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R&D Strategy and Knowledge Creation in Japanese Chemical Firms, 1980-2010

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This essay is concerned with the history of Japanese chemical firms' R&D strategies from the 1980s to the present. Although the three "ex-zaibatsu"-related general chemical firms (Mitsubishi Chemical, Mitsui Chemical, and Sumitomo Chemical) invested heavily in R&D in these new areas, they were not able to create the new large-scale businesses that they expected. Meanwhile, some high-performance specialized chemical manufacturers such as Shin-Etsu and Japan Synthetic Rubber (JSR) succeeded in developing new businesses in semiconducting or liquid crystal display materials independent of Ministry of International Trade and Industry (MITI) support. How did this happen? Large general chemical firms (Mitsubishi and the like) had the ability to conduct R&D in all three directions simultaneously, which had the effect of dispersing their efforts among several distinct, yet very ambitious, projects. On the other hand, the smaller, specialized chemical manufacturers concentrated their R&D on their areas of expertise. Further, through established long-term business relationships they obtained specific information about each customer's needs that was instrumental in commercializing their newly developed products. This outcome illustrates the unintended consequences of industrial policy and of the differing approaches to R&D strategy that determined failure and success in Japan's modern chemical industry.

Until relatively recently, the Japanese chemical industry was considered to be a very typical, unexciting industry. In the 1970s, the industry suffered from many problems, including the oil crisis, environmental pollution, overcapacity, and fierce competition. In the 1980s, chemical firms began to invest aggressively in R&D not only for petrochemicals but also in new technologies and new fields. As a result, their business structure gradually

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began to change. Companies expected that new technologies would bring stable profits in the future.

In the first half of the 2000s, indeed, the Japanese chemical industry began to transform into a high-tech–oriented industry, and it has attracted attention as a result. The industry produces the high-performance materials indispensable for the consumer electronics and automobile industries. For example, the consumer electronics industry began to mass produce personal computers, cellular phones, flat-panel display (FPD) televisions, portable music players, digital cameras and so forth. Because high-performance electronic materials are used to manufacture these digital consumer electronics, the concomitant steady growth in the electronic materials market greatly increased total chemical industry revenues. Their main products were semiconducting materials and liquid crystal display (LCD) materials. Surprisingly, the Japanese firms' market share of electronic materials is larger than that of final consumer products, electronic parts, and manufacturing equipment.[1] How did the chemical firms succeed? And what kinds of companies are profitable?

My purpose in this essay is to explain why some specialized chemical manufacturers achieve high profitability and why some general chemical firms are consigned to relatively low performance. I trace the history of the management strategy of several typical chemical companies in Japan. These companies diversified their business to electronic materials and/or pharmaceuticals. I also clarify how chemical firms best invested managerial resources to increase profits. It was not easy for general chemical firms that had mainly sold generic petrochemicals to diversify to high value-added products. When the general chemical firms entered the electronic materials, pharmaceuticals, and advanced structural materials businesses, they had to maintain earnings in the petrochemical business at the same time. Resource allocation among several areas requires strategic decision-making. Each company invested its managerial resources with economically rational forecasts, yet their investments resulted in unexpected consequences for individual firms.

The summary of this essay is as follows. Specialized chemical firms tended to concentrate on electronic materials markets. On the other hand, some general chemical firms aggressively entered the pharmaceuticals business. As a result, the general chemical firms were under assault by the specialized chemical firms in individual electronic materials markets, while at the same time they encountered competition with huge domestic and foreign chemical manufacturers in the pharmaceuticals market. Why did they adopt such a two-front strategy? Ironically, they were able to get into the market for electronic materials and the market for pharma-

[1] Ministry of Economy, Trade and Industry (METI), "Summary of New Industry Creation Strategy," 19 May 2004, available at http://www.meti.go.jp/policy/sougou/juuten/simon2004/simon2004_11-2.pdf. Japanese firms' world market share of home information appliances was 27% in 2003. That of panels and units was 32%, that of parts and semiconductors was 51%, and that of electronic materials was 65%. Japanese firms' share is larger in the upstream section of the value chain.

ceuticals at the same time simply because they possessed both sets of technologies. The general chemical firms considered such diversification reasonable to decrease the risk of R&D failure. They were not able to succeed in both areas simultaneously, however, because their managerial resources were dispersed.

The general chemical firms were proud of their technical ability, and as a result they attempted R&D projects with high risk. The targets they chose were difficult, but they expected to be able to obtain large markets if they succeeded. However, they did not achieve large breakthroughs in the pharmaceuticals business because biotechnology and genome science were still immature. Therefore, they did not succeed. On the other hand, the specialized chemical firms concentrated their investment on the electronic materials business. They were forced to attempt to develop products that were less risky because of the lesser resources available to them. Developing pharmaceuticals requires a great deal of human resources, specialized facilities, and capital. On the other hand, pharmaceutical intermediates, reagents, experimental drugs, and health foods were easy to develop and were more certain to be commercialized than pharmaceuticals. The specialized chemical firms were able to invest scarce managerial resources intensively in a more narrow area.

In the digital consumer electronic industry, companies form business relationships among firms that produce electronic materials, parts, and the final products. Companies that had original technological capabilities occupied important positions in these relationships. They improved their bargaining power by offering original products that only their company could create. Under such circumstances, entering important positions at an early stage is a way to build long-term competitive advantage. Once a company occupies an advantageous position, it can obtain important information from its partner. It is very hard to break into such a relationship later on, because once the knowledge creation process with the partner is formed, it has a self-reinforcement mechanism. The manufacturer gives information about its needs to the chemical company, and the chemical company offers products that are suitable for the manufacturer's needs. Therefore, it is critical for them to decide to invest heavily in and enter into a relationship that has not yet solidified. By this, I mean that they must take a substantial risk and invest a large sum of money in a relationship that may not bear fruit. Naturally, they cannot always succeed because their competitors do the same. In spite of the risks, it is far easier for them to enter the relationship at the early stage. Some specialized chemical firms adopted this method self-consciously when they entered the electronic materials market.

General and Specialized Chemical Firms

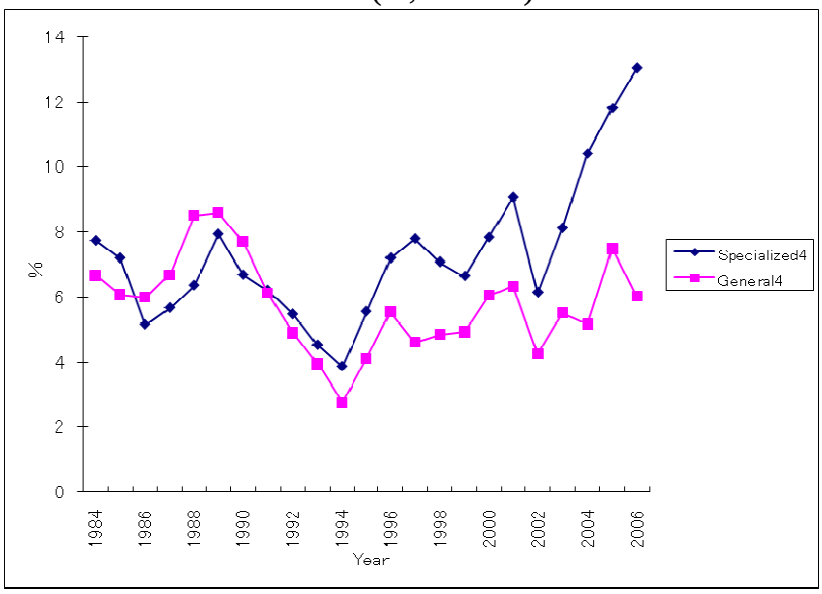
As mentioned above, broadly speaking, chemical firms are divided into two categories: general and specialized chemical firms. The distinction is based on the firm's size and on the share of the petrochemicals business in the firm's entire portfolio. Overall, the general chemical firms have large petrochemical plants and sell large volumes of petrochemical products. On

the other hand, the specialized chemical firms produce high-performance chemical products that have unique functions for a specific purpose. Normally, they are higher value-added products than commodity chemicals.

Japan's seven general chemical firms are Mitsubishi Chemical, Mitsui Chemical, Sumitomo Chemical, Asahi Chemical, Showa Denko, Tosoh, and Ube Industries. All have large ethylene plants. In particular, Mitsubishi, Mitsui, and Sumitomo are the three biggest chemical firms in Japan and they are ex-zaibatsu firms. On the other hand, it is harder to choose specialized chemical firms because there are many such companies in Japan. Although it is but one example, Kanai (2006) listed ten companies as specialized firms: Kaneka, JSR, Shin-Etsu, Sumitomo Bakelite, Daicel, DIC, Tokyo Ohka Kogyo, Zeon, Hitachi Chemical, and Mitsubishi Gas Chemical. All companies produce high value-added chemicals such as electronic materials.

Figure 1 is a comparison of the operating earning rates of the four specialized chemical firms and four general chemical firms. The operating earning rate of the specialized chemical firms is high in recent years because they have various high value-added products. Why did this occur?

Figure 1
Comparison of the Operating Earning Rates of Specialized 4 and General 4 Firms (%, annual)



Source: Each company's *Yukashoken Hokokusho* (Official Company Reports to the Ministry of Finance).
Note: The General 4 consists of Mitsubishi, Mitsui, Sumitomo, and Asahi Chemical. The Specialized 4 consists of Shin-Etsu, JSR, Hitachi Chemical, and Sumitomo Bakelite. Mitsubishi Chemical and Mitsui Chemical were established by mergers of predecessor companies in 1994 and 1997. The two firms' data for years before they were established in their current form are calculated using the sales and operational profit of the predecessor companies.

The general chemical firms such as Mitsubishi Chemical and Sumitomo Chemical earn large profits from the pharmaceuticals business. On the other hand, Shin-Etsu and JSR obtain a considerable amount of their profits from electronic materials. Mitsubishi and Sumitomo began the pharmaceuticals business on a large scale from the first half of the 1970s. On the other hand Shin-Etsu and JSR concentrated on electronic materials, and they invested in this field aggressively. At that time, they developed their products rapidly and flexibly according to the customers' requirements.

Why is the difference in the business development of the general and the specialized chemical firms so pronounced? In order to understand, we must look at the strategic concept and entry and withdrawal behavior of each chemical firm for the past thirty years.

The 1970s: Oil Shocks and the Beginning of Diversification

The history of the modern Japanese chemical industry begins with fertilizer and dye businesses in the Meiji Era (1868-1912). The petrochemical industry was introduced after World War II; the ethylene plant was one of the symbols of Japan's high economic growth.

However, the oil crises and social opposition to environmental pollution in the 1970s created major problems for the industry. Facility investment was excessive because of fierce competition, and the chemical industry suffered from overcapacity and structural depression. This problem was reduced after the government created a process to deal with excess capacity by enacting the Special Law for the Structural Improvement of Specified Industries. In this process, the chemical firms found it necessary to diversify out of petrochemical products.

Mitsubishi Chemical, Mitsui Chemical, and Sumitomo Chemical entered the pharmaceuticals business in 1971, anticipating the development of next-generation cancer medications. In the 1980s, they strengthened their pharmaceutical business because biotechnology appeared to be advancing rapidly; interferon, an epoch-making cancer medication, appeared during that time. The advent of biotechnology and breakthroughs in cancer treatments drove the pharmaceutical investment boom.

On the other hand, for the specialized firms, the general firms' movement toward high technology had a relatively small influence. Their target market was not pharmaceuticals, and they consistently focused their investment on the semiconductor materials market. JSR entered the photoresistor market in 1977. Shin-Etsu started its silicone resin business in 1978. JSR and Shin-Etsu entered the semiconducting materials markets earlier than three of the general chemical firms. The biggest problem for the specialized firms was how to make use of their relatively few managerial resources effectively when they entered new businesses. In some sense, they could not help but invest their resources into the narrow areas in which they had a competitive advantage.

The 1980s: High-Tech Boom

In the 1980s, Japan was confident that it was now one of the economically advanced countries. The idea had spread that Japan should not only incorporate technologies from the United States and Europe, but should also invent new, original technologies. As a result, R&D spending boomed. The Japanese government emphasized the significance of creative basic research under the slogan "Japan as a technology-oriented nation (*gijutsu rikkoku*)." The Japanese government was also eager to promote new technologies. The Ministry of International Trade and Industry (MITI) began the "Next Generation Industrial Infrastructure Technology R&D Project" in 1981. The technical target of the project was new electrical devices, biotech products, and advanced structural materials. These technologies appeared one after another in the 1980s, and people expected they would mature in the future. The mass media called the R&D boom a "New Industrial Revolution." The general chemical firms considered R&D activities in these areas to be the key for success in the businesses of the future. Fortunately, the chemical firms seemed to possess a latent ability in all three new technological areas. The official imprimatur associated with government financial support gave managers in the general chemical firms sufficient internal legitimacy to acquire the resources to hire scientists and engineers who specialized not only in chemistry but also physics or biology in order to conduct research in those areas. At that time, not only chemical firms but also firms in other industries tried to diversify their businesses toward high-tech. For instance, steel firms such as Nippon Steel and Kobe Steel tried to produce semiconductors, and food firms such as Suntory and Ajinomoto began to research biotech products.

The general chemical firms started to research and commercialize new technologies. Sumitomo Chemical developed a new class of medicines (1-aminoanthraquinones) in 1980 and a new class of dyes (phenylhydrazines) in 1982. In 1984, the company established Sumitomo Pharmaceuticals under a joint venture with Inabata Industries to expand its pharmaceuticals division.[2] In 1981, Sumitomo began to develop some advanced ceramics that were thought to be one of the most promising areas in the field of advanced structural materials.

In 1981, Mitsui Toatsu Chemicals (later Mitsui Chemical) began to develop silane gas, used to manufacture semiconductors. The company began making printed circuit boards by establishing an electronic materials division in the same year. The company also completed production facilities for magnetic metal powders for use in audiotapes in 1983. This was the first step toward entering the recording medium business. Mitsui Toatsu Chemicals established a biotechnology business development office in 1982. In 1983, the company began the production of tryptophanes, used in the production of pharmaceuticals and animal feed. Using biotechnology, Mitsui Petrochemical Industries (later Mitsui Chemical) was successful in culturing shikonin (a useful material contained in purple grass roots) on a large scale in 1984. Kanebo, a

[2]Inabata was a general sales agency of Sumitomo Chemical's medical business.

cosmetics company, manufactured and sold lipsticks using this novel material. In the same year, the company began shipping mask pellicles used for semiconductor manufacturing. This was the first mass production plant for this product in Japan.[3] Two chemical companies in the Mitsui group entered the semiconducting materials, recording medium materials, and biotechnology businesses, targets that the Japanese government wanted to promote.

In 1983, Mitsubishi Kasei (later Mitsubishi Chemical) constructed a floppy disk factory in Odawara. In the same year, it formed a joint venture corporation that dealt in carbon fiber fabric with a U.S. firm. The company developed an asthma medication based on its dyestuff technology in 1984. Mitsubishi Kasai cooperated with Mitsubishi Petrochemical (later Mitsubishi Chemical) on the pharmaceuticals business in 1985.[4] The targets of the Mitsubishi Group were recording medium materials, carbon fiber, and pharmaceuticals. These areas were also targets of government policy.

In 1985, Sumitomo Chemical registered a rice plant made by plant biotechnology as a breed. The company produced optical disks (CD-R) at the Ehime factory in the same year. Sumitomo established a joint-venture corporation for magnetic optical disks with Daicel Chemical and Sumitomo Metal Mining in 1990. Sumitomo established an advanced materials section that dealt in electronic materials, and tried to strengthen the photoresistor business for semiconductors in 1991. Sumitomo's targets were semiconducting materials and pharmaceuticals. The major general chemical firms such as Mitsubishi, Mitsui, and Sumitomo aggressively conducted technological R&D and the commercialization of electronic materials, pharmaceuticals, and advanced structural materials.

The petrochemical companies' diversification strategy was omnidirectional. In its 1989 Medium-Term Management Plan, Mitsui Toatsu Chemicals aimed at one trillion yen (80 billion dollars) in total sales in 2000. There were six priority areas: urethane, fine chemicals, chemical products, electronic materials, high-performance polymers and pharmaceuticals.[5] The target figure in each area was uniformly 100 billion yen (about 8 billion dollars) (see Table 1). Because of the notion of economies of scope, the general chemical firms had the idea that the various businesses would increase their business opportunities and decrease risks.

On the other hand, Shin-Etsu and JSR tried to promote intensively the semiconducting materials business in which they had a competitive advantage. Shin-Etsu laid out a strategy that concentrated on semiconductor silicon in a long-term management plan in 1988. The company concentrated its R&D efforts within or around the technologies where it had competitive advantages under the slogan "Pursue new business within or around existing business." Managing director Syunichi Koyanagi of

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[3] *Nikkei Sangyo Shinbun* [Business Daily], "Ima 'Shin Kagaku' Gundan kara me wo hanasuna" [Don't take your eyes off of the 'new chemistry' corps now] (Tokyo, 1987), 184.

[4] *Nikkei Sangyo Shinbun*, "Nikkei Shinbunsha," 17 Jan. 1986.

[5] Mitsui Toatsu, *Medium-Term Management Plan* (Tokyo, 1989).

Shin-Etsu explained, "We cannot parachute into new fields where we have no experience."[6] When developing new products in the materials business, Shin-Etsu created an organizational setting to satisfy customers' needs.

Table 1
Expected Sales in Mitsui Toatsu's 21st-Century Vision
(billion yen)

Items	1989 (actual)	1995 (expected)	2000 (expected)
Commodity Chemical	2,784	3,368	4,000
Performance Chemical	1,831	3,406	6,000
Urethane	464	764	1,000
Fine Chemical	484	800	1,000
Construction Materials	428	682	1,000
Electric Materials	101	363	1,000
Performance Polymer	52	236	1,000
Life Science	302	561	1,000
Total Sales	4,615	6,774	10,000
Ordinary Profit	461	588	1,000

Source: Mitsui Toatsu, *Medium-Term Management Plan* (Tokyo, 1989).

Note: Figures include Mitsui Pharmaceuticals.

The company integrated R&D, manufacturing, and sales in one system. In 1991, Katsuro Miyasaka (silicone division manager) explained this system as follows. "The users always come first. The sales department receives users' needs, and it feeds back them to the R&D department. The R&D department develops the products and the manufacturing department commercializes them. We have worked on our business with this Trinity. Users have supported this style."[7]

In its long-term management vision in 1989, JSR declared it would enter the electronic materials business in addition to its existing synthetic rubber business. JSR aimed to increase the ratio of electronic materials to reach one-third of total sales by 1995. The firm succeeded in commercializing the photoresistor and coating materials for optical fibers in 1982. It also succeeded in commercializing overcoat and oriented film for liquid crystal displays in 1988.[8] Facing technical difficulties, JSR had a hard time in the initial stages. Finally, the photoresistor business became a source of profits in 1991. The company established the "fine (advanced materials) section" separated from the petrochemical section to promote its electronic materials business and tried to understand customer needs

[6] *Nikkei Sangyo Shinbun*, "Ima 'Shin Kagaku Gundan' kara me wo hanasuna," 184.

[7] *Kagaku Keizai* (Chemical Business) (April 1997), 15.

[8] *Kagaku Keizai* (Chemical Business) (Nov. 1995), 70-71, and (April 1996), 23.

promptly. This section independently took charge of manufacturing, quality assurance and the distribution of electronic materials. President Yoshinori Yoshida of JSR explained this section as follows: "Not obsessed by tradition, thanks to the 'fine section,' the development section and the manufacturing section improved the performance of the photoresistor. The lead time of development, production, and sales was shortened."[9]

Shin-Etsu and JSR concentrated on semiconducting materials and had close relationships with their customers in order to understand their needs. On the other hand, the general chemical firms dispersed their investment targets among electronic materials, pharmaceuticals, and advanced structural materials. Because of the collapse of the bubble economy in the 1990s, however, this omnidirectional diversification had to be reconsidered.

The 1990s: Choice and Focus

The collapse of Japan's economic bubble in the first half of the 1990s caused an intense recession. Many commodity plastics manufacturers were hit with big losses. Chemical firms had to restructure their petroleum chemical businesses.[10]

Sumitomo Chemical realized the limitations to continuing in the vinyl chloride business alone. The company abandoned the initiative and integrated its vinyl chloride businesses with Zeon and Tokuyama in 1995, and Mitsui Toatsu Chemicals merged its vinyl chloride business with that of Denka and Tosoh for the same reason in the same year. Mitsui also withdrew from the vinyl chloride business. In contrast, Mitsubishi Chemical established Vitec with Toa-gosei in 2000 and continued in the vinyl chloride business, because the company also possessed a resin finishing business. Resin finishing uses vinyl chloride as an input.

Not dependent on mergers, Shin-Etsu and Kaneka independently continued their vinyl chloride businesses. Observing the other companies' behavior, each company formed alliances concerning vinyl chloride, because the chance of success changed depending on the strategy of the other companies. Firms that dealt in vinyl chloride decreased from fourteen to five companies after the middle of the 1990s. A similar phenomenon occurred in the polyethylene and polypropylene businesses. In the end, polyethylene-producing firms decreased from fourteen to eight. The work force of the thirty main Japanese chemical companies decreased by 5.5 percent in 1995 compared with 1990. The average ability and scale of the Japanese chemical firms were smaller than those of European and American firms. Their profitability was low because of overcapacity and their weak market power.[11] The chemical firms began to reconsider their

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[9] Functional Chemical Industry Society, ed., *Kinosei Kagaku: Kachi Teiangata Sangyo eno Cyosen* [Functional chemistry: A challenge to the value proposal industry] (Tokyo, 2002), 212.

[10] As that result, Asahi Chemical and Tosoh withdrew from polyethylene and Ube Industries from polystyrene.

[11] *Kagaku Keizai* [Chemical Business] (March 2001), 42. For example, the average production capacity per company of polypropylene was 415,000 tons in

diversification strategy: development targets had become too diffuse. The general chemical firms gave up on many development areas.

Mitsui Toatsu Chemicals withdrew from the advanced ceramics business in 1993. The company judged that it was difficult to continue R&D in that area. Sumitomo Chemical withdrew from magnetic optical disks in 1993, and Mitsui Petrochemical did the same in 1994. The two companies gave up on the recording media business. The director of Sumitomo Chemical explained this withdrawal as follows. “It might be too late to say this, but the era of selection and concentration had come.”[12]

Mitsubishi Kasei bought the magnetic optical disk business from Sumitomo Chemical. Mitsubishi judged that it was possible to expand the magnetic optical disk business using the dyestuff technology that the company had developed. In the 1990s, ex-zaibatsu chemical firms merged within the group. Mitsubishi Kasei merged with Mitsubishi Petrochemical, producing Mitsubishi Chemical in 1994. Mitsui Toatsu Chemicals merged with Mitsui Petrochemical, establishing Mitsui Chemical in 1997. Mitsubishi Chemical sold off the floppy disk business to a Taiwanese firm in 1998 and canceled the domestic hard disk business in 2000. The company gave up the photoresistor business, which it sold to a subsidiary of Rohm and Haas in the same year.[13] This company shut down the recording materials and the semiconducting materials businesses but, on the other hand, strengthened the liquid crystal display materials business after 1997. Sumitomo and Mitsui also entered the liquid crystal display materials business. Sumitomo Chemical started to produce color filters in 1994, in addition to optical phase contrast film. Mitsui Chemical (Mitsui Toatsu Chemicals at that time) also reorganized its divisions to enter the liquid crystal display materials market in 1994. The scale of the LCD materials market was only 179.8 billion yen in 1993. However, Windows 95 appeared in 1995, and thereafter the Internet spread quickly. The market for LCDs used for notebook computers and PC monitors expanded drastically. [14] Moreover, cellular phones and LCD televisions spread explosively in the 2000s.

At the same time, the ex-zaibatsu general chemical firms began to reinforce their pharmaceutical businesses. Mitsubishi Chemical merged its pharmaceuticals section with Tokyo Tanabe and established the Mitsubishi Tokyo pharmaceuticals in 1999. Human genome analysis attracted managerial attention at the beginning of the 2000s.[15] In 2000,

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Japan, 533,000 tons in the United States, and 719,000 tons in Western Europe (1999 year-end production capacity).

[12] *Nikkei Sangyo Shinbun*, 22 Jan. 1993.

[13] In 1998, Mitsubishi Chemical established a photoresistor joint venture with a South Korean firm.

[14] *Kagaku Keizai* [Chemical Business] (Sept. 1995), 9. The items are electrode circuit board glass (47.5 billion yen), color filters (42.1 billion yen), and polarizing film and phase difference film (29.5 billion yen).

[15] The sales (and operational profit) of health care or pharmaceutical business by Mitsubishi Chemical were 125 billion yen (8.2 billion yen) and those by

Sumitomo also established the Genome Science Institute in the research headquarters of Sumitomo Pharmaceuticals.[16] Only Mitsui Chemical was worried about continuing in the pharmaceuticals business. Finally, Mitsui sold off its pharmaceuticals business to German Schering AG in 2000 and withdrew from that sector.

The 2000: A Two-Front Strategy

In 2001, Mitsubishi Tokyo Pharmaceuticals merged with the Welfide Company, forming Mitsubishi Welpharma. Tomisawa Ryuichi, a long-time employee of the pharmaceuticals section, was selected as the new president of Mitsubishi Chemical in 2002. The company decided to withdraw from the pesticide business in the same year and sold it off to Nihon Nohyaku (Japan Agricultural Chemical). To expand the LCD materials business, Mitsubishi focused on the expansion of LCD reflection materials and PDP optical filters in 2000. Mitsubishi sold the hard disk business to the Showa Denko group and withdrew from it in 2002. It is clear that Mitsubishi wanted to enhance pharmaceuticals and LCD materials products at that time.

In 2001, Sumitomo Chemical reorganized and established the information and electronic chemicals section that took charge of semiconducting and LCD materials. Mitsui Chemical began to produce optical filters for plasma display panels (PDP) in the same year. Anticipating growth in the display market, the two companies aimed to expand production of the display materials. The ex-zaibatsu general chemical firms, except Mitsui, focused on electronics materials and pharmaceuticals at the same time. In 2002, Mitsubishi invested half of its R&D budget in pharmaceuticals: 48.1 billion yen out of a total of 93 billion yen. Sumitomo invested half of its R&D budget in pharmaceuticals and agricultural chemicals: 41.2 billion yen out of a total 72.8 billion yen. Only Mitsui invested half of its R&D budget in high-performance polymers and engineering plastics, because it did not have a pharmaceuticals business. Mitsui invested 21.2 billion yen in these high-performance structural materials, out of a total 37.1 billion yen R&D budget (see Table 2).

The specialized chemical firms such as Shin-Etsu and JSR were devoted to electronic materials in the 1990s, while the general chemical firms widely expanded their R&D to electronic materials, pharmaceuticals, and advanced structured materials. Vice-president Kawasaki of Shin-Etsu Semiconductor explains as follows: “Customers tell us their plans for the next generation of products. They offer information on what research we should do because they know which era will come next. We evaluate the

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Sumitomo were 143.1 billion yen (30.1 billion yen) in fiscal year 2001. In comparison with leading Japanese pharmaceutical companies like Takeda or Sankyo, even Mitsubishi and Sumitomo were midsize companies. Takada’s sales (and operational profit) were 378.4 billion yen (112.2 billion yen) and Sankyo’s were 209.5 billion yen (312 billion yen).

[16] *Kagaku Keizai* [Chemical Business] (Feb. 2002), 99-100.

future trends of this field objectively through the information provided by customers."

After the 2000s, Shin-Etsu and JSR provided a wide variety of semiconductor and display materials and displayed solid financial performance in the electronic materials business overall (see Tables 3 and 4).

Table 2
R&D Investment in 2002
(billion yen)

Mitsubishi		Sumitomo		Mitsui		Shin-Etsu		JSR	
Basic Research	10 8	Basic Research	93	Basic Research	99			Basic Research	20.9
Petrochemicals	86	Petrochemicals Basic Chemicals	39 21	Petrochemicals Basic Chemicals	39 21	(In)organic Chemicals Performance Chemicals	Confi-dential	Elastomers Emulsions Synthetic Resins	15.9 10.3 9.8
Performance Chemicals[a] Performance Materials Health Care Services	163 68 481 2	Agrichemical Pharmaceuticals	53 63 131 281	Performance Resins Performance Chemicals[b]	97 115	Electric Material	Confi-dential	Diversified[c]	83.4
Totals	910		728		371		273		140.2

Source: Each company's *Yukashoken Hokokusho* (Official Company Reports to the Ministry of Finance).
Notes:
[a] "Performance chemical" under Mitsubishi Chemical refers to medicine, food, information and electronics, optical record media, carbon materials, and functional color materials (voltage-sensitive pigments).
[b] "Performance chemical" for Mitsui Chemical contains electronic materials, agriculture chemicals, fine chemicals, and pharmaceutical raw materials.
[c] "Diversified" in JSR consists mainly of electronic materials.

Conclusion

After the 1970s, the general chemical firms were involved in R&D and commercialization of various products in the fields of electronic materials, pharmaceuticals, and advanced structural materials. After the bursting of the economic bubble in the early 1990s, this diversification strategy was reconsidered. Investment in R&D expanded, demand for petrochemical products stagnated, and companies' sales and profit decreased rapidly.

Who survived under such adverse circumstances? The difference in performance between the general chemical firms and the specialized chemical firms grew during the 2000s. It was not easy for the general chemical firms to withdraw from unprofitable businesses, because, in

Table 3
Principal Manufacturers of Semiconductor Materials

Materials	Manufacturers
Polysilicon	Hemlock (US), Tokuyama, Wacker (Germany), REC (Norway), Mitsubishi Materials
Silicon wafer	Shin-Etsu, SUMCO, MEMC (US), Siltronic (Germany), Toshiba Ceramics
Abradant	Fujimi
Reclaimed polished wafer	Mimasu Semiconductor Industry, RASA Industries
Photoresist	JSR, Tokyo Ohka, Shin-Etsu, Sumitomo Chem., Rohm and Haas(US), AZ (Luxemburg)
Lens for photolithography	Shin-Etsu & Heraeus (Germany), Tosoh
Mask substrate	Shin-Etsu, Tosoh, Toshiba Ceramics
Pellicle	Asahi Chem., Mitsui Chem., Shin-Etsu
CMP slurry	Cabot (US), Rohm and Haas, JSR, Hitachi Chem., Fujimi
CMP pad	Rohm and Haas, JSR
Low-k (application type)	JSR, Dow Chem. (US), Hitachi Chem., Zeon, Sumitomo Bakelite
Etching/washing	Kanto Denka, Zeon, Mitsui Chem., Sumitomo Chem., Tokyo Ohka, Mitsubishi Chem.
Passivation film	Sumitomo Bakelite, Hitachi Chem.& Du Pont, Asahi Chem.
Resist for bump formation	JSR, AZ, Tokyo Ohka
Die bonding material	Hitachi Chem., Sumitomo Bakelite, Tomoegawa
Encapsulant	Sumitomo Bakelite, Hitachi Chem., Nitto Denko, Matsushita Denko, Kyocera Chem.
Lead Frame	Hitachi Cable, Sumitomo Metal Mining, Mitsui Highteck, Shinko Electric Industries
Organic substrate material	Mitsubishi Gas, Hitachi Chem., Sumitomo Bakelite
Career tape	Denka, Shin-Etsu Polymer, Sumitomo Bakelite
Copper-clad laminate	Hitachi Chem., Matsushita Denko, Mitsubishi Chem., Sumitomo Bakelite
Circuit board	Ibiden, Shinko Denko, NGK, Hitachi Chem., Nippon CMK
Dry film resist	Hitachi Chem., Asahi Chem., Choko (Taiwan), Tokyo Ohka, Du Pont

Source: Takao Kanai, *Chemical Industry* (Nihon Keizai Shimbun, 2006), 65. I placed Shin-Etsu and JSR in white rectangles and underlined Mitsubishi, Mitsui, and Sumitomo Chemical.

Table 4
Principal Manufacturers of Display Materials[a]

Display Materials	Manufacturers
Polarizing film	Nitto Denko, Sumitomo Chem., Sanritz, Optimax (Taiwan), Polatechno, LG Chemical (Korea)
Phase difference film	Zeon, JSR, Nitto Denko, Konica Minolta, Kaneka
Oriented film	JSR, Nissan Chem.
Color filter	Toppan, DNP, Sumitomo Chem., Toray
Coloring resist	JSR, Fujifilm, Toyo Inc, Mitsubishi Chem.
Spacer	JSR, Osaka Yuki, Sekisui Chem.
Liquid crystal	Merck (Germany), DIC, Chisso
Insulation film	JSR
Glass substrate	Corning (US), Asahi Glass, NSG, Nippon Electric Glass
Prism sheet	3M (US), Mitsubishi Rayon
Diffuser panel and light guide plate	Mitsubishi Rayon, Kuraray, Asahi Chem., Teijin, Sumitomo Chem., Zeon

Source: Takao Kanai, *Chemical Industry* (Nihon Keizai Shimbun, 2006), 67. I put Shin-Etsu and JSR in the white rectangles and underlined Mitsubishi, Mitsui, and Sumitomo Chemical.

Notes:

[a]Internal production by panel manufacturers is excluded.

Japan with its tradition of lifetime employment, it was very difficult to fire employees, especially scientists and engineers with specific technical skills.

On the other hand, the specialized chemical firms promoted their relationships with their customers in their own particular fields. They tried to offer products that satisfied customers' specific needs. As a result, Shin-Etsu and JSR achieved high market shares. Ironically, the general chemical firms were not able to invest their resources intensively because they had many different technologies in which they could invest. The specialized chemical firms' only choice was to concentrate all of their corporate efforts on electronic materials. In addition, the general chemical firms tended to focus on technically difficult products with large expected markets. In each electronic materials product market, the specialized chemical firms were very strong because they had accumulated competencies by understanding customers' needs.

In conclusion, the omnidirectional development strategy of the general chemical firms was outperformed by the targeted strategy of the specialized chemical firms. Further, we can see that the general chemical

firms' high-risk, high-tech–oriented strategy, supported by their very high technical capabilities, was outperformed by the specialized chemical firms' customer-oriented, practical, product-oriented strategy.