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INTERNATIONAL DEPLOYMENT OF THE JAPANESE ELECTRONIC MATERIALS INDUSTRY: CASES OF ELECTRONIC DISPLAY MATERIALS MANUFACTURERS

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ABSTRACT

The Japanese chemical industry has built general chemicals factories overseas. Nevertheless, it has been reluctant to build factories that produce high-technology functional chemicals overseas, first because these factories are inseparable from R&D laboratories, second, because not all Asian countries have reached a sufficiently high level of technology to provide the necessary infrastructure and services for such factories.

However, the author takes notice that the chemical industry has recently built some factories that produce electronic display materials that are typical of high-technology functional chemicals, in Asian countries. The author first collects and analyzes cases in which chemical companies have built factories overseas and then analyzes the market structure of display materials to clarify the reasons why they do so.

First, the author has found that such deployment is a result of the increased production of electronic display in Asia, led by Korean companies. Second, the author has found a more fundamental factor underlying such deployment by observing the relation between the chemical industry and the electronics industry in this field in Japan from the viewpoint of technology. The chemical industry cannot formulate its R&D policy on its own and must depend on the electronics industry for policymaking. This is because it is not easy for the chemical industry, as a typical intermediate goods industry, to forecast which electronic display company will win the market, and which electronic display system will secure the market; liquid crystal electronic display (LCD); plasma electronic display panel (PDP); organic electroluminescence (organic EL); surface-conduction electron-emitter electronic display (SED); or electronic paper.

Key words: *Factory location, Industrial organization, Electronic display, Liquid crystal, Chemical industry.*
JEL Classification: L65, O53, F23

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1. INTRODUCTION

In regions covered by Free Trade Agreements (FTAs), factories move to their optimum locations. As the Japanese government is negotiating FTAs with a number of countries to remove various trade barriers, it should soon be even easier for Japanese industries that have already deployed internationally to build factories overseas.

The Japanese chemical industry has built general chemicals factories overseas, but has been reluctant to build factories that produce high-technology functional chemicals overseas. However, the author takes note that the chemical industry has recently built some factories that produce electronic display materials typical of high-technology functional chemicals, in Asian countries.

This paper surveys cases in which Japanese chemical companies build factories that produce liquid crystal display materials in other countries, to find the reasons for overseas deployment. This paper also reveals a more fundamental factor underlying such deployment by observing the relation between the chemical industry and the electronics industry in the field of electronic display materials in Japan, from the viewpoint of market structure and industrial technology.

The reasons that this paper focuses on liquid crystal display materials are as follows. First, liquid crystal display materials are typical of electronic display materials or high-technology functional chemicals. Second, in the liquid crystal display materials industry, we can collect many cases of overseas deployment of factories due to increasing demand for these materials. Third, we can narrow a discussion down to limited varieties of chemicals because any type of liquid crystal display is composed of common materials.

The author believes that the discussion within this paper should be useful to establish an industrial policy on high-technology functional chemicals. Moreover, it should contribute to policymaking to invite high-technology chemical companies to set up their plants in rural areas, as this paper suggests the local conditions that these companies require.

2. POSITION OF THIS PAPER AMONG RECENT STUDIES

With respect to the chemical industry, we have seen two types of international deployment of factories. First is the deployment of factories to areas of cheap land, energy and materials. Products of such factories are basic chemicals such as ethylene glycol, terephthalate and vinyl chloride monomer or general resin such as polyvinylchloride and polyethylene. Second is the deployment of factories to follow a Japanese assembly industry that locates overseas. Products of these factories include parts of domestic electrical appliances such as cabinet materials, or automobile parts such as bumper materials.

These are mass production chemicals that are used widely for various purposes. On the other hand, functional chemicals such as electronic materials have been produced in Japan. This is primarily because the factories producing functional chemicals, which are diversified small-quantity production chemicals, are not restricted by the cost of materials, energy, land or transportation; and also because factories that produce them are inseparable from R&D laboratories. However, there are recent examples of overseas deployment of factories producing electronic materials, especially electronic display materials, for which demand is rapidly increasing. Nevertheless, it is only in recent years that we have seen such overseas deployment and therefore, few academic studies on this industrial phenomenon have been conducted so far.

There are some business reports on the location of factories that produce liquid crystal display and display materials. Namikawa (2005) reports on the relationship between locations of liquid crystal display factories and those of display materials factories in Japan. Sakiura (2003) and Beppu (2003) report that the liquid crystal display factories of Sharp Ltd in Mie Prefecture attract various display materials factories. Nishimura (2002) of Sharp Ltd reveals the reasons why the company is determined to locate its liquid crystal display factories in Mie Prefecture. These reports make no mention of overseas deployment. With respect to overseas deployment, Shimizu (2003) reports on the competitive relationship between liquid crystal display companies of Japan and those of Korea and Taiwan. The report does not refer to display materials. The overseas deployment of factories that produce display materials is not discussed in any of these business reports. This topic is examined in this paper.

3. WHAT IS ELECTRONIC DISPLAY AND WHAT ARE ELECTRONIC DISPLAY MATERIALS?

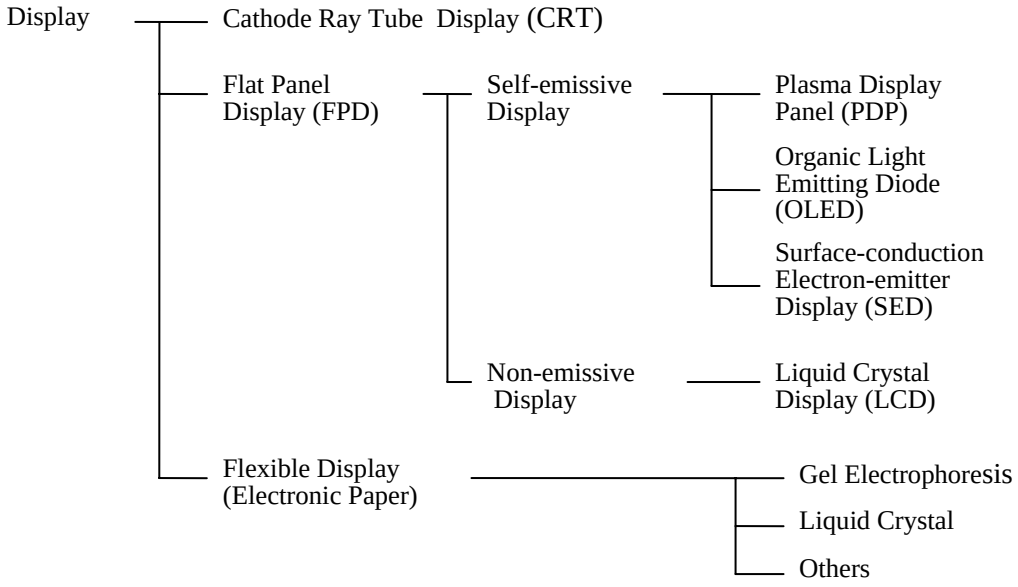
3.1. Electronic display

Electronic displays are widely used for televisions, personal computers, mobile phones, car navigation systems and so on. The demand in the world for electronic displays is rapidly increasing and it will reach 12 trillionYen in 2010 according to the estimation by the Ministry of Economy, Trade and Industry (2002). As shown in Figure 1, there are various types of electronic displays, some of which are under development and will enter the market in due course. They actively compete for market share.

Electronic displays are generally classified into three large groups for business purposes: Cathode ray tube displays (CRTs); Flat panel displays (FPDs); and Electronic paper that is as thin as paper and can be flexed. FPDs can be classified into two subgroups, that is, self-emissive display and non-emissive display, according to whether the display requires backlighting or not. Liquid crystal displays (LCDs) are non-emissive displays. Plasma display panels (PDPs), Organic electroluminescence or Organic light emitting diodes (OLEDs) and Surface-conduction electron-emitter displays (SEDs) are classified into the category of self-emissive displays. Electronic paper can

be classified into some subgroups. Electronic paper based on gel electrophoresis is currently the most developed form, while electronic papers based on LCD, PDP or OLED technologies are also being developed. Each display can be further classified according to technological details: LCDs are divided into reflective types and transmissive types, PDPs are divided into direct current types and alternating current types, and OLEDs are also divided into fluorescent types and phosphorescent types. Moreover, there are many types of display that are not listed in Figure 1.

Figure-1: Types of Display



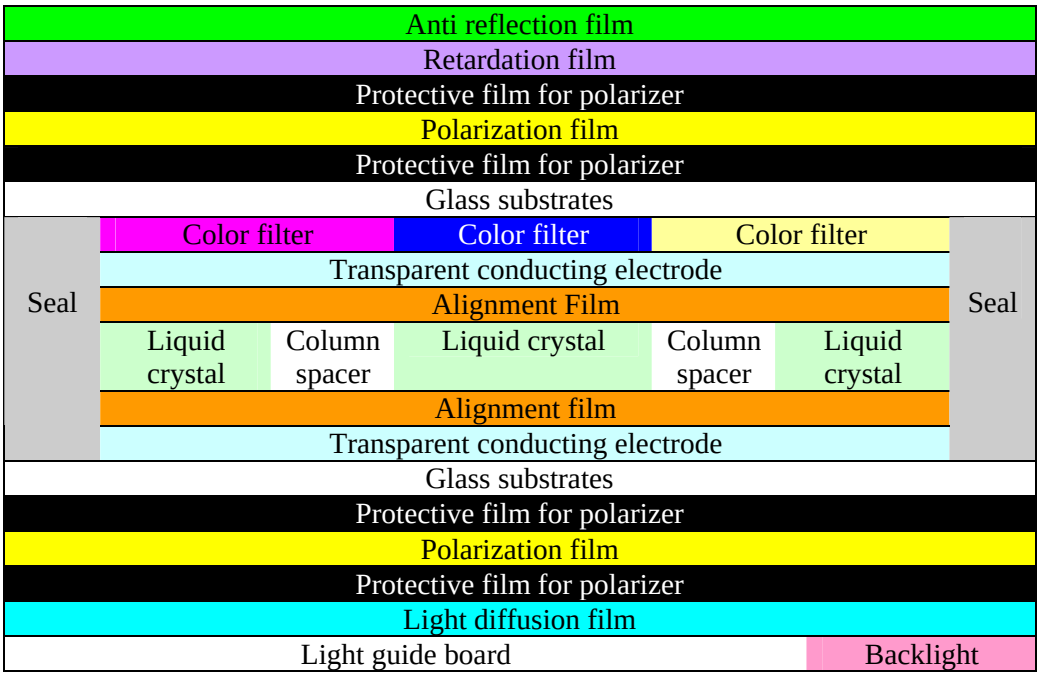
These displays are classified according to when they were put on the market: CRTs are first-generation displays (former generation); LCDs and PDPs are second generation (current generation); OLEDs and SEDs are the third generation (next generation); and electronic paper is the fourth generation (future generation).

The demand for CRTs is rapidly decreasing in spite of the high quality of the picture, because they occupy considerable space and consume a large amount of electricity. On the other hand, the market for LCDs, which are the leading FPDs, is expanding. For example, the world market size of monitors with LCD was 7 million sets in 2000, 105 million sets in 2005, and will be 150 million sets in 2008 (Japan Electronics and Information Technology Industries Association, 2002 and 2006). However, LCDs are encountering strong competition from PDPs. In the case of television, it is said that PDPs have an advantage over LCDs in cost, especially in the cost of large-screen displays, but LCDs have the advantage over PDPs in picture quality. This technological gap between them is narrowing owing to R&D on both sides and accordingly competition will strengthen in the future.

It has been said that OLEDs and SEDs are technologies of the next generation. However, OLEDs have recently been commercialized for small-sized electronic displays such as mobile phones and digital cameras. SEDs are scheduled for commercial production in television displays in 2007 in Japan. OLEDs are useful as a moving-picture display due to their quick responses and can be made very thin owing to their simple structure. It is forecast that the demand for OLEDs will sharply increase when their production cost decreases and the technology to produce large-sized panels is introduced. SEDs have an advantage in quality of picture as they are based on the same technology as CRTs. Besides, SEDs are energy saving and are easily made flat. The demand for SEDs could increase when the production cost decreases through mass production.

Electronic paper has been put on the market as a marketing exercise by a few companies, although neither the technology nor the cost has reached commercially viable levels. It is expected that electronic paper will not only replace conventional paper but also create new products or communication systems that will change social systems drastically.

Figure-2: Main Materials Composing LCD



3.2. Electronic display materials

Each type of electronic display is made of various functional chemicals. LCDs, for example, are composed of many thin films of functional chemicals, as shown in Figure 2. Each film, which is some tens or hundreds of micrometers thick, has its own special function to contribute to the performance of an LCD. Different types of electronic display are composed of different chemicals because each display is based on different technological principles. Strictly speaking, materials for

frames, adhesives, printed circuit boards and so on can be used for the three types of display: LCDs, PDPs and OLEDs. However, the key materials that control the performance of electronic displays are different. The main display materials for LCDs, PDPs and OLEDs that are already commercialized are listed in the left columns of Tables 4, 5 and 6.

This paper focuses on materials themselves and is not concerned with the process of assembling electronic displays from the materials. This paper adopts the simple term "electronic display," making no strict distinction among electronic display panels, electronic display modules or electronic display cells.

4. ANALYSIS OF CASES OF OVERSEAS FACTORY DEPLOYMENT

4.1. Method of survey and analysis

The author attempts to identify the reasons why chemical companies deploy their display materials factories overseas: first, in this chapter, by analyzing cases in which their factories are built overseas and second, in the next chapter, by analyzing market structure.

In this chapter, the author discusses the deployment of display materials factories focusing on LCD materials for the reasons mentioned above. Cases in which chemical companies have established their display materials factories overseas are listed in Table 1. The table shows the chemical companies, chemicals produced, the countries where the factories are built, the year of building completion (or commencement) and the objective of the deployment; in other words, the market for the materials produced in the factories. The objective of the deployment is classified into three types: Type 1: to supply materials to overseas specific factories of Japanese display companies including joint companies with foreign companies; Type 2: to supply materials to specific factories of local companies in the country of deployment; and Type 3: to supply materials to specific factories in and around the country of deployment and elsewhere. To clarify, the reason why the author prefixes the word "specific" to the word "factories" is that, unlike general chemicals, electronic display materials, which are typical high-technology functional chemicals, are never sold to many and unspecified companies. The objective of deployment is written as (Type 1) and so forth in Section 4.2.

The author explains the cases in which chemical companies build factories and shows the trend of deployment, before discussing why display materials manufacturers build their factories overseas, by analyzing these cases. The analysis is no more than qualitative, because it is not easy to collect standardized information, some of which is confidential.

4.2. Cases of overseas deployment of factories of display materials

Sumitomo Chemical Ltd is very active in deploying display materials factories overseas, particularly those involved in polarization films. The company used to produce polarization film in

Japan (Ehime), but it abandoned the policy and decided instead to produce it in Korea (Pyeongtaek) (Type 3) and Taiwan (Tainan) (Type 2) in June 2002. After that, the company increased its production capacity in Korea and Taiwan several times to cope with the increased demand for polarization film, driven by a large-screen LCD television boom. With respect to China, the company established factories to produce polarization panels by processing the film at Shanghai in 2001 (Type 2) and at Wuxi in 2005 (Type 2), both of which are joint ventures with local companies. Furthermore, in 2006, the company announced a plan to produce polarization film in China (Wuxi) where the company had its factory for film processing (Type 1). As a result, in June 2007, the company will have a production capacity of 3.7 million tons of polarization film per year in Korea and 5.45 million tons per year in the three countries, namely, Korea, Taiwan and China. These capacities comprise around 50% and 70% respectively of the total production capacity of the company, that is, 7.6 million tons per year. The destination of the polarization film produced in the factory (Dongwoo Fine Chem Ltd, which is a local affiliated company of Sumitomo Chemical Ltd) in Korea is not only in Korea but also China and Singapore. That is to say, the factory is the central base of the company's production operations in Asia. The company has also produced color filters in Korea (Pyeongtaek) since 2003 (Type 3), and began production in Taiwan (Hsinchu) jointly with a Taiwanese company, Prime View International Ltd, in 2005 (Type 2). In addition, in March 2006, the company announced a plan to build a factory to process polarization film to supply the processed product to the local affiliated factory of Sharp Ltd in Poland (Type 1). Furthermore, the company established a laboratory for display materials in Korea (Iksan) in April 2005.

Polatechno Ltd, which is a joint corporation between Nippon Kayaku Ltd and Arisawa Manufacturing Ltd, is a leading manufacturer of polarization film and retardation film. It began to build factories in China (Wuxi, Jiangsu) (Type 2) in 2003 and in Taiwan (Kaohsiung) (Type 2) in 2005. On the other hand, Zeon Corporation Ltd, which is another leading company of retardation film, is reluctant to deploy their retardation film factory overseas. It is within Japan (in Himi, Toyama) that the company plans to build a new factory for retardation film production, although it should be noted that the company established another factory, to produce rubber materials of automobile parts, in China (Guangzhou) in 2004.

Fujifilm Ltd, which is very active in expanding its display materials business, has not been active in producing them overseas. The company released, in 2004, plans for 2005 and beyond to invest a total of more than 100 billion Yen in factories to produce protective film for polarizers (triacetyl cellulose), of which 80% of the market share the company holds. These plans were to build new production lines in Japan (Kanagawa and Kumamoto). However, the company began to produce color resist for LCDs in China (Suzhou) in 2006 (Type 2). Furthermore, the company announced a plan to produce color filters for Thin Film Transistor LCDs (TFT-LCDs) in a joint corporation between Fujifilm Ltd and SVA Electron Ltd, a leading electrical appliance and electronic parts company, in China (Shanghai) in August 2006 (Type 2). Considering that the business field of the

joint corporation covers research and development, Fujifilm Ltd might have changed its policy on factory location. In addition, with respect to protective film for polarizers, Konica Minolta Ltd, which is a rival company to Fujifilm Ltd, is also constructing new production lines. However, these are located in Japan (Kobe). Thus, factories of protective film for polarizers are behind those of the other chemicals in overseas deployment, although the demand for the film is rapidly increasing.

Toppan Ltd, which had produced color filters for LCDs in Japan, began to produce them in Taiwan (Tainan) to meet the demand from the Taiwanese market in 2002 (Type 2). The company decided in August 2006 to give 40% of its share of the local affiliate company Au Optronics, which is a leading manufacturer in the field of TFT-LCD panels, in order to secure the Taiwanese market. Toyo Ink Ltd, which supplies photo resist for color filters to Toppan Ltd, followed the factory of Toppan Ltd to start production of the photo resist in Taiwan (Tainan) in 2002 (Type 1). In 2004, the company doubled its production capacity to supply not only the Toppan factory, but also the whole of the Taiwanese market (Type 1)→(Type 2).

Dai Nippon Printing Ltd began to produce color filters in a local Taiwanese company by investing in and transferring technology in 2001, and is now producing color filters in two Taiwanese companies (Type 2). JSR Ltd began to produce color resist in 2004 and photosensitive column spacer materials in 2005 in Korea (Ochang) (Type 2) and completed a factory to produce color resist in Taiwan (Huwei, Yunlin County) in July 2006 (Type 2).

Nippon Oil Ltd started production of liquid crystal film (viewing angle improving and color compensation film), which is a main product of the company, in China (Suzhou) in 2004 and now has plants with capacity of 1.2 million square meters in China, which is around 50% of the total production capacity of the company. The company intends to supply the film to various countries' mobile phone manufacturers who have factories in China (Type 3).

Adeka Ltd (former Asahi Denka Ltd), which is a leading manufacturer of liquid crystal materials, had exported electronic materials to Taiwan, although the company already had the affiliate factory to produce an additive to resin in Taiwan (Tainan). However, the company established a factory for liquid crystal materials in Tainan in 2005 (Type 2). Chisso Ltd had produced display materials in Japan (Tobata, Minamata and Goi), but the company announced plans to construct plants producing alignment film in Korea (Pyeongtaek) (Type 2) and plants to blend liquid crystal materials in Taiwan (Tainan) (Type 2) in 2005. These factories will be completed in the last quarter of 2006.

Asahi Glass Ltd is one of frontrunners in deploying overseas factories to produce display materials for LCDs and PDPs. When the company decided to build a factory in Taiwan in 2000, Taiwan's share of the world TFT-LCD market was no more than 5%. The company established the factory to process the glass substrates for LCDs in Taiwan (Duoliu, Yunlin County) in 2001; built the furnace for the glass substrates for LCDs there in 2004; and then increased these production lines. These factories supply the products to the Taiwanese market (Type 2). Then, the company built the

factory to process glass substrates in Korea (Gumi) in 2005, owing to the expanding market there (Type 2).

Nippon Electric Glass Ltd began to build factories to process the glass substrates for LCD in Korea (Gumi) in 2002 and in Taiwan (Taichung County) in 2003. In 2006, this company and LG.Philips LCD Ltd established a joint corporation and started to process the glass substrates in Korea (Paju) (Type 2). Furthermore, in August 2006, the company announced that it would build a factory in conjunction with SVA Electron Ltd in China (Shanghai) to supply the glass substrates for TFT-LCDs to the joint corporation between NEC Ltd of Japan and the SVA group (Type 1). Nippon Electric Glass Ltd has maintained a policy of producing the glass substrates themselves in Japan. Nippon Sheet Glass Ltd, which is also a leading glass manufacturer, established a joint corporation with the US firm Applied Films Corporation Ltd in China in 1998 and has supplied the glass substrates prepared by a thin film of Indium tin oxide (ITO) to LCD panel manufacturers in China and the other countries (Type 3). The company then obtained 100% share of the joint corporation in 2005.

There are some other companies producing display materials overseas. Asahi Kasei Chemicals Ltd started to produce light guide boards in Korea (Pyeongtaek) in 2003 (Type 2), and the company announced that it would produce light diffusion film in a joint corporation between the company and Raygen Ltd in Korea in January 2006 (Type 2). NH Technoglass Ltd, a joint corporation between Nippon Sheet Glass Ltd and Hoya Ltd, a manufacturer of the glass substrates for LCDs, and Nitto Denko Ltd, a functional chemical specialist manufacturer, also deploy their factories in Korea, Taiwan and so on.

4.3. Features of overseas deployment

Some features of overseas deployment of chemical companies to produce display materials are summarized as follows.

The first feature is which companies have built their factories overseas. Not all of the chemical companies that produce display materials have their factories overseas, as can be seen by comparing Table 1 with Table 4. Although a considerable number of companies have their factories overseas, they are rather a minority. The author can also see great contrasts among overseas deployment policies of companies. For example, on one hand, Sumitomo Chemical Ltd, which is a giant display materials maker, produces its main product overseas; that is, polarization film. The company will soon have 70% of its production capacity overseas. On the other hand, Fujifilm Ltd, which is another giant, has continued to produce its main product, that is, protective film for polarizers, within Japan.

Table 1: Main Display Materials Manufacturers that Have Factories Overseas

Manufacturers	Display materials produced	Place of factories	Year	Main Market
Sumitomo Chemical	Polarization film	Korea	2003	Korea, China, Singapore
		Taiwan	2004	Taiwan
		China	*2006*	China
		Poland	*2006*	Sharp Ltd in Poland
	Polarization panel	China	2001	China
		China	2005	China
	Color filter	Korea	2003	Korea, Taiwan, China
		Taiwan	2005	Taiwan
Polatechno	Polarization film	Taiwan	*2005*	Taiwan
	Polarization film Retardation film	China	*2003*	China
Fijifilm	Color filter	China	*2006*	China
	Color resist	China	2006	China
Toppan	Color filter	Taiwan	2002	Taiwan
Toyo Ink	Resist ink	Taiwan	2002	Toppan in Taiwan
Dai Nippon Printing	Color filter	Taiwan	2001	Taiwan
JSR	Color resist	Korea	2004	Korea
		Taiwan	2006	Taiwan
	Protective film for LCD	Korea	2005	Korea
	Photosensitive spacer	Korea	2005	Korea
Nippon Oil	Liquid crystal film	China	2004	Portable phone makers of various countries in China
Adeka	Liquid crystal	Taiwan	2005	Taiwan
Chisso	Liquid crystal (Blending)	Taiwan	*2005*	Taiwan
	Alignment film	Korea	*2005*	Korea
Asahi Glass	Glass Substrates (Processing)	Taiwan	2001	Taiwan
	Glass Substrates	Taiwan	2004	Taiwan
	Glass Substrates (Processing)	Korea	2005	Korea
Nippon Electric Glass	Glass Substrates (Processing)	Korea	*2002*	Korea
		Taiwan	*2003*	Taiwan
		Korea	2006	Korea
		China	*2006*	SVA-NEC in China
Nippon Sheet Glass	Glass Substrates with ITO	China	1998	China and others
Asahi Kasei Chemical	Light diffusion film	Korea	*2006*	Korea
	Light guide board	Korea	2003	Korea

(Note) The figures except for those in *italics* are the year of completion of factories. The figures in *italics* are the year that the plan was revealed.

The second feature is the countries where the companies decide to build their factories. As Table 1 shows, Korea and Taiwan are the top two countries, followed by China. It is notable that China, where various Japanese industries are now flocking, is not at the top. Table 1 also shows that there are no cases where companies have built factories in South East Asian countries, where various Japanese industries have built their factories.

The third feature is the years when the companies built their factories overseas. It is only in recent years that they have built their factories. They did not deploy their factories overseas in the

1990s while the LCD business was encountering smooth waters, but began to look favorably toward overseas deployment from about 2002, and still retain such an attitude.

The fourth feature is the market for the materials produced in their overseas factories. As can be seen, most companies supply their display materials to the local electronic display companies in the country where their factories locate (Type 2). A few companies supply the materials to the Japanese electronic display factories there (Type 1); Sumitomo Chemical Ltd followed Sharp Ltd in Poland, Toyo Ink Ltd followed Toppan Ltd in Taiwan, Nippon Electric Glass Ltd followed NEC Ltd in China. Thus, the display materials factories do not necessarily follow the electronic display factories. Only a few companies supply materials not only to the country where they locate, but also to the other countries, in a global strategy (Type 3).

The fifth feature is the products in the overseas factories. Most display materials, except for protective film for polarizers, etc., are produced overseas. The author stresses the fact that there are two types of factories; those that *produce* display materials, that is, chemicals, and those that only *process* the display materials. For the latter type, factories process the materials, which are produced and given special functions in Japan, to meet the structural standard of a local electronic display company. Table 1 shows that the factories in China have relatively taken the role in processing until 2005, although factories that produce chemicals, including those under construction at the end of 2006, have very recently been increasing there.

In addition, although it is not in Table 1, only a few companies have located their research laboratories overseas, which are inseparable from display materials production, to meet the strict and changing demands of the customers. These are Sumitomo Chemical Ltd in Korea (Iksan) and Fujifilm Ltd in China (Shanghai). Most companies are deemed to be interested only in production. Moreover, the majority of companies produce display materials in their own wholly owned companies, although some companies establish joint corporations with a local electronic display company.

4.4. Reasons for overseas deployment: from the cases

In this section, it is discussed why these chemical companies deploy their display materials factories overseas, based on the above-mentioned features.

The fact that they have mainly selected Korea and Taiwan as countries to build their factories, instead of flocking to China, and the fact that few of them build factories in Southeast Asia implies that they do not seek a cheap labor force, land or an expanded consumer market. Next, the fact that they supply their products to local companies in the country where they locate factories (Type 2), and considering that display materials are typical intermediate goods, suggests that they seek buyers of display materials, i.e., electronic display companies in Korea and Taiwan. This implication is supported by the fact that their period of active overseas deployment coincides well with the period when FPD companies in Taiwan and Korea were increasing their market share and those of Japan

were losing it. Hamamoto (2006) states that Japanese companies' share of the FPD market has declined drastically with the rise of Korean and Taiwanese companies and, as a result, Japanese companies' market share declined from 100% in 1994 to below 35% at the end of 2005. According to the release of DisplaySearch Ltd. (2006), with respect to the market share of large-area TFT-LCDs by region (shipment base), Japan had over 40% in the first quarter of 2001, but Taiwan had 46% and Korea 44% in the first quarter of 2006.

Although Korean and Taiwanese companies hold an overwhelming market share, there are many Japanese display materials manufacturers that have not built factories in those countries and have kept producing their chief products in Japan. Why is this? One reason could be that the Japanese display materials industry has been in the process of transition from domestic production to overseas production, as the industry started overseas production only some years ago. Another consideration is the fact that there are many companies that only process overseas display materials that were produced in Japan, which means that they transfer general technology overseas, keeping high technology in Japan. Considering that only a few companies have established research laboratories overseas and that Japan still has higher technology than Korea and Taiwan in materials science, there is an implication that the technology level of countries should be an important factor in determining whether they locate factories overseas. This implication is supported by the fact that many companies produce display materials in their own wholly owned affiliate companies overseas. One of the reasons for them to do so would be to prevent the outflow of technology to other companies.

Thus, the reason why the Japanese chemical companies have deployed their display materials factories overseas is that they hope to supply their products to Korean and Taiwanese electronic display industries, which overtook the Japanese electronic display industry that had been the world leader. However, on the other hand, differences in levels of technology in materials science have made some companies reluctant to deploy overseas. As a result, a number of companies have built their factories overseas, while a number of others are just waiting watchfully, although they are interested in overseas deployment of factories.

5. ANALYSIS FROM THE VIEWPOINT OF MARKET STRUCTURE

5.1. Method of analysis

In this chapter, the author discusses the reason why display materials factories are built overseas from the viewpoint of market structure and industrial technology; that is, the relationship between the chemical industry producing display materials and the electronics industry producing electronic displays. The chemical companies have built the factories, as shown in the previous chapter, in the countries that have a large share of the electronic display market. The chemical companies have done so, although display materials are diversified small-quantity production chemicals that do not

incur large transportation costs and are inseparable from R&D laboratories. The author supposes that chemical companies should have found something meritorious in doing so.

5.2. Status of the chemical industry in the market

Table 2 shows Japanese companies that produce FPDs, and Table 3 shows business cooperation among LCD-producing companies. Two features are noted.

First, chemical companies do not diversify into electronic display business but specializes in display materials. Chemical companies are not listed on these tables except for Asahi Glass Ltd, which produces LCDs in the joint corporation with Mitsubishi Electric Ltd. With respect to the future technology of electronic paper, some chemical companies such as Idemitsu Kosan Ltd, Dainippon Ink and Chemicals Ltd, Fujifilm Ltd and Toyo Ink Ltd are pursuing R&D, but have not succeeded in producing the display and are not assured of success.

Table 2: Main Japanese FPD Manufacturers and their Field of Business

FPD Manufacturers	LCD	PDP	OLED	SED	Electronic Paper
Canon			△	△	△
Sanyo Electric	○		(1)		
Sharp	○		(2)		
Seiko Epson	○		△		○
Sony	○	(3)	○		○
Toshiba	○		○	△	△
NEC	○	(4)	(5)		
Pioneer		○	○		△
Hitachi	○	○	△		(6)
Fujitsu	(7)	(8)			△
Matsushita Electric	○	○	○		○
Mitsubishi Electric	○				

(Note)
1. ○: Products on the market. △:Under development
2. The business or development in the affiliated companies is included in the Table.
3. Cases where company sells the consumer goods equipped with the display made by the other company are not included in the Table.
4. Supplementary explanation

(1) Sanyo Electric Ltd revealed, in January 2006, that it would liquidate the affiliated company (SK Display) which had produced OLED.
(2) Sharp Ltd established the joint corporation with Tohoku Pioneer Ltd and Semiconductor Energy Laboratory Ltd to produce OLED substrates in 2001. However, Semiconductor Energy Laboratory Ltd obtained a 100% share of the corporation in 2006.
(3) Sony Ltd revealed, in January 2006 that it would close down the business of plasma TV sets.
(4) NEC Ltd sold off the PDP business to Pioneer Ltd in July 2004.
(5) NEC Ltd transferred the patents on OLED to Samsung Group in February 2004.
(6) Hitachi Ltd. opened the HP on electronic paper in September, 2005.
(7) Fujitsu Ltd revealed, in April 2005, that it would sell off the business of liquid crystal device to Sharp Ltd.
(8) Fujitsu Ltd concluded the contract to sell off the major parts of the business of PDP to Hitachi Ltd. Fujitsu Ltd still has 19.9% share of Fujitsu Hitachi Plasma Display Ltd, but, in fact, Fujitsu Ltd has closed down its PDP business.

The second feature concerns the electronics industry. Many electronics companies are competing with each other for a share of the market for each type of electronic display. The competition is tough and some companies have lost the competition as is shown in the note to Table 2. Each company produces or develops not only LCDs or PDPs, which are the current generation of displays, but also OLEDs, SEDs or electronic paper, which are the future generation of displays. Nevertheless, as mentioned in Section 3.1., there are too many types of electronic display for each company to produce them all. Accordingly, each company allocates their resources to only a few types of electronic display. To avoid the risk caused by pouring their resources into only a limited range of product types, they actively cooperate in production or development with other nonaffiliated companies as Table 3 shows.

Tables 4, 5 and 6 show the chemical companies that produce materials for currently commercialized displays: LCDs, PDPs and OLEDs, respectively. The main points in these three tables are summarized in Table 7. The author can find three further features in these tables.

Third, only some chemical companies are listed in all three of these tables (Table 4, 5 and 6). That is, most chemical companies are no more than suppliers of materials for one or two types of electronic displays. This is because each type of electronic display is based on a different principle of technology; that is, different electronic displays are composed of different chemicals.

Table 3: Cooperation among LCD Manufacturers

Types of Display	Partners	Joint Corporation (Types of Cooperation)
Under Cooperation		
CRT	Toshiba, Matsushita Electric	Matsushita Toshiba Picture Display
LCD	Toshiba, Hitachi, Matsushita Electric	IPS Alpha Technology
LCD	Epson, Sanyo Electric	Sanyo Epson Imaging Devices
LCD	Asahi Glass, Mitsubishi Electric	Optrex
LCD	Sony, Toyota Industries	ST-Mobile Display, ST-LCD
LCD,OLED	Toshiba, Matsushita Electric	Toshiba Matsushita Display Technology
SED	Canon, Toshiba	SED
PDP	Hitachi, Matsushita Electric	(Joint Operation)
OLED	Sumitomo Chemical, Seiko Epson	(Joint development)
Electronic Paper	Sony, Dai Nippon Printing, e-Ink, Philip	(Joint development)
PDP	Hitachi, Fujitsu	Fujitsu Hitachi Plasma Display
Liquidation of joint corporation		
PDP	NEC, Pioneer	NEC Plasma Display
OLED	Sharp, Pioneer and the other	Eldis

Table 4: Main LCD Materials Manufacturers in Japan

Display materials		Manufacturers
Anti Reflection film		Fujifilm, Sanyo Vacuum Ind., Dai Nippon Printing, Toppan, Nissan Chemical Ind.
Viewing angle improving film		Fujifilm, Nippon Oil LC Film
Retardation film		Nitto Denko, Polatechno (Nippon Kayaku + Arisawa Manufacturing), Nippon Oil LC Film, Sumitomo Chemical, Optes(Zeon)
	Polarizer with retardation film	Sanritz（Fujifilm）
Protective film for polarizer		Fujifilm, Konica Minolta Opt
Polarization film		Nitto Denko, Sanritz (Fujifilm), Polatechno (Nippon Kayaku + Arisawa Manufacturing), Sumitomo Chemical
Glass substrates		Asahi Glass, Nippon Electric Glass, NHTechnoGlass (Nippon Sheet Glass＋Hoya)
	Glass substrates with transparent conducting electrode	Nippon Sheet Glass
Color filter		Dai Nippon Printing, Toppan, Toray, New STI Technology (Sumitomo Chemical), Andes Electric, Micro Technology
	Transer	Fujifilm
Transparent conducting electrode	ITO: Indium-tin-oxide	IS Electrode Materials (Idemitsu Kosan＋Sumitomo Metal Mining), Mitsui Kinzoku, Nikko Materials, Ulvac Materials, Tosoh
	Deposition of thin films	Sanyo Vacuum Ind., Geomatec
Liquid Crystal Alignment Materials		Nissan Chemical Ind., JSR, Chisso
Liquid crystal materials		Chisso, Adeka, Dainippon Ink and Chemicals, Seimi Chemical (Asahi Glass)
Photo resist		Zeon,Tokyo Ohka Kogyo, Inctec Inc
	Pigment-Dispersed Color Resist	JSR, Fujifilm Electronic Materials (Fujifilm), Inctec Inc., Hitachi Chemical
Column spacer		Sekisui Chemical, JSR、Hitachi Chemical, Tokuyama, Ube-Nitto Kasei (Ube industries), Catalist & Chemical Ind. (JDC), Fujifilm

(Note) The main shareholders of the companies are showed in the parenthesis

Table 5: Main PDP (AC-type) Materials Manufacturers in Japan

Display materials		Manufcturers
Glass substrate		Asahi Glass, Nippon Electric Glass, Nippon Sheet Glass, Central Glass
Transparent conducting electrode		IS Electrode Materials（Idemitsu Kosan＋Sumitomo Metal Mining）, Mitsui Kinzoku, Nikko Materials, Ulvac Materials, Tosoh, Sanyo Vacuum Ind., Geomatec
Transparent dielectric layer dry-film		JSR etc.
Protective layer for electrode		Mitsubishi Materials, Tateho Chemical ind., Ube Material Ind.
Barrier ribs		Tokyo Ohka Kogyo, Nippon Electric Glass
Fluorescent layer		Kasei Optonix, Nichia, Nemoto, Mitsubishi Chemical
Others	Back plate (Glass substrates + Electrode + Barrier ribs ＋ Fluorescent materials)	DAP technology (Dai Nippon Printing＋Asahi Glass)
	Glass paste (Barrier ribs, Dielectric layer, Protective layer for electrode, Fluorescent materials)	Asahi Glass, Nippon Electric Glass, Noritake, Central Glass, Toray
Gas		Taiyo Nippon Sanso, Japan Air Gases, Air Water
Electromagnetic waves shield film		Dai Nippon Printing, Hitachi Chemical, Fujifilm, Asahi Glass, Mitsui Chemicals, Sumitomo Ghemical

(Note) The main shareholders of the companies are showed in the parenthesis

Table 6: Main OLED Materials Manufacturers in Japan

Display materials		Manufacturers
Glass substrates		Asahi Glass
	with transparent conducting electrode	Nippon Sheet Glass
Transparent conducting electrode		IS Electrode Materials (Idemitsu Kosan ＋ Sumitomo Metal Mining), Mitsui Kinzoku, Nikko Materials, Ulvac Materials, Tosoh, Sanyo Vacuum Ind., Geomatec
Electron injection layer		Toyo Ink etc.
Electron transport layer		Chisso, Nippon Steel Chemical, Toyo Ink
Hole blocking Layer		Mitsubishi Chemical etc.
Emissive layer	Fluorescence (Host)	Idemitsu Kosan, Mitsui Chemicals, Chemipro Kasei, Sumitomo Chemical
	Fluorescence (Dopant)	Idemitsu Kosan, Hayashihara Biochemical Labs, Toray
	Fluorescence (Non-Dope)	Chisso,Toyo Ink
	Phosphorescence (Host)	Mitsubishi Chemical, Konica Minolta, Nippon Steel Chemical, Pioneer, Sumitomo Chemical
	Phosphorescence (Dopant)	Dainippon Ink and Chemicals
	Others	Showa Denko
Hole transport layer		Hodogaya Chemical, Bando Chemical Ind., Chemipro Kasei K., Nippon Steel Chemical, Mitsui Chemicals
Hole injection layer		Mitsubishi Chemical, Bando Chemical Ind., Chemipro Kasei K., Nippon Steel Chemical, Toyo Ink

(Note) The main shareholders of the companies are showed in the parenthesis

Table 7: The Number of Kinds of Display Materials Produced by Chemical Companies

Type of Display	LCD		PDP		OLED		Type of Display	LCD		PDP		OLED	
Makers	M	I	M	I	M	I	Makers	M	I	M	I	M	I
Adeka	1						Nemoto			1			
Air Water			1				Nichia			1			
Andes Electric	1						Nikko Materials,	1		1		1	
Arisawa Mfg.		2					Nippon Elec. Glass	1		3			
Asahi Glass	1	1	3	1	1		Nippon Kayaku		2				
Bando Chemical Ind.					2		Nippon Oil LC Film	2					
Central Glass			2				Nippon Sheet Glass	1	1	1		1	
Chemipro Kasei					3		Nippon Steel Chem.					4	
Chisso	2				2		Nissan Chemical	2					
Dai Nippon Printing	2		1	1			Nitto Denko	2					
Dainippon InkChem.	1				1		Noritake			1			
Fujifilm	5	3	1				Pioneer,					1	
Geomatec	1		1		1		Sanyo Vacuum Ind	2		1		1	
Hayashihara Labs					1		Sekisui Chemical	1					
Hitachi Chemical	2		1				Showa Denko					1	
Hodogaya Chemical					1		Sumitomo Chemical	2	1	1		2	
Hoya		1					Sumitomo Mining		1		1		1
Idemitsu Kosan		1		1	2	1	Taiyo Nippon Sanso			1			
Inctec Inc	2						Tateho Chemical			1			
Japan Air Gases,			1				Tokuyama	1					
JDC		1					Tokyo Ohka Kogyo	1		1			
JSR	3		1				Toppan	2					
Kasei Optonix			1				Toray	1		1		1	
Konica Minolta		1			1		Tosoh	1		1		1	
Micro Technology	1						Toyo Ink					4	
Mitsubishi Chemical			1		3		Ube industries		1				
Mitsubishi Materials			1				Ube Material Ind.			1			
Mitsui Chemical			1		2		Ulvac Materials	1		1		1	
Mitsui Kinzoku	1		1		1		Zeon	1	1				

(Note)
1. This Table is made by summarizing Tables 4, 5 and 6.
2. Figures in Column M of each display the mean number of kinds of materials produced by each company. Figures in Column I mean the number of kinds of materials produced by subsidiaries of each company.
3. For reference, 17 kinds of materials are listed in Table 4 (LCD), 10 are listed in Table 5 (PDP) and 14 are listed in Table 6 (OLED).

Fourth, no chemical companies can produce all materials for each type of electronic display. Each chemical company, excluding Fujifilm, supplies only one or a few kinds of materials for a specific type of electronic display, because each type of electronic display is composed of so many kinds of functional chemicals with very different physical and chemical properties. It is also because each company must pour its resources into innovation and production of limited kinds of chemicals, for which the company's expertise is greatest. As is well known, the speed of innovation of functional chemicals is very fast and the R&D costs for chemicals are enormous.

Fifth, needless to say, there are two or more chemical companies in the market for each of the display materials. No chemical company monopolizes the domestic market for each of the display materials. Nevertheless, the market, for a few kinds of materials, is under an oligopoly. For example, it is estimated that Fujifilm Ltd holds around 80% of the share in the market for protective film for polarizer for LCD. However, Konica Minolta Ltd, the rival manufacturer to Fujifilm Ltd, has succeeded in developing a new product that is only 40 micrometers thick, which is half the thickness of the comparable product of Fujifilm Ltd, and therefore it is not assured that Fujifilm Ltd will be able to retain such a large market share in the near future.

5.3. Relation between the display materials and electronic display industries

Based on the features of the market structure as mentioned above, the author discusses the relation between the display materials and electronic display industries, which should suggest reasons why chemical companies deploy their display materials factories overseas. There are two areas of competition in the electronic display industry, which affect the display materials industry.

First, a chemical company is affected by competition among the various types of electronic displays, as mentioned in Section 3.1. This is because each company is no more than a supplier of materials for limited types of electronic display. For instance, if LCDs fail to compete with OLEDs, the chemical companies that have produced materials for LCDs must close their businesses.

Second, many electronics companies are competing for a share of the market for each type of electronic display. When an electronic display manufacturer fails to compete adequately and withdraws from the display business, even if the type of display survives, the chemical companies that have supplied the display materials to the electronics company must also close their businesses. After losing a client, it is difficult for chemical companies to find a new client company, because other chemical companies already supply their display materials to these client companies, since no chemical company monopolizes the market for each display material. This is also because each electronics company has its own strict standards for each display material, which is different from those of other companies, even if these companies produce the same type of electronic display.

These two areas of competition are a difficult problem for chemical companies because the serious consequences result, regardless of their efforts put into research and development, as described below. Electronic displays are composed of many sorts of chemical products. The physical or

chemical properties of each chemical product contribute to only a part of the performance of the electronic display, although they are important to the performance. In other words, a chemical company that is only a producer of each material has no control over the performance of the final electronic display. With respect to the performance of the display, there is no simple competition among materials but a competition among systems composed of these materials. Accordingly the chemical company has no choice but to accept the consequences of those two areas of competition. It is difficult for the chemical company to control its own future through its own efforts as far as the display materials are concerned.

In order to survive, chemical companies must get detailed information on trends in electronic display technology, the tendencies of the competition among display manufacturers, and the tendencies of consumers' needs. To be concrete, they must know exactly what type of electronic display and which electronic company will dominate the market, and what kinds of materials will be required for these displays. However, chemical companies as a rule do not diversify into electronic displays business, but specialize in display materials. They therefore find it difficult to get such information on their own.

In the past, in Japan it was generally possible for intermediate goods companies, such as chemical companies, to receive useful information on final goods through affiliated companies (Keiretsu). However, at present, chemical companies cannot depend on the old-fashioned affiliated companies groups in the field of electronic displays. This is firstly because electronic display companies actively cooperate in production or development with companies outside the affiliated group. It is secondly because Japanese companies that are losing market share in international competition in the field of electronic display do not have competitive and complete information on the displays.

There are not many other ways for Japanese display materials companies to acquire practical information, except to depend on the client electronics companies to which they are supplying materials. Consequently, chemical companies are deploying their display materials factories to the world centers of electronic display production, namely Korea and Taiwan, not only to supply their products to the leading electronic display companies but also to develop close relationships with them.

6. CONCLUSION

The Japanese chemical industry has been reluctant to build factories that produce high-technology functional chemicals overseas. However, the chemical industry has recently built factories that produce electronic display materials, typically of high-technology functional chemicals, in northern Asian countries. This paper first collects and analyzes cases in which chemical companies have built factories overseas to clarify the reasons why they do so. Then this paper analyzes the market structure of display materials to find a more fundamental factor underlying such deployment.

It is found that the Japanese chemical companies have deployed their factories overseas in order to supply their products to Korean and Taiwanese electronic display companies that now hold an overwhelming share of the electronic display market. The other reason is that chemical companies cannot formulate their R&D policy for display materials on their own and must depend on Korean and Taiwanese electronic display companies for policymaking. In addition, it is estimated that on the other hand, the differences in levels of technology in materials science has made some of them reluctant to do so.

These views are formed by analyzing cases of Japanese chemical industries and considering the generalized market structure in Japan. To confirm these views, it would be necessary to analyze the cases more strictly, obtaining more detailed information through actual surveys in Korea and Taiwan and comparing with cases in other countries' chemical industry.

The government has the view that high technology industries remain in Japan, saying in a report that increasing production in overseas factories activates the domestic economy because those factories are supplied high-technology materials from Japan (Ministry of Economy, Trade and Industry et al., 2007). However, this paper shows that high technology industries producing intermediate goods are "siphoned over" by overseas final goods industries. The government will have to take measures to cope with the phenomenon of "Siphoning over", considering the background, some of which are pointed in this paper.

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