Radical Innovation in Supplier-Initiated Modularity

—A Case study of an alliance between suppliers of semiconductor devices—

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Abstract— The process of expertise acquisition and the organizational learning capability is studied by analyzing interaction between suppliers of different technological fields. The organization, which achieved commercialization, has an ability to build up new knowledge and to improve credibility and reproducibility. The ability corresponds to the third of absorptive capacity divided into evaluation, assimilation and commercially application.

Index Terms – absorptive capacity, commercialization, expertise, integration, interaction, radical innovation

Ⅰ. Introduction

It is worthy of note that a lot of firms make an effort to develop high value-added products, or to enter new fields by R&D alliance and M&A. Some firms have achieved success in what is called radical innovation. The research is the case study of device suppliers which took the initiative in alliance for modularity and succeeded in radical innovation. It contextualizes the technical contents and analyzes the process of interaction among different technological fields. As a result, it was possible to study the process of expertise acquisition and the organizational learning capability.

In the previous, knowledge-based view by internal and external interaction, the notions of knowledge management and learning capability were developed.

Sanchez [1] argues that organizational learning consists of not only processes for creating new knowledge [2] but also processes to leverage knowledge effectively within and across organizations. And the ability to leverage knowledge means identifying, acquiring, codifying, and transferring new knowledge.

Cohen and Levinthal [3] defines organizational absorptive capacity a firm's capability to assimilate external knowledge and apply it for commercialization. Combinative capability is defined as the ability to synthesize and apply current and acquired knowledge by Kognut and Zander [4].

By view of alliance, Qualin [5] points that absorptive capacity is indispensable to fruit alliance. By Hamel [6], Receptivity is as a determinant of learning, enables acquiring skills and knowledge. And to success internalization, It is necessary to upgrade acquired skills at the level of competent speed [7].

However, these studies do not clarify how wide range of knowledge should be covered for commercialization. Also, the studies do not concretely refer to what sort of R&D management has an influence on organizational capability as mentioned above.

Therefore, I put research questions as follows: How much knowledge should each organization assimilate through interact with different-field organizations and achieve the new knowledge creation and commercialization.

Some organizations achieved brilliant success as a result of interaction with different-field organizations, but other organizations didn't. What are the differences between these two types? The study is to focus on the differences between them especially in R&D structure and management.

Ⅱ. Case Analysis

A. Outline

The research is to study the case of an alliance among semiconductor device suppliers in different technological fields. The alliance was made for the purpose of developing a module device. In 1994, Matsushita Electronics Industry Corporation commercialized an integrated optical pick-up module for a disk, named "A Super Thin Laser-Detector-Hologram Unit". It has been used for CD-ROM, MD, and DVD for personal computers, and has greatly contributed to the spread of multimedia. Sharp Corp. and Sony Corp. have also

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supplied the module, but Matsushita Electronics is the most successful in miniaturizing and lightening the module. One of the main reasons for the success was that Matsushita Electronics made a technological alliance with Olympus Optical Co.,Ltd. famous for optics, and Mitsubishi Chemical Corp. famous for semiconductor materials.

B. Contents of the Technological Innovation

As shown in Fig. 1, Matsushita Electronics has successfully reduced the thickness of a pick-up from 40mm to 8mm by modularizing a pick-up into a hologram unit. Also, Matsushita Electronics has been able to streamline the assembly and adjustment processes drastically by reducing the number of parts. Other makers have also realized the module miniaturization and process streamlining, but there is a big difference between Matsushita Electronics and others in the structure of a hologram unit.

As shown In Fig.1, there are two optical axes in the previous pick-up, while there is one optical axis in the hologram unit. It is because Matsushita Electronics has built into the hologram unit a mirror-surface structure to change the optical axis. Sony arranged a mirror itself in a hologram unit, but Matsushita Electronics realized the mirror-surface structure by silicon etching technology, and has succeeded in making a laser perpendicular to the hologram unit. Therefore, Matsushita Electronics could save the weight and cost of a mirror and the time required for an extremely precise mirror-mounting operation. The key element technologies at this stage were the semiconductor property and the optics.

C. Process from Technological Development to Product Development

1)Phase1: Grand Concept

An optical disk market has been expanded since CD players were put on sale in 1982. On the other hand, each device supplier has been agonizing over cutthroat cost competition. Matsushita Electronics had supplied stand-alone laser chips. Mitsubishi Chemical Corp. had supplied primary materials for the laser chips. Olympus Optical Co.,Ltd., taking advantage of its optical technology, had assembled laser chips and mirrors into pick-ups. In 1988, Matsushita Electronics, Mitsubishi, and Olympus, with respective technicality, entered into a contract for a joint research for the purpose of challenging to modularize high value-added pick-ups. The three suppliers had already had business connections, and the contract was signed by the directors of each laboratory. Each engineer's ambition for technological innovation was also a motivation for the joint research.

> "I thought that we would have a monolithic IC with an optical technology applied into a semiconductor manufacturing process, but that a Hybrid IC like the module would be out before that.", said the then chief engineer of Olympus.

The task was to work out expertise on an individual basis, but the engineers involved explored possibilities in a free and voluntary atmosphere.

2) Phase2: Concept Development

The product architecture of the module was constructed in 1992 by integrating element technologies of each supplier. Until then, engineers in the alliance team had repeated meaningful exchanges of expertise beyond the boundary of each supplier. "Transparency" meaning to give partners opportunities to study , which Hamel pointed out in 1991 [6] , was good enough in the alliance team. The following comments tell how they were in the team; "We engineers were in the same boat.", "We were in close communication, dialing directly home each other", "I aimed for a goal in closer cooperation with the engineers of other laboratories rather than with my fellow engineers." The interaction at this stage was done not on an individual basis, but on a team basis, for the purpose of sharing their developing technological knowledge.

As follows is the expertise categorization of the three sub-components which composes a module.

<u>Laser chip</u>

Physics:

Laser luminescent mechanism technology and three other element technologies (Matsushita Electronics)

Semiconductor property:

Junction-to-active-layers technology and three other element technologies (Mitsubishi Chemical)

Chemistry:

Compound etching control technology and two other element technologies (Matsushita Electronics)

Design technology of hetero-junction materials (Mitsubishi Chemical)

Optics:

Mode control technology and three other element technologies (Matsushita Electronics)

Photo-detector

Integrated circuit:

Design technology of open area ratio and two other element technologies (Matsushita Electronics)

Optics:

Noise technology (Olympus)

Conversion efficiency technology (Matsushita Electronics)

Semiconductor property:

Anisotropic etching technology and three other element technologies (Matsushita Electronics)

Hologram

Optics:

Design technology of Optical phase diffraction and three other element technologies (Olympus)

Chemical:

Etching technology and two other element technologies (Matsushita Electronics)

It was the anisotropic etching technology that contributed to the technological innovation, in which a mirror-surface structure, instead of a conventional mirror, was realized based on silicon etching technology. An engineer in charge of the anisotropic etching was a staff belonging not to the alliance team but to the other team of Matsushita Electronics Laboratory. An engineer in the team reviews those days as follows:

"We always had discussions with the staffs around in the laboratory. Since we often team up together with the other team members, we have good communication in the lab. I remember asking Mr.U after working hours whether I can manufacture a mirror by a silicon etching technology. Mr.U said, "You can do it sure enough.", and he kindly showed me his VMOS and gave me technical guidance. Under his guidance, I got to work on. I had Olympus evaluate the mirror completed. Then, it appealed to them. I and Olympus are not sure if the mirror, as a product, would be accepted or not. Since then, however, we have been hand in hand for enhancing the quality of the mirror and for working out an optical design."

As in the review above, the role of Olympus was to evaluate optical performance of the mirror. In other words, the technical innovation has been realized by internal and external interactions beyond the boundaries. Olympus conducted a mirror performance test to evaluate if a sample mirror from Matsushita Electronics was available as a pick-up. As an optical-instrument maker, Olympus had pick-up inspection equipment, and as a pick-up assemble maker, it had technical know-how. On the other hand, since Matsushita Electronics had manufactured stand-alone lasers only, it had neither inspection equipment nor experiences.

A laser chip, one of the three sub-components above, propelled the module development. For the development of a noiseless, low-power-consumption chip, Matsushita Electronics took charge of designing, and Mitsubishi took charge of lamination process. As a result, what was successfully developed was a RISA chip with the increased yield. Due to the RISA chip, Matsushita Electronics could take the initiative among the three suppliers.

3) Phase3: Product Design

In the spring of 1993, Matsushita Electronics Industry Corporation secured the first customer of the module, Matsushita-Kotobuki Electronics Industries, Ltd.. Matsushita-Kotobuki, which had supplied CD-ROM to a PC maker in the United States, was strongly motivated to mount a small-sized, light-weighted modular unit onto a pick-up. But the order price asked by Matsushita-Kotobuki was very low, with one-tenth of conventional pick-ups. Under such circumstances, Matsushita Electronics had to use heat-proof plastics as a material both for a hologram and a unit package. Heat-resistance of the plastics, however, is worse than that of metals and seramics. What worked out a solution to this problem was a low-power-consumption RISA chip mentioned before. Other makers have not been able to adopt plastics yet.

Matsushita Electronics Industry Corporation determined the first commercialized design rule (specifications of the materials, figuration, and property) based on the asking price. Not only Olympus but also Optical-Disc Center of Matsushita Electric Industrial Co.,Ltd., the parent company of Matsushita Electronics, have cooperated as optical experts in evaluating the design rule technically. According to the design rule, Matsushita-Kotobuki planned the projects for a lens and a mirror except a modular unit in Fig. 1. In other words, Matsushita Electronics has succeeded in standardizing its own project.

4) Phase4: Detail Design

In the Autumn of 1993, Matsushita Electronics, with SBU (Strategic Business Unit) started, got down to manufacturing products based on the design rule. The team in Matsushita Electronics Lab was divided into the following groups; laser chip, photo-detector with mirror-surface structure, hologram, unit-package, pick-up evaluation, project promotion. Sub-component teams collaboratively put a biweekly-renewed milestone into operation, and proceeded the milestone to the next stage. The project directors checked the degree of progress. Staffs in charge of the performance evaluation worked in cooperation with Olympus, Matsushita-Kotobuki, and Matsushita Electric Industrial Co.,Ltd.. After the six-month adjustment of sub-component teams, SBU was dissolved.

Ⅲ. Findings

Now, along the product-development process, let me show you, as model case, how Matsushita Electronics Industry Corporation has learned and assimilated external knowledge.(See Figure 1)

At first, in the phase of grand design, Matsushita made a study of expertise on the element technologies available for the construction of new architecture. In this phase, a farseeing capability is indispensable to decide roughly a product concept. After deciding a range of expertise necessary for the architecture (inside a dot line), those expertise had continually been acquired and integrated through interactions. In the phase of concept development, new knowledge was created through close interactions for integrating expertise.

As stepping forward from the phase of product design to the phase of detail design, expertise integration had been advanced more deeply to accomplish the whole architecture by clarifying and adjusting the relation between sub-components.

However, the unassimilated expertise outside the circles played an important role. These expertise are based on the very specialty, and are indispensable to a performance evaluation. Matsushita could not but rely on Olympus for the performance evaluation to the last. It is evident in that Matsushita has not changed the basic architecture of a module yet. It is because Matsushita can not assess the performance after changing the architecture. And Matsushita has not launch into products which requires more advanced specialty on optics. The only supplier of MO pick-ups with the highest accuracy and credibility is Olympus.

In the phase of detail design, the detailed design rules were regulated to achieve sufficient performance. For product commercialization, high credibility and reproducibility were investigated.

I summarize findings.

It is evident that the optical pick-up module is a case of radical innovation, for structurally it features a new integral architecture and functionally there is radical change 〔8〕. Success factors of the radical innovation are found as follows:

- An innovator estimated the external and minimum knowledge required for successful innovation , and assimilated the knowledge effectively
- An innovator had core-competence 〔9〕 which promoted innovation and connected one-field knowledge with other-field knowledge.
- A Lead-User〔10〕 clarified the design-rule.

Ⅳ. Discussion &Implication

In the conclusion, I represent conclusions and inferences drawn out of the study.

It is not necessary to assimilate excessive expertise for creating new knowledge, that is, new architecture attained by various-fields technological integration. If an innovator can grasp how high performance should be accomplished, he will effectively be able to commercialize the products. That is to say, there is an appropriate scope and depth of knowledge assimilation in order to create knowledge and to commercialize the products through interactions.

Olympus, in spite of its assessing the product performance, could not commercialize the products. Are there any differences between Matsushita and Olympus in each R&D organizational structure and management? This discussion is informative to the second research question mentioned before.

The reason why Olympus failed in commercializing the products was that it could not promote the phase of detail design. It did not have a ability to build up new knowledge generated from expertise integration and to improve credibility and reproducibility. The ability corresponds to the third and last ability of absorptive capacity. Absorptive capacity is composed of three abilities; the ability to value new external knowledge, the ability to assimilate new external knowledge, and the ability to commercially apply new external knowledge [3], [11]. Therefore, compared between Matsushita and Olympus about each organizational structure and R&D management, it is possible that we investigate some factors influencing the third ability.

Lane and Lubatkin [11], focusing on the relation between the two suppliers being in R&D alliance, conceptualize the relative absorptive capacity. They demonstrated the similarities between the two that knowledge bases, management formalization, and research centralization depend on the absorptive capacity of each supplier.

The purpose of the study, however, is to examine the absorptive capacity absolutely rather than relatively. It might be inferred from this case study that such factors as organizational structure and R&D management influence the ability to commercially apply new external knowledge. However, further research will be needed to formulate the hypotheses.

1) The product life cycle of main existing projects is relatively short.
2) A research engineer in R&D laboratory is concurrently in charge of multi-projects.
3) A research engineer in R&D laboratory frequently communicates with customers and end-users.
4) There exists an R&D culture in which a commercialization mind is made much account of.

The factors of 1) and 2) above give research engineers a lot of experiences for commercialization, whose experiences contain diverse products, user environments and production systems. In particular, the factor of 2) brings about synergy effect. Also, these experiences lead to knowledge application by Iansity [12]. He categorizes the effective process for technology integration into three types of mechanisms: the mechanisms for knowledge generation, knowledge retention, and knowledge application.

The factor of 3) above brings engineers abundant information and market direction. The factor of 4) empowers engineers to put new products on the market.

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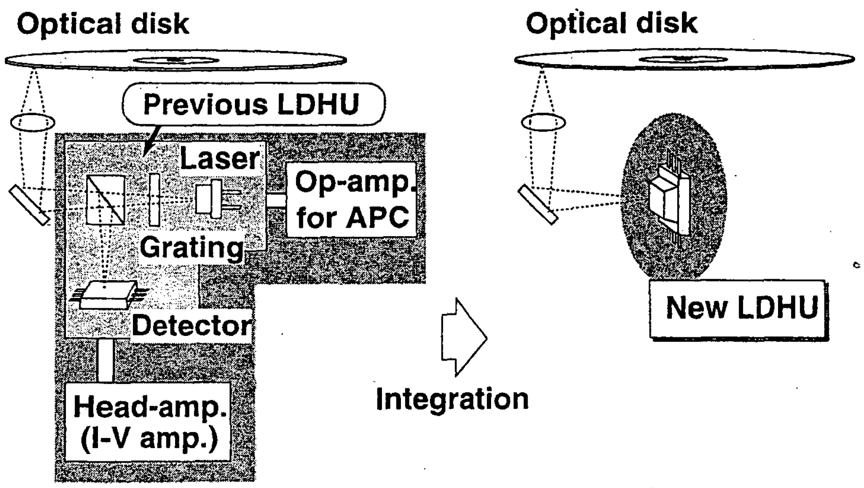

Fig.1. Previous and New Optical Pick-up by Matsushita Electronics Corporation
(Proceeding from an oral presentation on IEEE ISSCC '96 in San Francisco)

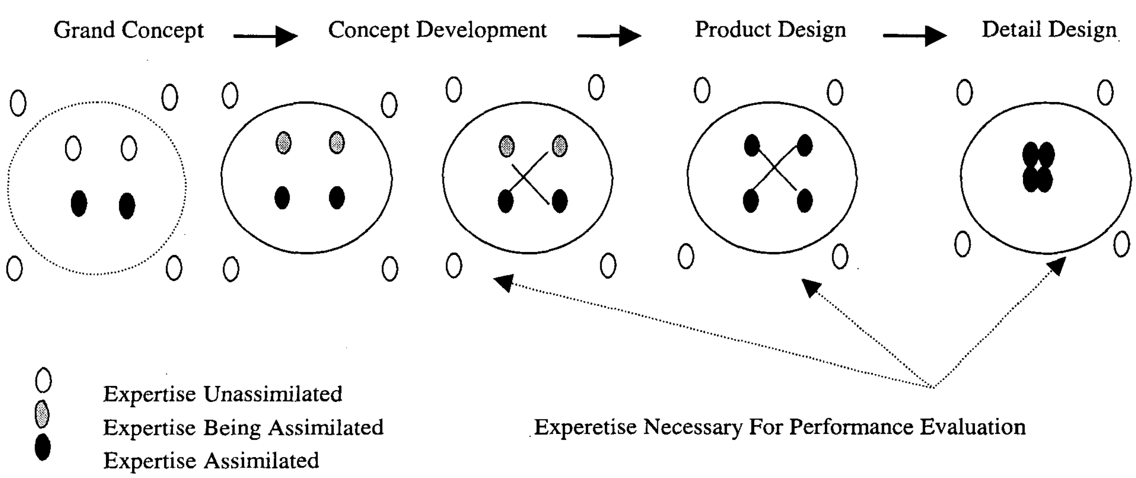

Fig.2. The Product Development process and Expertise of
Matsushita Electronics Industry Corporation