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Latest Trends in the Optical Disk Industry
– The Superiority of Japanese Companies and a New China-U.S. Joint Effort for Standardization –

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1 Introduction

The principles of optical disks, including the compact disk (CD) and the digital versatile disk (DVD), which are in widespread use by consumers worldwide, were invented in the Netherlands. However, Japanese companies have been winning an overwhelming victory in the optical disk industry by leading it in all areas of mass-production technology, standardization, and business. The situation has changed over the past few years, and Japanese firms are now forced to collaborate with Korean and Taiwanese manufacturers through joint ventures and to face a new standardization proposal from China. The latter refers to the Enhanced Versatile Disk (EVD), a standard advocated jointly by China and the U.S. in a move that can be considered part of their market acquisition strategy intended for reducing royalties paid to Japanese license holders.

This article discusses the characteristics of the optical disk industry, which is faced with such a situation, from four perspectives: (1) technology, (2) business, (3) standardization, and (4) patent status. More specifically, the following topics are covered: (1) Why was it in the Netherlands where an invention as significant as the optical disk was accomplished?, (2) Following the invention, how has Japanese technology come to dominate the world? How did corporate research laboratories and public institutions contribute to this dominance as well as to next-generation optical disk technologies?, (3) How has the optical disk evolved as a product? How has the worldwide market share structure in favor of Japan been formed, and in the formation process, how have Japanese manufacturers been taking the initiative in standardization?, and (4) Does Japan have a strong patent position?

This article also provides details about the announcement of EVD as part of a new China-U.S. joint effort toward standardization. Then it examines the structure of the optical disk industry, which is experiencing such a movement, in comparison with the structure that caused the Japanese semiconductor industry to see a continuous decline in the worldwide market since the mid 1990s. Through this, the report warns that if Japan takes wrong measures, a profound change in the market share structure, which has already occurred in the semiconductor and liquid crystal display industries, can take place in the optical disk sector as well. To prevent this from happening, Japan needs to increase its patent strength by linking it with industry standards. That is to say, Japan should direct its research efforts toward more fundamental themes and aim at a stronger patent position in terms of the number as well as quality of patents, so that Japan's patented technologies can achieve levels that are high enough for adoption as industry standards. Moreover, the article presents a proposal, from a medium- to long-term perspective, in which Japan should take steps to build productive environments to promote the activities of creative researcher groups and more effectively facilitate breakthroughs in science and technology that can compare to the invention of the optical disk in the Netherlands.

2 Evolution of optical disk technology

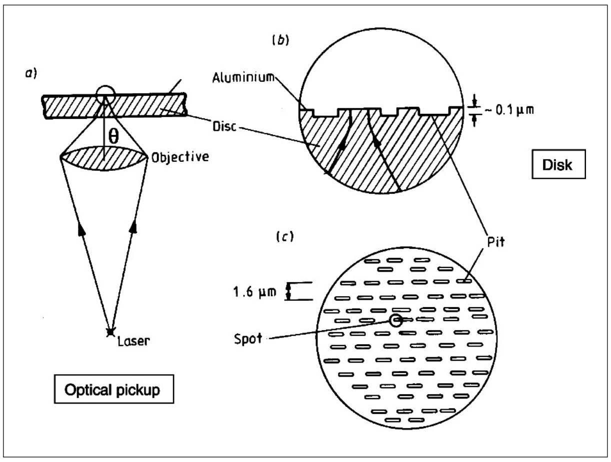
2-1 Optical disk technology

As shown in Figure 1, the basic structure of the optical disk system[1] consists of an optical pickup, a disk on which digital signals are recorded, a driving mechanism for them and its control circuit, and a circuit for decoding digital images and audio. The optical disk has the following characteristics: (1) Since the disk does not come into contact with the pickup, there is no wear on the disk surface, no matter how many times it is read; (2) Disks are available at low cost because mass duplication is easy; (3) Because of high recording density, a disk can store not only audio but even a two-hour movie; and (4) A single portable device can record and play a number of types of disks.

Competing high-density memory technologies such as semiconductor memory and magnetic memory do not provide such features. It is a known fact that for this advantage, the optical disk has come into widespread use worldwide as an external storage medium for audio, video, and computer data, both at homes and offices.

The recording density of an optical disk is determined by the spot size, which is restricted by the diffraction limit caused by the wave motion of light. In this case, the spot diameter (d) is given by d = λ /NA, where the wavelength of the light source is (and the numerical aperture for the disk side of the condenser lens is NA (NA = sin θ , where θ is the angle that the optical axis makes with the outermost beam, as shown in Figure 1). According to this formula, improvement in the recording density of an optical disk can be achieved by shortening the wavelength of the light source and increasing the numerical aperture of the condenser lens. By using this formula as the guiding principle, relentless efforts have been made to develop technology that can shorten the wavelength of the light source for the laser diodes used for optical disks, and improve the numerical aperture of lenses. In fact, as shown in Table 1, the wavelength of laser diodes has been shortening as the generation number for the optical disk technology increases: 780 nm with infrared laser diodes for CDs, 650 nm with red laser diodes for DVDs, and, for the next generation, 405 nm with blue-violet laser diodes for High-Definition (HD) DVDs and Blu-ray Disk (BD) formats. The numerical aperture has also increased as the generation number advances, from 0.45 for CDs to 0.65 for DVDs, 0.65 for HD DVDs, and 0.85 for BDs.

Figure 1 : Structure of the read-only optical disk



Source: Author's compilation based on reference[1].

Table 1 : Development of optical disk technology

Generation	Research stage	0th	1st	2nd	3rd	4th (Post-Blue)
Year Product	'62 –	'72 Video Disk	'82 CD	'94 DVD	'03-'04 BD/HD DVD	('12) (TB Disk)
Storage capacity	–	2 hours (30 cm)	0.68 GB	4.7 GB	15-20 GB	(Terabyte)
LD* wavelength	LD Emission	633 nm (He-Ne**)	780 nm	650 nm	405 nm	(405/280 nm)
Lens NA	–	0.45	0.45	0.65	0.85/0.65	(0.85/0.65)
Cover thickness	–	1.2 mm	1.2 mm	0.6 mm	0.1/0.6 mm	(Multilayer)

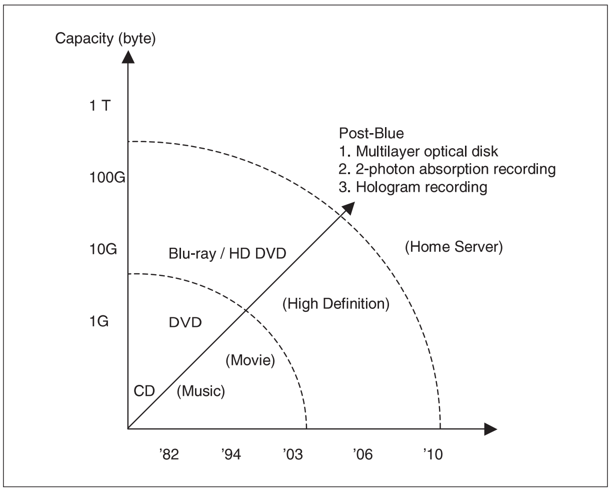
*LD: Laser Diodo
**He-Ne: Helium Neon gas laser

2-2 The future of optical disk technology

Figure 2 shows the roadmap for optical disk technology, where the vertical axis indicates the recording capacity and the horizontal axis the year. Following CDs and DVDs, the HD DVD and BD formats are becoming ready for commercialization. This section explains what technologies are expected after them. For the purpose of further reducing laser diodes' wavelength, which determines the recording density of optical disks, use of ultraviolet light in the range of 300 nm or less should be considered. Recently, a light-emitting diode (LED) that can emit light at a wavelength of 280 nm was reported, suggesting continued efforts toward the development of seed technologies. However, there are some challenges regarding materials, such as that plastic, the substrate for the current optical disks, absorbs light in the 200 nm range and is therefore unusable as it is for the next-generation technology. New materials need to be developed as a breakthrough. Another problem is that the energy of ultraviolet light is so high that using an ultraviolet LED as the laser diode source will increase light intensity per unit area, resulting in a higher possibility for crystals to be damaged. This highlights the need for developing technologies to ensure long life by preventing the deterioration of crystals over time through, for example, the ultimate minimization of crystal defects, which cause damage.

One approach, aside from shortening the wavelength, to increasing the recording capacity is multi-layering the optical disk. While multi-layering does not raise the recording density per two-dimensional area, it increases the recordable space within the disk layer by allowing it to contain additional recording layers to provide extra recording capacity. A problem with this approach is the interlayer crosstalk (receiving unwanted information from an adjacent layer). To solve this issue, there has been a proposal in which voltage is applied selectively to the target layer that is to record or reproduce information, so that the layer is colored and thus becomes able to absorb laser light. Such properties are known as electrochromism, and electrochromic materials remain transparent while no voltage is

Figure 2 : Optical disk roadmap



applied, which is the key to preventing crosstalk with other layers. Multilayer disks with this kind of structure can have a recording capacity of 20 GB per layer, if the blue-violet laser is used. This means that a disk consisting of 50 layers can record as much as 1,000 GB or 1 TB (terabyte) of information. Optical disks for home use have so far developed as storage media to contain either 60 minutes of music (with 0.68-GB CDs) or a two-hour movie (with 4.7-GB DVDs). In the future, when optical disks are expected to find application as large-capacity memory devices for the Internet, to which individual homes are connected, there will be an increased need for storage media with a capacity as large as 1 TB. In terms of downsizing, on the other hand, a disk measuring 30 mm in diameter, which is much smaller than the now-prevalent 3.5-inch magneto-optical (MO) disk, is under development, presumably aiming at incorporation into personal digital assistants (PDAs) and mobile phones.

2-3 The environment that facilitated the invention of the optical disk principles

This section focuses on research and development environments, taking the optical disk, the theme of this article, as an example. The two fundamental physical requirements for optical disks, namely, (1) the light spot diameter larger than the pit size and (2) the pit depth one-quarter the size of the wavelength of the light source, have become the two major principles of read-only optical disks. Both of these principles were discovered at the central research laboratory of Royal Philips Electronics in Eindhoven, the Netherlands. They were probably inspired by Dutch Nobel Laureate Zernike's principles of the phase-contrast microscope (1935). If you trace this farther back in the history of science and technology, the physical model of the diffraction limit determined by the light wave comes down to Huygens' principle (Christian Huygens: 1629-1695, the Netherlands) on wavefront formation. These facts suggest that the Netherlands has a long history in optics and that the nation's accumulation of profound physical knowledge in optics contributed to the invention of the optical disk principles.

The central research laboratory of Philips can be considered as a research group sponsored by the company, and also as an environment that facilitated invention and discovery by gathering Nobel-class scientists and researchers who have an acute awareness of science and technology. No one can invent or discover more than what he or she knows. When a new phenomenon occurs, a careless person tends to overlook its essence. By contrast, a person who is always making efforts to understand unknown phenomena and has a matured and acute awareness of things could feel and capture the essence of the phenomenon. This is how discovery occurs and what makes science different from careless speculation. There is no easy way to allow science to take deep root. Relentless and rigorous efforts alone will count. In order to maximize the national level of scientific and technology and to lead the world with its superiority, Japan needs to gather Nobel-class scientists and researchers with a shrewd awareness of science and construct for them an environment that promotes invention and discovery. It is important that outstanding talent who are young and confident come together so that they can develop themselves, while inspiring one another and achieving research results. These human resources must have substantial interest in and curiosity about science. Loyalty to the organization is a favorable character but not as valuable to a scientist as a personality to regard imitation as a shame, while trying to do what no one has attempted. In fact, when I was in the Philips laboratory, one of my Dutch colleagues said something like this, "In the Stone Age, those who handled only stone tools never had a chance to discover any metal tools. It was the existence of odd (daring) persons who had interest in other than stone tools that enabled the invention of metal tools. This is the essence of research." Such an approach, though it may not be necessary when incremental progress in science is deemed satisfactory, should be taken if Japan seeks a great leap forward, and this would be the only way to enhance the possibility of significant invention and discovery. Under the current economic slump, instead of private-sector companies, which cannot afford to support activities toward this end, the government is expected to take the initiative. We should recall the Institute of Physical and Chemical Research[2] in the prewar era, although a private research organization, as an excellent example of traditional Japanese models.

3 The superiority of Japanese technology and the formation of the worldwide market share structure

3-1 The role that the R&D division of Japanese companies played

The principles of read-only optical disks such as CDs and DVDs available today were, as described earlier, invented at Philips in the Netherlands, which introduced in 1972 the world's first optical disk equipment onto the market. The disk of those days measured as large as 300 mm in diameter and was designed to record a two-hour movie in the analog method (frequency modulation). Since the light source used in the equipment was a helium-neon laser that had a wavelength of 633 nm and consisted of a vacuum tube, shrinking the size of the equipment was impossible. This intensified the need for the commercialization of laser diodes that, like those available today, consumed less power, were small in size, and allowed for direct modulation.

As shown in Table 1, the world's first laser diode oscillation was confirmed in a low-temperature environment at Bell Labs and others in 1962. In 1972, 10 years later, Bell Labs in the U.S. designed the first laser diode that could operate continuously at room temperature by using the double-heterojunction technique invented by Dr. Izuo Hayashi and others, paving the way for commercialization. The most challenging problem in the early days of this new technology was the extension of life. Several Japanese electric machinery manufacturers, including Hitachi, Ltd. and NEC Corporation, addressed and invested in the issue as their priority R&D themes, resulting in the completion of technology to improve the crystal quality of GaAs (gallium arsenide) semiconductors. Put another way, technology to ultimately minimize the number of crystal defects, which are responsible for degradation, was successfully developed in Japan and brought about the realization of the long-awaited extended-life laser diodes. Japanese manufacturers subsequently devised other useful technologies such as the one for controlling the oscillation mode for improving laser diodes' performance and optical technology for aberration correction, while playing the key role in developing optical pickup technology, which was pursued concurrently.

Japan's optical technology, whose superiority was demonstrated in the development of optical pickups, has its roots in the technologies invented by traditional optics manufacturers, including those making cameras and microscopes. For example, the object lens for the optical pickup was originally a combination of multiple glass lenses for which cost reduction was difficult. To tackle the problem, Konica Corporation attempted to produce a single lens that is plastic and even aspherical, and eventually developed a low-cost lens of such kind whose performance is equivalent to that of glass compound lenses. However, not all optics makers could enter the optical disk equipment business, because optical technology, despite its connection with the core of the optical disk principles, was only a part of the overall hardware, for which electric companies had a total advantage with respect to the ability to design the overall system embracing digital signal processing, control circuits, and so forth. For this reason, optical engineers at electric machinery makers played an important role even in the field of optical technology like the optical pickup. Thus, Japan's traditional optics was combined with its electronics technologies, including laser diodes and electronic circuits, and the national strength in crystal growing techniques to help Japan fully secure technological advantage over the rest of the world in the optical disk sector.

3-2 The role of Japanese universities and public institutions

The importance of the contributions by universities and public research institutes to the advance of Japan's optics should not be underestimated. Specifically, this refers to lens design technology through the application of geometrical optics and optical measuring technology based on wave optics, which both have been studied at the Institute of Industrial Science of the University of Tokyo and the Department of Applied Physics, the School of Engineering of Osaka University, and also to applied optical technology such as holography researched at the Schools of Science and Engineering of the Tokyo Institute of Technology. These universities maintain world-class academic standards through logical and in-depth research into optics and future-oriented research themes, which are too risky for businesses to address. With respect to applied research, the universities have also contributed to improving the research standards in the private sector by raising interest in more basic themes and providing the logical foundations for applied research, whereby they can honor the authors of outstanding papers with a doctor's degree as an incentive that motivates corporate researchers.

Some of the research themes regarding future optical disk technologies being addressed at universities include super-high-density optical memory, which applies near-field optics, and holographic memory. In these fields, the School of Engineering of Osaka University and the Schools of Science and Engineering of the Tokyo Institute of Technology are working on unique projects. Because of the uncertain prospects of successfully recovering investments, such themes are not viable options for companies, and this is one of the areas where universities and public research institutes assume an essential role.

Another important aspect of the role of

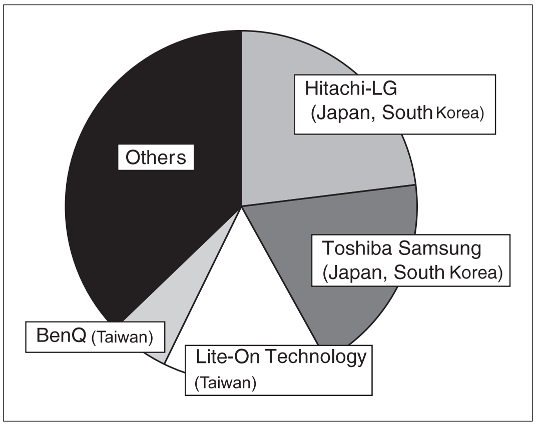
universities and public research institutes is scientific society activity. The International Symposium on Optical Memory (ISOM), a world-class international society for optical disks initiated by Japan in 1987, has been holding meetings at locations in Asia every year to serve as a place to present the latest findings. Every three years, the ISOM is held as a joint symposium with the Optical Data Storage conference, which is organized by the Optical Society of America.

3-3 The formation of the worldwide market share structure

The proliferation of full-fledged optical disk equipment, as previously described, started with audio compact disks (CDs). Japanese electric machinery manufacturers such as Sony Corporation and Hitachi, Ltd. forged alliances with Royal Philips Electronics, the inventor of the optical disk, to successfully acquire a large share in this market. In particular, Sony, which developed an excellent technology on error correction code in optical disk devices, established an industry standard by striking a technological balance between its proprietary technology and the optical disk principles invented by Philips, mentioned earlier, and established the so-called golden age of Compact Disk Digital Audio. Following the huge success in CD as an audio application, CD formats as external memory media to use with proliferating personal computers, such as CD-ROM (Read Only Memory), CD-R (Recordable), and CD-RW (Rewritable), emerged to contribute to the rapid growth of the computer-applied optical disk equipment business.

Meanwhile, those who developed the optical disk equipment had long dreamed of recording a two-hour movie on a CD-size (120 mm in diameter) medium. It was the research team at Toshiba Corporation[3] who realized this dream. They used laser diodes whose wavelength had shortened from 780 nm in infrared to 650 nm in red, while increasing the lens NA from 0.45 to 0.65, to expand the recording capacity of an optical disk by sevenfold. The result was a DVD that can contain a two-hour long movie, as mentioned earlier. They were able to increase NA to 0.65 because they reduced the thickness

Figure 3 : Worldwide optical disk equipment market share (based on unit shipment)



Source: Author's compilation based on an article in the September 23, 2003 issue of Nihon Keizai Shimbun.

of the cover layer on the disk from 1.2 mm to 0.6 mm to prevent malfunctions arising from the lens aberration. The thicker the cover layer is, the more likely aberration occurs. The concept of the Toshiba team was just like Columbus' egg. They discovered that the conventional cover layer thickness of 1.2 mm for dust protection was over-specified or simply too much.

Movie companies in Hollywood, the world's largest content provider community, welcomed this invention and formed alliances with Toshiba and other Japanese electric appliance makers. This allowed these electronic companies to acquire an overwhelming share in the worldwide markets for the all optical disk applications for music, movies, and computers. Their dominance in market share continued through the nation's bubble era in the 1980s and the early 1990s, as a matter of course, and still continues even after the bubble burst. A major change in share structure, which the semiconductor and LCD markets experienced, has not occurred, at least nominally, in this sector. However, since the leading Japanese manufacturers currently manage to maintain top shares through alliances, or joint ventures, with Korean or Taiwanese firms, future developments in the market should be carefully observed.

Actually, as indicated in the global market share in Figure 3, Japan-Korea joint ventures have proven to be competitive, such as the one established through a merger between Hitachi and LG Electronics of South Korea and the one founded through a merger between Toshiba and

Samsung. The global optical disk equipment market for 2002 has been valued at a little over ¥1 trillion, of which these top Japan-Korea joint ventures secured sales worth about ¥200 billion each. As opposed to this, the U.S. optical disk industry has contracted as once-dominant IBM, Xerox, Kodak, and Bell Labs lost their competitiveness in both the market and the R&D fields. From Europe, only Philips in the Netherlands manages to maintain a certain presence as a company of long standing.

Recently, a blue-violet (with a wavelength of 405 nm) laser diode based on gallium nitride (GaN) was developed in Japan, technically opening the door for the production of an optical disk that has four to five times the storage capacity of a DVD. This marked the start of a race between two major standardization groups to take the initiative in the third-generation optical disk. One group, led by Sony Corporation and Matsushita Electric, promotes the Blu-ray disk (BD), which can store up to 20 GB of data, and the other, headed by Toshiba Corporation and NEC Corporation, advocates HD DVD (formerly known as Advanced Optical Disk or AOD), which is a 15 GB storage medium. BD's recording capacity is larger than HD DVD by approximately 33%. However, the NA value of BD's object lens, which is as large as 0.85, poses a challenge concerning aberration due to the lens inclination caused during assembly or operation. To prevent such aberration, the thickness of the cover layer for dust protection has been reduced to 0.1 mm. A concern raised here is that since the 0.1-mm thick cover layer does not sufficiently serve its original purpose, extra protection against dust is required in the form of a cartridge, which could render BD more expensive or less easy to use compared with HD DVD. While it is still too early to predict which format specification will become prevalent, this is a matter that should be discussed from the perspective of cost and ease of use for consumers. Both groups should be careful to pay due attention to consumers in the standardization process and to prevent domestic disputes from growing so overheated as to allow other overseas standardization organizations to forestall them.

4 The initiative in standardization and the patent status

4-1 The initiative in standardization

The previous section mentioned how Sony and Philips led the standardization activities in the CD sector. In the area of recordable optical disks, however, there was a time when a different standardization process was adopted because the market was still immature, that is, several companies came together to agree on a single direction of standardization, thereby reducing the cost to develop large-scale integrated (LSI) chips. For error correction, Japan made a proposal against long distance code developed in the U.S., only to lose when Europe supported the strong will of the U.S. Japan, however, did not easily withdraw and continued a persistent and tough battle for a long time. Today, the reality is that there are a number of different format specifications for recordable media, whether it is for CD or DVD including -RAM, -R, -RW and +R, and manufacturers would rather let the market choose the optimum specification than standardizing the format. Although it would be desirable to advance technology through technological competition, this process could cause inconveniences to consumers and waste resources. A solution reasonable to both consumers and businesses is hoped to be found.

Thus, there have been desperate battles for survival among companies to acquire the initiative in international standardization. There are two organizations that played a critical role in uniting standardization activities by Japanese firms throughout this period: the Electrical Laboratory (now National Institute of Advanced Industrial Science and Technology) and the Optoelectronic Industry and Technology Development Association (OITDA)[4]. Their contribution is evident considering the fact that the first meeting of the SC23 (Special Committee 23), a sub-organization of the International Organization for Standardization (ISO), was held in Tokyo as shown in Table 2. Opinions of Japanese manufacturers were always perceived seriously at any of the total 17 international conferences held up until this year. Such a strong position of Japan can also be attributed to Japanese companies' outstanding capacity for technological development, which was demonstrated in the specifications for DVD, and patent strategy, mentioned later. Today, the standardization war is ongoing for the third-generation optical disk, which uses the blue-violet laser diode as the light source, and the two camps, each supporting BD and HD DVD (formerly AOD) respectively, are vying for leadership.

The digital video bandwidth compression technology that DVD adopts is a technology being employed in a variety of fields from optical disks to broadcasts, to communications. The Moving Picture Experts Group (MPEG), a standardization organization, advocates this technology and is actively promoting the standardization of bandwidth compression technology for video signals. The MPEG is a lower branch of ISO/IEC JTC1/SC29, of which SC29 is chaired by Professor Hiroshi Yasuda of the University of Tokyo. Table 3 shows the data transfer rate, major applications, and the effective date for individual MPEG phases.

Recently, three Japanese men became the heads of international organizations that set the global standards for electronic equipment and communications technology-Mr. Masami Tanaka for the International Organization for Standardization (ISO)[5], Mr. Yoshio Utsumi for the International Telecommunication Union (ITU), and Mr. Seiichi Takayagi for the International Electrotechnical Commission (IEC). Since standardization committees are international stages where experts discuss issues concerning industrial competitiveness, which are directly related to national interest, participating countries present opinions from diverse points of view with the intentions to acquire leadership. How the Japanese leaders of these organizations will manage the process of defining international standards in a fair manner is receiving considerable attention.

Table 2 : Past meetings of the optical disk standardization committee[3]

ISO/TC97/SC23			
1.	May 29-31, 1985	Tokyo	Japan
2.	September 22-24, 1986	Geneva	Switzerland
3.	October 13-16, 1987	Washington DC	USA
ISO/IEC JTC1/SC23			
4.	November 29-December 1, 1988	Maastricht	Netherlands
5.	October 25-27, 1989	Tokyo	Japan
6.	October 22-24, 1990	Washington DC	USA
7.	September 12-13, 1991	Sofia	Bulgaria
8.	April 22-23, 1993	Eindhoven	Netherlands
9.	November 3-4, 1994	Geneva	Switzerland
10.	October 26-27, 1995	Seoul	Korea
11.	October 24-25, 1996	Berlin	Germany
12.	October 16-17, 1997	Washington DC	USA
13.	October 29, 1999	Beijing	China

4-2 Japan's patent status in the optical disk industry

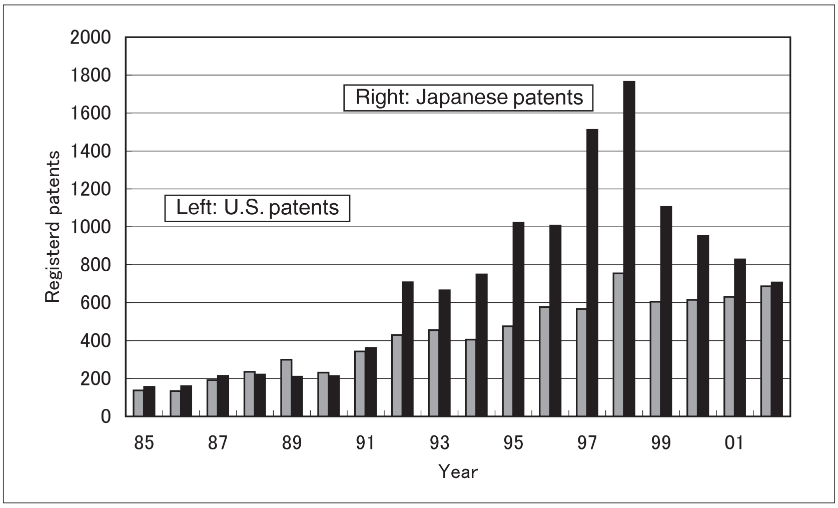
Figure 4 shows the change in the number of patents related to optical disk technologies registered with the Japan and U.S. patent offices over the years. While both countries' figures remained at almost the same level in 1991 and earlier, and in recent years, Japanese registered patents outnumbered those of the U.S. around 1998. Since the majority of the patent applications

Table3 : An overview of MPEG and the time of standardization

Phase	Data transfer rate	Major applications	Became effective in
MPEG-1	Approx. 1 Mbps	Video CD	March 1993
MPEG-2	Approx. 4-10 Mbps (SDTV) A few tens of Mbps (HDTV)	DVD Terrestrial/BS/CS/cable broadcast	March 1995
MPEG-4	Up to 384 Kbps (QCIF) 128 Kbps-2 Mbps (CIF) Approx. 15 Mbps (SDTV) 38.4 Mbps (HDTV)	Video phone, mobile communications, Internet, broadcast applications	May 1999
MPEG-7	–	Electronic program guide (EPG) Home server applications	September 2001

Source: Author's compilation based on the Web site of Pioneer Corporation.

Figure 4 : Change in the number of optical disk-related patents registered in Japan and the U.S.



Source: Author's compilation based on data published on the Web site of the Japan Patent Office.

to the Japan Patent Office are submitted by domestic organizations, most of the registered patents in Japan are assumed to belong to Japanese firms. The U.S. Patent Office, on the other hand, receives many applications from Japan and other countries. These facts indicate that, of the total patents granted in the optical disk field, at least 50% are owned by Japanese institutions. Therefore, it can be inferred that Japan's patent position is considerably strong at least in terms of number. In addition, from my own experience of patent application, I have discovered that over half of the citations presented by the U.S. Patent Office as public domain references to patent applications from Japan originate in Japan.

This strength in patents can be linked to specifications for standardization, as a means to reinforce the standardization efforts. In other words, it is necessary for Japanese organizations to pursue more fundamental research themes so as to obtain patents that can act as the basis for new products, seek stronger patent positions in both number and quality, and aim at adoption of their original specifications as the industrial standard. Another possible strategy is that individual patent holder companies, instead of separately utilizing their patents outside Japan, collaborate with one another to strengthen their positions.

5 EVD – A new China-U.S. joint effort for standardization

5-1 An overview of the EVD announcement

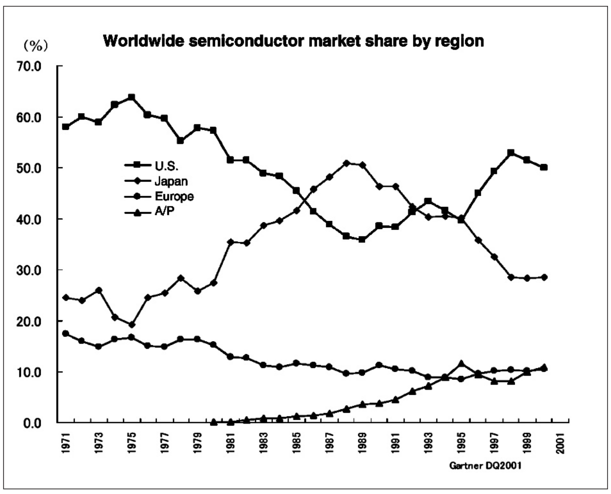
The previous chapter outlined the superiority of Japanese companies in the optical disk industry with an eye to technology, business, standardization, and the patent position. Despite their strength, Japanese corporations have been forced for the past few years to roll out their businesses through alliances with Korean and Taiwanese counterparts, which are rapidly growing. It was under such circumstances that a Chinese industry consortium announced EVD, China's original optical disk format. They claims that EVD uses VP5 and VP6, which are the high-definition video bandwidth compression technologies transferred from On2 Technologies of the U.S. to Chinese firms including Beijing E-World Technology, and that the EVD format can store a high-definition movie in a storage capacity equivalent to DVD (4.7 GB). With EVD, China probably intends to compete with the DVD camp, which has proposed a high-definition version based on the MPEG standard. So far, there is no telling which format can provide higher image quality, since there is no way to compare the two. It seems true, however, that EVD is an attempt to develop business in a new direction that is different from the path MPEG-based DVD has followed for standardization.

As explained in earlier chapters, DVD, in both image quality and ease of use, excels the videocassette tape, which is widely used throughout the world as a recording medium that can contain a two-hour or longer movie. For the past few years, DVDs have been quickly displacing videotapes in Japan as well as the U.S., and have been becoming an increasingly attractive product to Japanese electric appliance manufacturers. The retail market for DVD Video software is actually experiencing explosive growth and, according to an industry forecast, will reach ¥1.3 trillion in sales this year to outstrip the North American box-office revenue for the first time.

As a matter of fact, most DVD players are produced in China, which claims up to 70% of the global output of home DVD players. Last year, more than 30 million units of DVD players were manufactured in China, with most of them shipped to the U.S. for sale at low prices. The sale of these Chinese products is reportedly incurring considerable amounts of license fees payable to Japanese and Dutch manufacturers (USA Today, Nov. 18, 2003).

China's announcement of the EVD strategy is aimed at reducing royalty payments and to diminish domestic DVD producers' reliance on overseas technologies for optical disk equipment. EVD uses as the light source, the decisive factor of recording capacity, the red laser diode with a wavelength of 650 nm and provides a 4.7 GB recording capacity, which is equivalent to DVD. EVD is a standard that intends to seek technological strength in its high-definition video compression technology, as opposed to the existing standardization efforts toward next-generation high-resolution DVD based on MPEG. A noteworthy issue in this movement is that China plans to complete EVD by transferring U.S. venture firm On2's bandwidth compression technology to Chinese corporations, with reportedly lower license fees paid to On2 than what China now pays to Japanese and Dutch companies (USA Today, Nov. 18, 2003). The developers working at the core of China's EVD project are assumed to be a number of outstanding students sent to the U.S. by the Chinese government. Taking into consideration a characteristic of the Chinese market that consumers prefer inexpensive products, even if their image quality is somewhat inferior, there have been many attempts to standardize optical disks used for video. China, at one time, even presented proposals to IEC TC100 (home appliances) instead of IEC JTC1 as part of the move that has led to the unveiling of EVD. It is still uncertain whether the China-U.S. joint standardization strategy will prove effective as it is, because high-definition display equipment has yet to come into widespread use[4]. However, if the Japanese optical disk industry takes wrong measures, their scheme might pose a threat to Japan. In connection with this, China plans to introduce the "Chinese standard" onto the third-generation cellular phone industry, in an effort to secure patents related to their original standard so as to navigate the intellectual property negotiations with Japan, the U.S. and Europe in a manner favorable to them.

Figure 5 : A dramatic change in worldwide semiconductor market share



5-2 Comparison with the decline of the Japanese semiconductor industry

The semiconductor industry experienced a sea change in the global market share structure in the 1990s. It should be interesting to compare this with the case of the optical disk industry. As shown in Figure 5, the market share of the Japanese semiconductor manufacturers has significantly declined since the mid 1990s[7, 8]. One of the reasons is said to be the trade friction between Japan and the U.S. in the 1980s[9]. The U.S.-Japan semiconductor agreement

Table 4 : Industrial system structure for the optical disk/personal computer sector with Hollywood/Microsoft at the top and commodities at the bottom

<table>
<tr><th></th><th colspan="2">Optical disk</th><th>PC</th></tr>
<tr><td>Content</td><td colspan="2">Movie companies (Hollywood)</td><td>Microsoft</td></tr>
<tr><td>Key devices</td><td>DVD disk
Decoder (LSI)
(MPEG as standard)</td><td>EVD disk
Decoder (LSI)
(VP6 as standard)</td><td>Windows
CPU (LSI)
(Intel as standard)</td></tr>
<tr><td rowspan="2">Hardware</td><td>DVD player</td><td>EVD player</td><td rowspan="2">PC</td></tr>
<tr><td colspan="2">No compatibility</td></tr>
<tr><td>Commodities</td><td colspan="2">Optical pickup, semiconductor memory, control circuit, mechanics</td><td>Memory (HDD, DRAM)</td></tr>
</table>

Knowledge intensity increases toward the upper part of the table.

required that Japan allow U.S. products to hold a 20% share of the Japanese market, while the U.S. Anti-Dumping Act regulated Japanese semiconductors' export prices to the U.S. This event marked the start of the fall in Japan's market share. Meanwhile, competitors elsewhere concentrated investments in their business strengths. Intel Corporation of the U.S. made the critical decision of abandoning the DRAM sector to focus on central processing units (CPUs), which resulted in success. Another U.S. firm Micron Technology, based on the analysis results that the cost of the mask layer used for DRAM production had a large impact on overall product cost, reduced mask count and significantly improved its cost competitiveness. Samsung and other Korean manufacturers took an approach of concentrating investments in DRAM itself, while Taiwanese counterparts became specialized in production technology; as a result, both groups successfully overtook Japan. A well-known fact is that in each country, excellent students who had studied in the U.S. and returned home played key roles. Some point out another reason behind the fall of the Japanese semiconductor industry. Since the specification of the CPU is reliant on Microsoft's design specifications for personal computers, Intel naturally formed a vertical alliance with the software giant that acted as a market access barrier to Japan before the two firms were even aware. This caused Japanese semiconductor manufacturers to be unable to have clear future visions, thereby contributing to a further reduction in market share.

Here is a comparison of the change in the worldwide market share structure in the semiconductor sector and the current situation in the optical disk industry. As Table 4 indicates, Microsoft corresponds to content producers, that is to say, the highly knowledge-intensive Hollywood movie companies. Recently, some of them are moving the production process to China in order to reduce the cost of filmmaking. In this context, the worst possible scenario might there emerge from a factor that can justify Hollywood adopting EVD rather than DVD to effectively promote its movie content in the enormous Chinese market, leaving all Japanese optical disk makers only to serve as commodity suppliers[10].

6 Conclusion

As described earlier, the principles of read-only optical disks such as CDs and DVDs, which are now widely available across the world, were invented and developed at the Dutch company Philips. Nevertheless, Japanese corporations, by taking advantage of their outstanding mass-production technology, have been the world leader in the optical disk sector in all aspects of technology, business, and standardization for over two decades since the 1980s. They have maintained the position as the overwhelming winner in this market. Now, Japan also takes the initiative in setting next-generation standard recording formats such as BD, which provides a storage capacity as large as over 20 GB, and HD DVD, which can contain 15 GB of data, with both formats using the 405-nm blue-violet laser diode developed in Japan. This makes Japan's dominance in the optical disk industry look promising into the next generation.

Japan should, however, carefully watch subsequent developments because, for the purpose of maintaining the lion's share, Japanese manufacturers have been forced to collaborate with Korean and Taiwanese rivals through the establishment of joint ventures. Now, at a time when high-definition displays are not yet in widespread use, it is unlikely that the present China-U.S. joint strategy for standardization will work effectively as it is[5]. If Japan takes a wrong measure, the optical disk sector might have to go through a sea change in the worldwide market share structure, as what occurred in the semiconductor and LCD markets. In connection with this, China plans to introduce the "Chinese standard" onto the third-generation cellular phone industry, in an attempt to secure patents related to their original standard so as to navigate the intellectual property negotiations with Japan, the U.S. and Europe in a manner favorable to them.

Yet another concern is the current domestic situation in which the BD group and the HD DVD group are in conflict. In addition, attention should also be paid to how Hollywood, which rules current-generation DVD content, moves in the process of standardization for next-generation optical disks intended for high-definition video recording.

To address these problems, Japan can use its dominance in all directions of technology, business, and standardization, and can also reflect its patent advantage into standard specifications for strengthening the standardization framework. In other words, it is necessary for Japanese corporations to pursue more fundamental research themes so as to obtain patents that can act as the basis for new products, seek a stronger patent position in terms of both number and quality, and raise the position to a level that is high enough for adoption as standards. Another possible strategy is that individual patent holder companies, instead of separately utilizing their patents outside Japan, collaborate with one another to improve their positions.

From a medium- to long-term standpoint, additional measures are needed to further promote open and active environments for researchers and facilitate scientific breakthroughs like the invention of the optical disk in the Netherlands. The Institute of Physical and Chemical Research in the prewar era was said to be ideal for such research activities, although it was a private-sector organization. Under current recession, it is not realistic to expect such sponsorship only from the private sector. This is where the government could play a supporting role.

To conclude this article, the author would like to express his personal opinions formed while writing this material. It is my fear that U.S. companies aim to confine their Asian counterparts to commodities production, in the manner where they caused a worldwide shakeup in the semiconductor and LCD market structures as discussed in section 5-2. More specifically, this is a strategy that intends to keep the brain and core components of systems under the control of U.S. firms and to let Asia produce unimportant parts. If this scenario becomes a reality, Japanese companies might be driven into a situation in which Japan is positioned at the same level with rising Asian countries such as South Korea, Taiwan, and China, and therefore is involved in cost competition with these Asian nations that, along with Japan, serve as parts production centers for the U.S. Japan must avoid such a situation. Japan should, rather than resigning itself to be a mere commodity producer, retain its strength in manufacturing, look to products that have higher added value and are more knowledge-intensive, and pursue transition to a post-industrial society with a diverse structure. The author believes Japan needs to search for ways to leverage the massive untapped market in Asia, including China with the world's largest population, to ensure the sustainable development of the Japanese economy and mutual coexistence with other countries in the world.

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