1C01 科学主導イノベーションにおける大学研究者の役割：
光触媒のケース

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1. Introduction

The emerging "entrepreneurial university" integrates economic and social development as part of their mission (Etzkowitz, 1998). University-industry collaboration takes many different forms, depending on national and regional contexts. In the United States, research universities are free to own and exploit patents on government-sponsored research and are encouraged to solicit industry support. High-tech start ups are funded by venture capitals and are often spun off from university research. The Japanese system, on the other hand, while there have been traditions of informal collaboration which cross institutional lines and represent significant exchange of knowledge with industry, has not been successful in coupling scientific seeds and social needs effectively (Kodama and Branscomb, 1999).

One of few exceptions is the commercialization of a new material, namely, titanium dioxide (TiO_2) photocatalyst. New materials, based on understanding of advanced scientific fields, such as nanotechnology, embody novel functions which had not been realized before. With the novel functions of decomposition of organic substances and hydrophilicity, TiO_2 photocatalyst has proved to be useful for various applications, ranging from self-cleaning building materials to anti-bacterial ceramic tiles and anti-fogging window glasses. That has led to the creation of new markets which did not exist ten years ago, with the current size of commercial products embodying photocatalysts estimated to be 300 million US dollars in 2002. The case of photocatalyst is also unique in that, while the Japanese performance on scientific research is comparable to that of the United States or Europe, Japan surpasses the United States and Europe significantly in terms of patent and commercialization activities.

In this research, we analyze how and why Japan has successfully developed and commercialized TiO_2 photocatalyst through collaboration between university and industry. We examine how basic research and product development are conducted and interacted with each other, leading to successful creation of new markets, in a way which is particularly appropriate to the commercialization of new materials. We place an exclusive focus on the activities of two professors, namely, Professors Akira Fujishima and Kazuhito Hashimoto of the University of Tokyo, who have made crucial contributions to the development and commercialization of TiO_2 photocatalyst. An intensive analysis is conducted on jointly applied patents between Fujishima-Hashimoto and firms in industry to examine the way in which university researchers interact with relevant industrial actors to produce one of few successful cases of university-industry collaboration in Japan. Policy implications of our observation will be discussed briefly.

2. Science and New Materials Innovation

Recently, new advanced materials have been developed and started to be applied for use in many fields. What characterizes new materials is the embodiment of novel functions which had not been possible to achieve by traditional materials. Embodying novel functions, new materials innovation will work to extend the range of applications of new materials drastically to diverse fields with varying degrees of market potential. Thus in accomplishing new materials innovation it will become critical to explore and articulate demands leading to robust markets in the long run. Firms have already entered the business of proposing market solutions to their customers through these new functional materials. What has turned out to be important in conducting the solution-proposing business are "embodiment of functions" and "proposal of values". Firms face the challenge of maintaining capabilities sufficient to evaluate functions and control their performance. This requires not just knowledge on production processes, but also sound scientific understanding of the mechanisms on how to achieve and control the desired functions of new functional materials. Only based on these capabilities, firms can propose the best solutions to their customers proactively. Therefore, new materials innovation requires appropriate coupling of sound scientific understanding and well-defined user demands.

Articulation of user demands has been regarded as one of the most important steps in bringing forth successful product development (Kodama, 1995). It has also been argued in the field of materials science and engineering that the most effective way to shorten the process to market innovations made in laboratories is to forge stronger links with users. Traditionally, manufacturers first collect information on new product needs and then start to develop products which meet the discovered needs. Forming an accurate understanding of user needs, however, is not simple, fast, nor cheap. As user needs change more rapidly and products are used in more diverse conditions, this approach has been coming under increasing strain.

Recent research on cases of industrial innovation has revealed the effectiveness of a new approach to developing breakthrough products, the so-called lead user approach (Lilien, Morrison, Searls, Sonnack, and von Hippel, 2002). Many commercially important products are initially thought of and even prototyped by users rather than manufacturers. Such products tend to be developed by the lead users, that is, companies, organizations, or individuals that are well ahead of market trends and have needs that go far beyond those of the average users. The lead user process is designed to collect information about both needs and solutions from the leading edges of a company's target market and from markets that face similar problems in a more extreme form. Applying the concept of the lead user process to new materials innovation, we should recapitulate the importance of interactions between university researchers and industries.

As commercialization of new materials requires sound understanding of advanced science and technology and detailed information on articulated market demands, it will be necessary to establish a mechanism for properly coupling scientific and technological knowledge and user demands. What would be effective for this purpose is to maintain close interactions between university researchers who develop new technologies and industries who utilize them. The proactive scientists in entrepreneurial universities are those who are willing to cooperate with industrial users for discovering market applications of their scientific findings. Those scientists and industrial users interact closely, forming a type of "communities of practice" (Wenger, 1998). The communities of practice are groups of people informally bound together by shared expertise and passion for a joint enterprise. While people in the communities of practice may meet regularly or be connected primarily by e-mail networks, they share their experiences and knowledge in creative ways that foster new approaches to problems.

For bringing about new materials innovation, a small group of university researchers who have accurate understanding of new materials science and leading industrial users who have real problems to solve at hand work together over a period of time with a common sense of purpose and a real need to comprehend what each other knows. By forming communities of practice through competent university-industry networks, firms could help to articulate demands for new materials which have prospects for robust markets in the future; university researchers, on the other hand, could enhance scientific investigation to further increase their understanding of new materials with commitment from industry.

3. Case Study of Innovation on Photocatalyst

By observing the nature of industrial collaboration, we find different types of "communities of practice" regarding Fujishima and Hashimoto's collaboration scheme. Firstly, there is a community comprising core industrial partners. Fujishima and Hashimoto collaborate closely with core firms, which we define as firms which have co-published scientific papers and co-invented patents involving identical individuals in each firm. This type of intensive collaboration in terms of scientific as well as technological research has enabled the core firms to develop a series of industrial products with established markets.

Secondly, we can acknowledge the influence of the science and technology community which was formed specifically for the promotion of photocatalysis research for industrial application. Partly supported by the activities of the community, the number of firms starting research on photocatalysis has greatly increased. Consequently, we see a hike in the number of patent applications in the 1990s. The degree of market growth, however, has been far less than expected so far because a majority of the members of this community, which have only recently entered into research on photocatalysis, are unable to tackle strategic problems of how to utilize this new technology for articulating demands of their potential customers. With limited experience on the material involving novel functions, their scientific understanding of the technology is not sufficient for managing strategic considerations. We find many cases of co-inventorship between the focal scientists and members of S&T communities, but only a small number of cases of co-publishing scientific papers across academic and business institutions. At the moment, many of the co-inventors in the community have failed to create new markets with their proposed products.

Thirdly, we find a new type of community which is formed by the incorporation of institutions in the public sector as sponsors for research and development. The introduction of the public sector has also shifted the research target towards large-scale, complex social issues. Photocatalysis has now become a kind of society-oriented technologies; currently, research projects cover such fields as city systems, medical treatment, agriculture, and water treatment.

Observing these industrial collaborations of Fujishima and Hashimoto, who have been the star scientists in the area of photocatalysis over 20 years, we find the emergence of different communities and a type of evolution of university-industry networks. When Fujishima and Hashimoto collaborate with core industrial partners, they are linked by co-authorship as well as co-inventorship and create a certain type of network. The configuration and evolution of the network characterize the nature of collaboration among Fujishima and Hashimoto and industrial partners. The mechanism is typified by the behavior of scientists who proactively contact with potential industrial users and that of firms which seek to collaborate with the best scientific partners, that is, the hub in the "community of practices."

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