from Spider Fiber.)

Spiber's challenge now is to achieve economies of scale and dramatically cut production costs while also maintaining good properties for the final applications of the material.

Spiber is associated with the Keio University Institute for Advanced Biosciences. Both are located in Tsuruoka City, Yamagata Prefecture. The Institute accepts Keio students as young researchers. Students have been inspired by its charismatic leader, Professor Masaru Tomita. In 2007, Kazuhide Sekiyama, a fourth-year student, and Junichi Sugahara, a second-year student, began research to develop a synthetic silk fiber. They engaged in microbiology research, using several different spider species, to determine at the molecular level the genetic code and amino acid sequence in each type of spider silk (a protein).

The function of a protein depends on its amino acid sequence. There are 20 kinds of amino acids in each protein, which typically are made from as few as 50 to as many as 3,000 amino acid units. It is through the manipulation of protein molecules that Spiber's materials are made. It involves the application of biological theory in a wide range of ways – a sort of sophisticated trial and error – that leads to final materials.

The raw material development process has two stages. In the first – molecular design – the DNA from specimen spiders is analyzed and artificial proteins are designed. The next step – gene synthesis – involves inserting the new, synthetic DNA into microbes. Once these microbes have been created, they become the producers of the synthetic silk. The manufacturing process has two steps. The first is microbial fermentation, which produces protein polymers. The next step – processing –

involves taking the polymers (raw powder) produced through fermentation and creating fibers, sponges, resins, and other types of materials.

The protein polymers are then considered for commercial applications, that is, prototyping possible products. Not every formulation yields viable prototypes. Thus, a great deal of the research involves trial and error in testing the wide range of possible combinations. Spiber has now developed a platform technology to design novel protein materials from the molecular level, and engage in their large-scale, low-cost production. Creating new molecules requires the effective synthesis of any type of gene sequence. Spiber has developed a proprietary technology to synthesize the repetitive genes in as little as three days. So far it has designed and added more than 1,400 sequences to Spiber's synthetic gene library. This is an ongoing process of continuing advances.

Spiber began as a seminar at the Keio Institute Lab. The co-founders in 2007, together with Hideya Mizutani, a certified public accountant and Sekiyama's high school classmate, made their first batch of synthetic fiber protein and then incorporated Spiber. The goal was to develop the technology so as to improve production quality, dramatically reduce costs, and become commercially competitive. They built a small pilot production facility in 2013. In 2019 Spiber will begin construction of a full-size production plant in Thailand, scheduled to become operational in 2021

The company has virtually no revenues, so it has accumulated losses. Obviously, funding has been key. The founders put in the initial ¥10 million to establish the company. Since then, Spiber has been constantly engaged in financing activities, with multiple rounds in 2018 alone. The latest, which was announced on October 2nd, 2018, raised 5 billion yen (about $44.1 million at the time). This increased Spiber's total paid-in capital to 22.4 billion yen ($197.2 million), among the largest for a Japanese startup company. Investors, not all of whom have been disclosed, include strategic partners and Cool Japan Fund (a public-private fund founded in November 2013 with the aim of supporting and promoting the development of demand overseas for excellent Japanese products and services).

As I understand it, early funding of $6 million was obtained from JAFCO (an Asian venture capital firm) and others. Strategic partners include Kojima Press Industry Co Ltd and Goldwin Inc. (a

Japanese sports apparel and lifestyle maker which owns the North Face trademark and pursues their own R&D, product development, and sales in the Japan and Korean markets), and Toyota Boshoku Corporation. Institutional investors include the MUFG financial group and Dai-ichi Life Insurance Company.

Government support has been significant, both in providing subsidies and in signaling Spiber's potential to financial and other markets. In October 2011 Spiber was selected by Yamagata Prefecture's local industry support fund for an "Incubation Support Project Grant for New Technology", and the next month the national government selected Spiber for subsidy assistance to evaluate its "hyper-tough protein fiber" in METI's Innovation Center Establishment Assistance Program. In 2013 the National Federation of Small Business Associations provided a manufacturing subsidy. In 2014 Spiber was selected as a core research institute by the Cabinet Office under its ImPACT (Impulsing Paradigm Change Through disruptive Technologies) program.

Spiber's strategy is to demonstrate its great commercial potential by bringing its new production plant into operation. To be feasible as a business, Spiber will have to produce at costs at least $100 per kilogram of protein. The long-run target is below $30 per kilogram.

Its two main markets initially are apparel and auto parts. There is growing awareness and demand in the apparel market for sustainable materials, ones that do not rely on petroleum-based fibers, and is also animal-free, both of which Spiber can provide. Auto parts because there is great need for tough materials to reduce car weight and increase safety and mileage.

Spiber materials have been used for The North Face Moon Parka prototype, introduced in Japan in 2016, and a Lexus car kinetic concept seat component. "The coat is the first QMONOS product to be built on a manufacturing line, and its threads and proteins were selected for feel and protection. The Moon Parka is biodegradable in addition to it being nearly indestructible — a strange misnomer that somehow exists in the protein synthetic world." (backpacker.com) Spiber and partner Goldwin plan to expand the use of the synthetic silk, possibly for outer, middler, and inner products used by mountain climbers or for casual wear.

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In early December 2018 Spiber announced plans to build a facility in Thailand to mass-produce synthetic spider silk materials, financed by its October 5 billion yen equity funding, announced in October and completed in December 2018. The plant will produce several hundred tons of proteins annually, 100 times more than the existing plant. Thailand has ample supplies of the biomass resources (notably sugar) needed for the production process. Construction will begin in mid-2019, and production will begin in 2021. The protein made there will be processed into fibers at Spiber's spinning plant in Tsuruoka.

Once the Thai production plant's process proves its profitability, Spiber will license its technology to select firms throughout the world. If Spiber further develops its own production facilities abroad, it will be in sugar-growing areas, as raw sugar is a basic ingredient in the fermentation step of its production process.

Although cost depends greatly between protein types and processing methods for different applications, the goal for production cost of some of Spiber's materials in the Thailand facility are estimated to be reduced to around $40-50 per kilogram.

Spiber faces only low competition. Large firms have ended their research in this area; it requires assuming significant risk and is capital-intensive. Moreover, each step in the production process is very sensitive to changes in other steps, meaning that only large, highly multi-disciplinary teams can achieve significant optimization. This makes it difficult for smaller firms to enter.

Spiber is a young company with a young staff, numbering about 200 (as of November 2018) and a unique wage system. Average age is 35. About 30 percent came from the local area. The wage system is the most transparent I have ever heard of. Employees each set their own wage, which the company accepts. The employee announces that monthly wage; in addition, overtime work is paid. Each person's wage is posted online, and is known to all the other employees. It is subject to online comment from other employees. Accordingly, employees check about each other's salary and the comments being made online, and set their wages to be in line.

Interestingly, this so far has generated somewhat lower wages than a person with similar education, background, and experience, would receive in another firm. My guess is they are in high demand from other innovative, biotech-oriented firms, but like the goals and spirit of the company (both of which are stressed in recruitment material). It reflects the oft-forgotten truism that not all compensation is cash compensation.

This wage system may work for a firm with 200 employees, but how about 2,000 employees? How about employees (Japanese and foreign) in foreign countries? From a managerial perspective, as the technology becomes more established and operational, and the firm continues its rapid employment growth, it has to develop a cadre of managers who stay long term. Perhaps one solution will be to establish market-based wages for production and clerical workers, and to maintain this transparent system only for employees at or above a certain skill or job title level.

I briefly visited the next-door Keio University Institution for Advanced Biosciences with Kazuhide Sekiyama and Daniel Meyer. It is an adjacent large building with a huge lab with equipment doing all kinds of tests. We simply looked in. I did not meet with any of the Keio team, which was all right since my purpose was to learn about Spiber. The Keio faculty has now incubated seven start-up companies. Spiber was the second. The first, in 2003, was HMT (Human Metabolome Technologies Inc), which develops very sophisticated mass spectrometers used for drug discovery, diagnosis, and food production; it was established by two Keio University professors.

Although commercialization and profitability are a top objective today, in the long-run Spiber's ongoing research may well develop other, even more fantastic industrial materials. Are there other spiders with even better fiber silk? Will other amino acids and gene sequencing tested for different time periods and at different temperatures result in even better products? Can this technology be applied to other insects, such as the rubbery resilience of grasshopper legs? Spiber is well positioned in a fundamental new area of research. And perhaps more fundamentally so will be the Keio University Institute for Advanced Biosciences.

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I want to visit Spiber again about three years from now, and also meet people at the Keio University Institution for Advanced Biosciences.

Acknowledgments

On Thursday, November 8, 2018 I visited Spiber with Hirofumi Maki, a senior official at the Development Bank of Japan, a CJEB Visiting Fellow 9 years ago, and my good friend. He had arranged my visit.

I was introduced to Spiber co-founders Junichi Sugahara and Kazuhide Sekiyama, and Daniel Meyer, an employee for three years who heads international business development.

Our meeting began at 9 am and continued to noon, including a brief visit to the next-door Keio University biotech lab. Mr Sekiyama participated in the entire meeting, which was run by Daniel Meyer, who made a presentation about Spiber in considerable detail, using slides and charts, and his own text. This report is also based on documents Spiber subsequently provided me by Spiber, press reports, and other website sources.

Larry Meissner, my long-term research associate and editor, provided additional information incorporated here, from a range of online sources.