Paper supplement to "Study on the PAN carbon-fiber-innovation for modeling a successful R&D management"

— An excited-oscillation management model —

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In the paper, "Study on the PAN carbon-fiber-innovation for modeling a successful R&D management", published in *Synthesiology*, Vol. 2 No. 2, pages 159-169, some errors and inaccurate expressions have been found, which do not sufficiently convey the authors' intentions and could lead to misunderstandings. The errata, additional references, and supplemental commentaries are presented as follows.

[Errata]

1. Page 155 left, subchapter 2.1(2)

Original: Originally, carbon fiber was developed in the United States in 1956, using rayon as the raw material.
Correction: In 1956, W.F. Abbott of the United States developed the carbon fiber using rayon as the raw material, and applied for the patent for the first time[1][14].

2. Page 157 right, subchapter 2.4(1)

Original: Toray Industries, Inc., which is currently highly successful in the commercialization of PAN carbon fiber, started production of carbon fiber in full force around 1968.
Correction: Toray Industries, Inc. decided to engage in commercialization in 1970, and started the production and sales of the carbon fiber in 1971 after obtaining the patent license from Dr. Shindo[15][16].

Corresponding to this correction, figures 1 and 3 are corrected as shown.

3. Page 158 right, subchapter 2.5(1)

Original: However, there were several cases where technological transfer to companies was done through official technical assistance or joint research, and some companies have expressed gratitude to GIRIO in the "company history".
Correction: However, there were several cases where technological transfers to companies were done through official technical assistance or joint research, and these were mentioned in places such as the "company history".

4. Page 160 right, subchapter 3.3

Original: They sought technical assistance "unofficially" …
Correction: They came to collect technological information …

[Additional references and place of insertion]

[14] T. Takamatsu: *Gijutsu To Bunmei: Journal of the Japan Society for the History of Industrial Technology*, 12 (1), 2 (2000) (in Japanese).
(Page 155 left, subchapter 2.1(2) as in Errata 1)
[15] http://www.fujimura-lab.mot.titech.ac.jp/class/CASE05-03TORAY(1).pdf
Y. Aoshima and T. Kawanishi (Hitotsubashi University Institute of Innovation Research), and METI "Promotion of the MOT Human Resource Training Program": *Technological development of Toray carbon fiber composite material "Toreka" by Toray*, page 3 (2005) (in Japanese).
(Page 157 right, subchapter 2.4(1) as in Errata 2)
[16] Toray Industries, Inc.: *Toray Gojunen Shi (Fifty Year History of Toray)*, 199,308(1977).
(Page 157 right, subchapter 2.4(1) as in Errata 2)
[17] J. Matsui: Carbon fibers, part 3: Birth of PAN based carbon fibers - Researches by Shindo and Watt, *Reinforced Plastics*, 43 (8), 298 (1997) (in Japanese).

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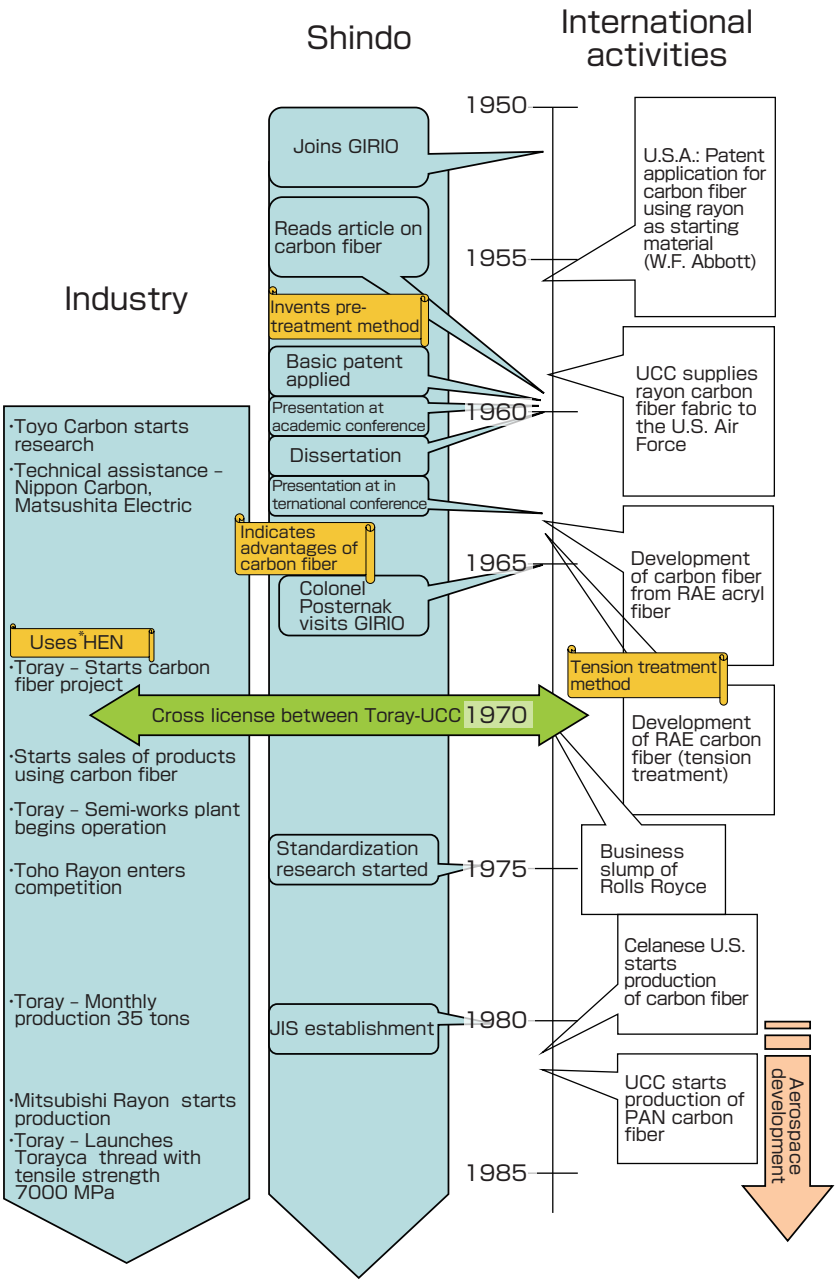
(Page 160 left, subchapter 3.3: Through the presentation of Dr. Shindo at the Carbon Conference in the United States in 1963, the British carbon researchers realized the advantage of using PAN fiber and started research of PAN carbon fibers[17]-[19].)

[18] A. Shindo: Special - Japan Innovation Story: Light, strong, and hard-to-stretch PAN carbon fiber, *Monthly Chemistry*, 65 (1), 22-25 (2010) (in Japanese).
(As in [17])

[19] D. Swinbanks: Graphitic carbon copies, *Nature*, 349, 97 (1991).
(As in [17])

[20] J. Matsui: Carbon fibers, part 6: Industrialization of carbon fibers – Toray Industries Co. 1968-1979, *Reinforced Plastics*, 44 (1), 31 (1998) (in Japanese).
(Page 160 right, subchapter 3.3: …And technological transfers were done 10 years prior to the actual marketing of the product.)



∗ HEN: Abbreviation of hydroxyethyl acrylonitrile. By copolymerization, firing time was reduced and great improvement in mechanical property was achieved.

Fig. 1 Flow of carbon fiber development

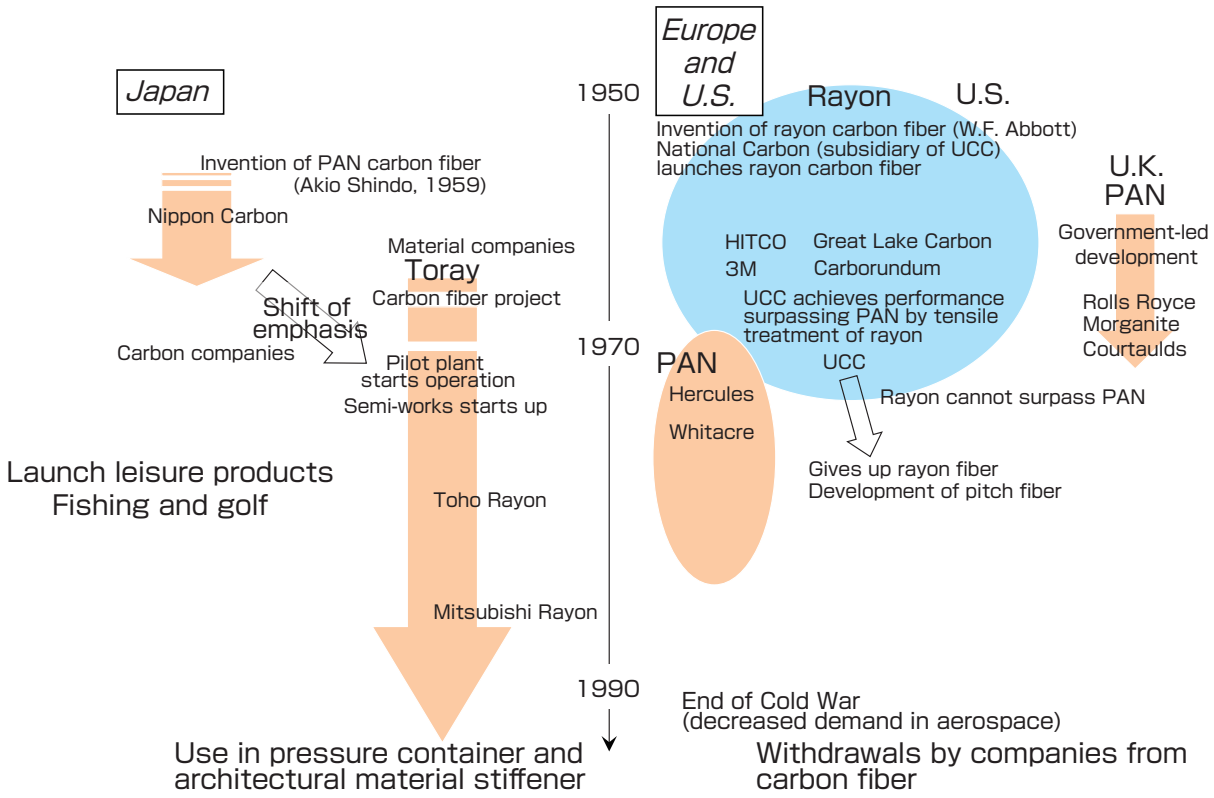


Fig. 3 Efforts by Japanese and overseas industries on carbon fiber

[Additional explanations]

As stated in the "Abstract" and "Introduction", this paper is an investigation and a construct based on the interviews to the people (listed in the "Acknowledgement") who were directly involved in the initial phases of the innovation, with focus on the internal motivation of the researchers and the actions taken by the GIRIO management, in the process where research results of a public institution were recognized by society, transferred to industry, and led the industrial transformation. Therefore, this paper is not a technological history that follows the whole development phases of the PAN carbon fiber.

1 "Strategic" research promotion at GIRIO

Page 155 right, subchapter 2.1(2)

Original: …It could be imagined that the results of PAN carbon fiber research was strategically announced…

The statement "strategically announced" is based on the analysis and interpretation from the interviews with the people involved. It is the authors' interpretation that the fact that the research was "announced" seems to indicate that there was some strategy rather than being a random course of events.

Pertaining to the research itself, it is clearly stated in several places that "the topics were determined according to personal interest and concern". This is part of the instruction given by the superiors at the time (in case of Shindo, the supervisor was Sengoku), and derives from the fact that "the degree of freedom for the research topic selection and how the research was carried out differed greatly by person". It is also clearly stated in the paper that for Shindo, "the development of carbon fiber was incidental upon seeing the newspaper article." The topic selection and new findings were dependent on the autonomy of the researchers or on some incidental encounters with newspaper coverage, and this is quite distinct from the recent MOT evaluations that emphasize that the "R&D must be conducted strategically and should be planned".

The "strategy" of the model discussed in this paper includes the spontaneous activities of the individual or group in the initial phases of the R&D. This means that the organization does not impede the activities or the diffusion of the products, but various measures (such as encouraging securement of intellectual property) are taken to incite and enhance the activities. This paper states that research, an individual spontaneous activity, and organizational strategy are not in antinomy, but are compatible, and moreover, innovation will be accelerated if the two work hand in hand.

The statement "GIRIO … organized the infrastructure

and raised people's enthusiasm (Page 155 right, subchapter 2.2)" given as an example of the managerial background that produced research results was confirmed through the interviews with the people involved, according to the descriptions in *Osaka Kogyo Gijutsu Shikenjo Gojunenshi (Fifty Years History of GIRIO)*[11]. This reference material records the increase in the number of research publications and patent applications, the building of the radiation chemistry lab, the opening of the technical consultation office, and the concentration from Daini (Osaka) to Ikeda. These are the indications of the managerial efforts. Moreover, the description "…and we could see that this was an organizational effort (Page 156 left, subchapter 2.2)" is based on the fact that the "research on fibrous graphite" set by the organization (GIRIO) was included amongst the "carbon material research" according to the description in the *1959 GIRIO Annual Report*[9].

Also, the principle of filing the patent application before publication at the academic society was followed. The importance of patents started to be recognized at the national research institutes and universities after 1999, when the Act on Special Measures for Industrial Revitalization (Article 30), a Japanese version of the Bayh-Dole Act, went into effect. This vitalized the procurement of intellectual properties by the public institutions, and their importance increased drastically. It should be particularly noted that the principle of "patents first" was executed shortly after World War II in the 1950s and '60s. The authors noted this point, and considered this as one of the proofs where the organizational strategy and individual spontaneity could be compatible.

2 Explanation of the actions for quick development for innovation

Page 158 left-right, subchapter 2.5(1)

Original: One of the authors has heard that when a corporate researcher obtained certain results after solving a problem or produced new proposals after getting help by technological information obtained from daily conversations at GIRIO, the researcher went on to company presentation without mentioning that the idea was picked up at GIRIO.

In the context of this paper, this expression is limited to the "results obtained by the individual effort of the corporate researcher based on the information gained through the daily conversations at GIRIO". This is not seen as a problem. Instead, the paper describes that there was a general awareness by GIRIO at the time, that even if there was a serendipitous inspiration based on the information obtained, the company may not necessarily make it clear that there was a contribution of the GIRIO information behind a certain result. If some source information leads to some inspiration or research development that produces an innovation, the range of opinion exchange will expand and the possibility of additional development grows when the source information and the thought process that lead to the inspiration are introduced in the course of the discussion, rather than reporting the conclusion only.

3 Explanation on the reduction of the "valley of death" in innovation

Page 158 right, subchapter 2.5(2)

Original: the primary group and the secondary group

This grouping was done for the sake of convenience by the authors, to enhance the reader's understanding. This refers to the necessity of background research in new material development, where one looks for something better than the primary material but can not find any, as this is a common occurrence in material research. (This is based on the information obtained from the interviews with Dr. Shindo and other people involved.)

When the new material is discovered and is recognized and praised by society, it is necessary to confirm whether the new material is truly better than the other materials in terms of competitiveness in performance, cost, reliability, and durability. Of course, such survey should be completed at the time of announcement, but further considerations are required taking into account the manufacturing process as well as the use and application of the material. The other companies of the same industry with different ways of thinking or companies of different industries will enter the research as they seek commercial opportunities. In case the standard of the material is not yet set, more companies may develop interest as they pursue the potential. Such a situation is included in the concept of "valley of death" in a wider sense. In this paper, the primary group and the secondary group are terminologies introduced to explain this phase. The companies that set the "product" and send it out to society comprise the "primary group", while the companies that are interested and seek different commercial opportunities are called the "secondary group". The "secondary group" is necessary to thicken the layer of the field, but often their projects fail to produce intended results. Such negative information are not released to society and become dead storage. In general, the range that can be covered by a single research or a single company tends to be limited. Therefore, to achieve innovations, the government must create a mechanism for efficiently overcoming such a "valley of death", though this may be a difficult order to fulfill.

As an attempt or a revision by the national institute, though the effect was partial, the authors took notice of the following: "The ways in which the results were presented to

society (patent, papers, reporting sessions, and others) were always planned according to the progress of the research and contact with industry. To propel the results, the scale of the research funding was controlled carefully according to growth. (Page 159 right, subchapter 3.1(2))" The facts that GIRIO created the Shindo Lab and allowed the participation of new researchers may support this point. This was an organizational research management within GIRIO and the paper does not state that an organizational (systematic) research was executed involving the companies.

The "daily exchange with companies (Page 160 left, subchapter 3.2(2))" much like the recent innovation hub function may be useful for the above objective. It is rather questionable that such activities were done intentionally back then, but now, if the corporate researcher spontaneously visits the national institute to engage in dynamic discussions, the time needed to overcome the "valley of death" can be somewhat shortened.

4 Explanation of the PAN carbon fiber developers

Page 160 left, subchapter 3.3

Original: Through the presentation of Dr. Shindo at the Carbon Conference in the United States in 1963, the British carbon researchers realized the advantage of using PAN fiber and started research of PAN carbon fibers.

The following references are added as the basis of this statement.

In Reference [17], there is a description, "Shindo's research result was presented at the Carbon Conference in the United States held in June 1963, and this touched off the PAN carbon fiber researches in Europe and the United states." Also, the following sentence says, "The only conceivable reason that RAE UK started to work with PAN was because it was stimulated by Shindo's presentation."

There is a similar statement in Page 24 left of Reference [18]. The following description can be seen in Reference [19]: "W. Watt et al., *Nature* 213, 690-691 (1967) and *Nature* 220, 835 (1968); referenced Shindo's earlier work, and PAN carbon fibres were first made by Shindo and…."

5 Timeline from the first invention to the innovation

Page 160 right, subchapter 3.3

Original: …And technological transfers were done 10 years prior to the actual marketing of the product.

The time when the product was actually marketed is considered to be 1972, as described in Reference [20]: "The fishing pole and Black Shaft (author's note: name of the actual product) using the carbon fiber reinforced plastic was known in the world from around 1972." On the other hand, the "technical guidance" by Shindo *et al*. called the "manufacture method of graphite fiber" provided to Nippon Carbon Co., Ltd. and Matsushita Electric Industrial Co., Ltd. was given in 1960, and the timeline is as stated in the original text.

The point of this paper is to express the difficulty of the innovation. From the first invention (1959) to the achievement of something that was truly useful (product), diverse and voluminous researches as well as the work of individual researchers, efforts, and time were necessary. The paper does not attempt to describe the ten-year span in a strict manner like a chronology of technological history.