11355 Research Boulevard, Suite 305
Austin, TX 78759
December 9, 1998

Mr. David A. McMurrey
Technical Research Associates, Inc.
1307 Marshall Lane
Austin, TX 78705

Dear Mr. McMurrey:

In keeping with our agreement, I am submiting the enclosed report entitled *Report on DVD Technology and Applications*.

As we agreed, the purpose of this report is to provide potential investors with introductory information on DVD technology and applications. The report provides an explanation of the differences between CD and DVD technology. Additionally, the report describes the construction of a DVD and summarizes applications of the DVD. We conclude with an overview of past and projected sales and revenues of DVD media.

I hope this report meets with your expectations.

Respectfully,

Thurston Taylor

Encl.: Technical background report on DVD technology

Report
on
DVD TECHNOLOGY AND APPLICATIONS

submitted to
Dr. David McMurrey
Technical Research Associates, Inc.
1307 Marshall Lane
Austin, TX 78705

May 6, 1998

by
Thurston Taylor
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This report examines digital versatile disc (DVD) technology as a possible avenue for research and development. DVD technology is described, and it characteristics are compared with those of CD. Product development and economic forecasts conclude the main discussion of the report.

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ABSTRACT

Digital versatile disc (DVD) is a collection of new optical disc technologies that have the potential to significantly improve the quality of a number of consumer electronic and personal computer products. DVD was invented and tested by Toshiba Corporation to fulfill two primary goals: (1) to provide higher throughput and (2) to provide higher capacity than current CD-ROM technology.

A digital versatile disc is similar in many ways to the current CD; however, small differences between the two allow for DVD to be implemented in ways that a DVD cannot. These differences allow for a capacity increase of of up to 26 times and transfer rates up to 4 times faster than conventional CD-ROM. The major difference that provides these increases is the use of a shorter wave-length laser, which allows for decreased tolerances in the manufacturing process and the use of multiple layers of storage on each side of the disc. While surface storage is vastly different from that used in CD technology at the microscopic level, the advances allow the DVD to be the same exact size as the CD-ROM.

These advances brought about by DVD open up a wealth of products and possibilities in modern applications. Current applications include DVD-video, which is capable of displaying broadcast-quality feature-length movies on the surface of a single disc, and DVD-ROM, which can be used in computer applications to provide higher throughput and higer storage capacity on a single disc. Other applications, already developed but not in widespread use, include DVD-audio, high-capacity, high-quality audio disc; DVD-R, a write-once DVD format for high-capacity data storage in computing applications; and DVD-RAM, a multiple read-write format also used for high-capacity storage in computing applications.

With the current base developed in DVD-video and DVD-ROM markets, familiarity with the technology increases exponentially every month. This coupled with lower prices brought about by manufacturing process refinements has caused a surge in DVD device sales worldwide. The current projections forecast DVD sales overtaking those of CD technology within the next two years, providing millions of dollars in revenues for corporations poised to release DVD format in consumer products.

Report
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DVD TECHNOLOGY AND APPLICATIONS

I. INTRODUCTION

Digital Versatile Disc, or DVD is a collection of new optical disc technologies that have the potential to significantly improve the quality of a number of consumer electronics and personal computer products. These discs are capable of holding up to 17 gigabytes (GB) of data storage, with current research offering a potential for 15 times more storage. This technology is made available through advances in laser technology and advances in manufacturing processes for optical discs. A Digital Versatile Disc is basically a double density, double sided, compact disc. In addition, the laser used to read a DVD utilizes a shorter wavelength, allowing the storage surface of each of these layers to be more compact.

The purpose of this report is to present the format, creation, current applications, and economic forecasts for DVD technology. To emphasize the advances afforded using this technology, a side by side comparison with current Compact Disc technology will be used. Motorola's Research and Development is currently investigating the possibilities for implementation of a DVD Group to interact with current research and product groups. This report will give the introduction and background necessary to determine the feasibility of DVD integration into current marketing and research products. This report will provide a simplified explanation of the construction methods required for DVD replication, solely for the purpose of presenting the difference in construction needed to manufacture a DVD.

The four parts of this report will discuss (1) a technological overview of DVD, utilizing a comparison of CD vs. DVD technologies, (2) the construction of a DVD, (3) current applications utilizing DVD, and (4) projected sales and revenues of DVD devices. The technological overview section will use a comparison of current CD specifications vs. DVD specifications to convey the advances made possible using DVD. The construction section explains the manufacture of a DVD to show the physical advantages of DVD for data storage and retrieval. The section covering current applications examines the five current formats for DVD specifications and how they are currently being used today. Finally, the sales and revenues section includes forecasts of DVD sales and distribution, based upon current sales and technology release.

II. DVD TECHNOLOGY OVERVIEW

Before getting into the details of manufacturing DVDs and their applications and market potential, consider their basic construction and comparisons to CD-ROMs.

DVD Development Process

Digital Versatile Disc (DVD) technology was pioneered in 1993 by the Toshiba Corporation to fulfill two primary technical goals, provide both higher throughput and higher capacity than current CD-ROM technology. While DVD optical discs are quite similar to CD-ROM optical discs, there are a number of key physical differences, as well as philosophical differences. CD-ROM technology was originally designed to accommodate high quality audio data, and a large quantity of textual data. While the use of CD-ROM has been extended to include video data, the format falls short of providing broadcast television quality video and cannot store full-length feature films. The DVD format was specifically designed to address each of these limitations.

Beyond the inception of DVD technology, advances have been developed by a group of ten consumer electronics companies, called the DVD Forum, who have agreed on the set technical specifications for each DVD format. Until recently, there were two competing groups of companies: one led by Sony, and the other by Toshiba, that were both trying to develop proprietary high-density optical disc formats. Fortunately, these two groups joined forces and agreed to form the DVD Forum. The DVD Forum has also actively encouraged participation from members of the entertainment and computer industries so that the DVD format will have a broad base of support in both the consumer and computer electronics areas.

As mentioned before, two of the primary goals of DVD are to provide both higher capacity and higher throughput than current CD-ROM technology offers. To demonstrate the advances afforded using DVD, this section will reference the specifications of CD-ROM vs. DVD technology.

CD-ROM vs. DVD Comparison

The table on the following page shows some of the key similarities and differences between the CD-ROM and DVD formats.

Table 1. CD-ROM vs. DVD Specifications.
Source: "DVD: The Dawn of a New Generation." July, 1998. *Computer User*

Category	**CD-ROM**	**DVD**
Disc Diameter	120 mm	120 mm
Disc Thickness	1.2 mm	1.2 mm
Disc Structure	Single Substrate	Two Bonded 0.6 mm Substrates
Laser Wavelengths	780 nm (infrared)	650 and 635 nm (red)
Track Pitch	1.6 microns	0.74 microns
Shortest Pit Length	0.83 microns	0.4 microns
Data Layers	1	2
Data Sides	1	2
Data Capacity	650 Mbytes	4.7 – 17.0 GB
User Data Rate	1.4 Mbits/sec	10.0 Mbits/sec

The key features, which comprise the difference between CD and DVD technologies, are the physical characteristics, data structure characteristics, and operating characteristics.

Physical Characteristics. The physical characteristics of the optical discs including thickness, diameter and structure are nearly identical, with the only exception being the DVD possessing a double substrate with half the thickness of a conventional CD. This allows multiple layers of data to be stored within the same thickness of a conventional CD single layer, as seen in Figure 1.

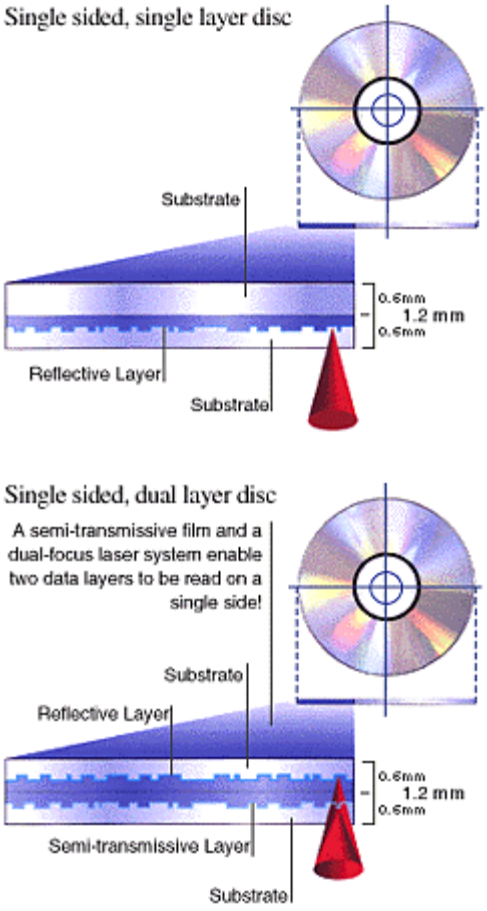

Figure 1. DVD Comparison. Source: Smith, James. *DVD Handbook*, p. 19.

Data Structure Characteristics. The data structure characteristics of the optical discs include laser wavelength, track pitch, and pit length. All of these characteristics differ from CD to DVD and allow for the significant improvements in data capacity and throughput seen in the DVD operating characteristics. Using a red laser for DVD devices vs. a standard infrared laser used for current CD devices, provides a much smaller wavelength, allowing better selectivity and smaller data structures, as seen in Figure 2. Data can be stored in half the length previously necessary using conventional CD technology.

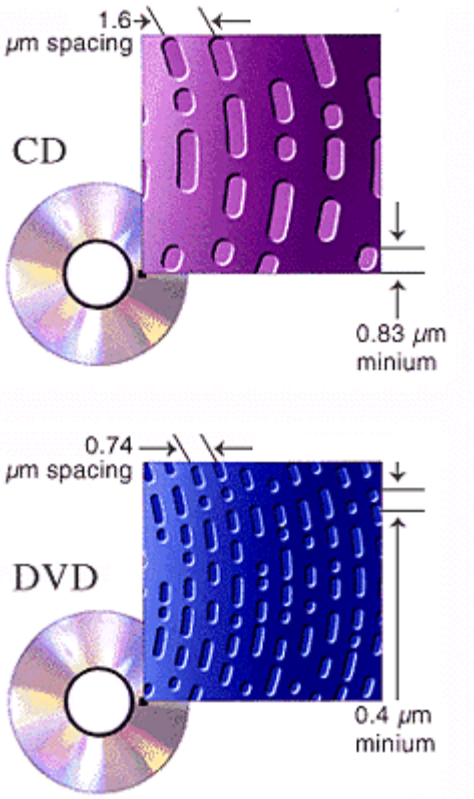

Figure 2. Data Structures. Source: Smith, James. *DVD Handbook*. p. 22.

Operating Characteristics. The advances provided by the shorter wavelength laser and multi-layer structure, exponentially increase the throughput of DVD devices vs. CD devices. All DVD formats and playback devices will support a minimum throughput rate that is eight times faster than conventional CD-ROM, and many DVD playback devices will support even higher transfer rates. In addition, by doubling both the number of layers and the number of sides utilized, capacity of DVD has been increased to a maximum of 17.0 GB of memory, compared to 650 (megabytes) MB of storage on a standard CD-ROM, an increase of more than 26 times the capacity.

III. CONSTRUCTION OF A DVD

DVD construction is similar to traditional CD-ROM construction with a few added steps, and a much higher degree of manufacturing tolerance required.

Process in DVD Construction

Each of the following major manufacturing steps will be presented using an explanation followed with a diagram to show the actual progression of the disc construction:

Physical formatting. Analog signal is converted to a digital signal and compressed using DVD compression standards, then stored for transfer onto the DVD.

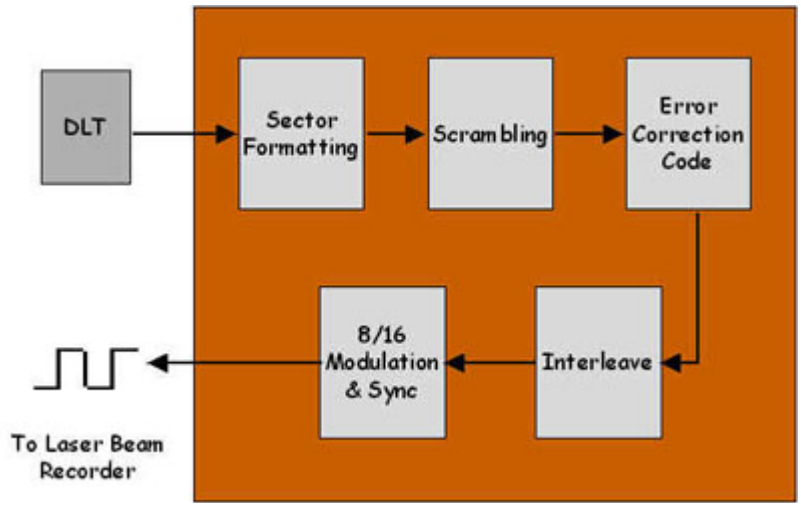

Figure 3. Physical Formatting.

Glass mastering. A glass base is coated with light-sensitive photoresist, which is then developed in a sodium silicate solution, using a laser to implant the digital signal.

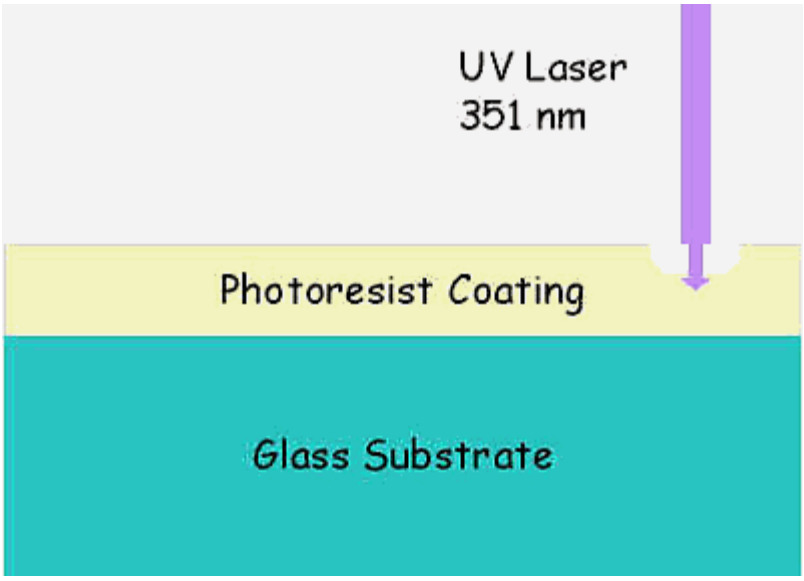

Figure 4. Glass Mastering

Metallization. Nickel is evaporated on the surface of the master, providing a conductive layer for the electroplating phase.

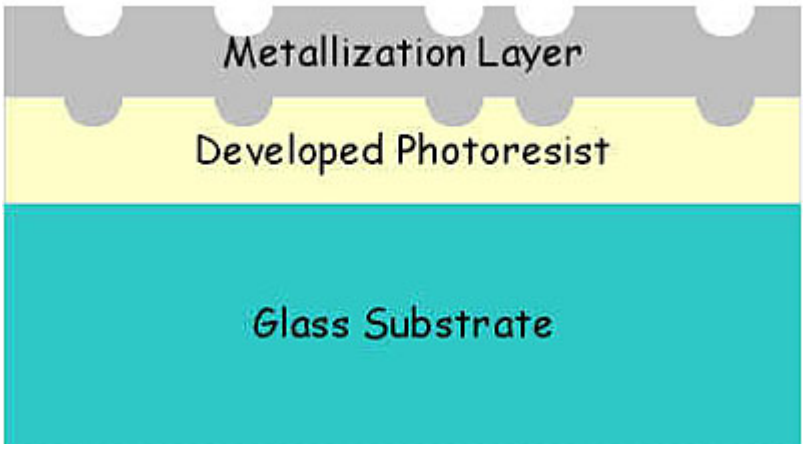

Figure 5. Metallization.

Electroplating. A wet process in which the master is bathed in nickel sulfamate and a stamper is applied to create the pattern required for multiple disc replication.

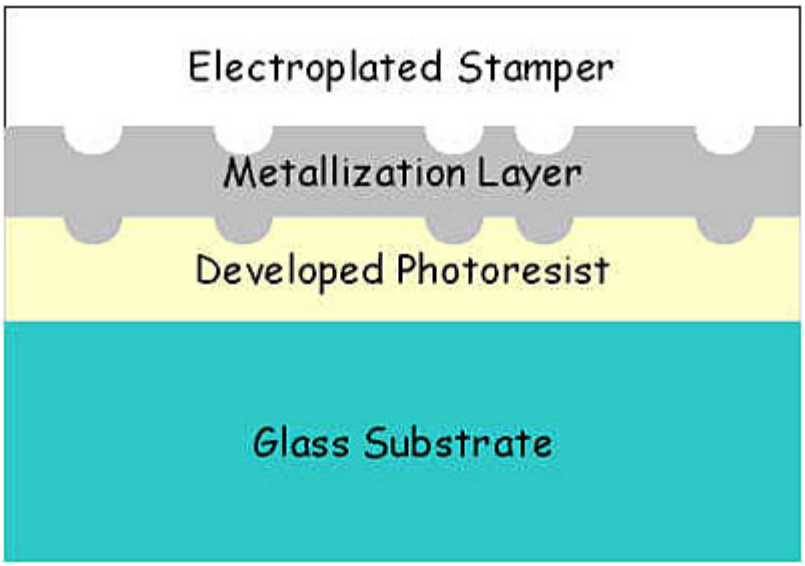

Figure 6. Electroplating

Molding. The previously created master is used as a base, giving a pattern pressed onto an injection molded polycarbonate substrate.

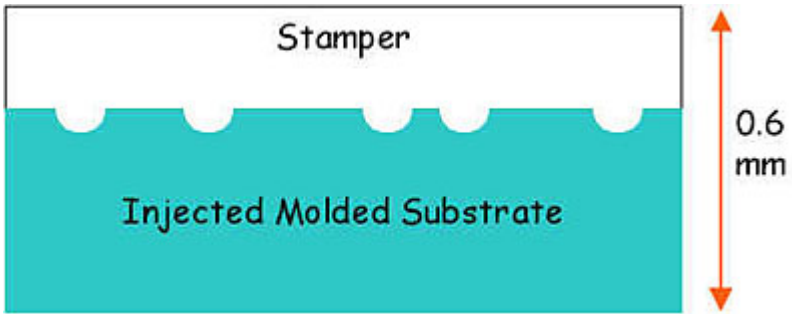

Figure 7. Molding

Sputtering. Similar to semiconductor sputtering, a metal layer is formed on the surface, aluminum for single layer, gold or silicon carbide for dual layer discs.

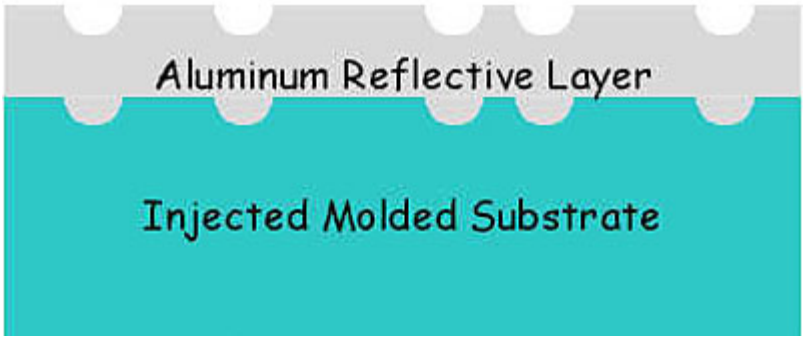

Figure 8. Sputtering.

Bonding. Multiple layers are bonded together using either hot melt or ultraviolet processes. This bonding requires extreme precision to prevent the DVD from becoming unbalanced.

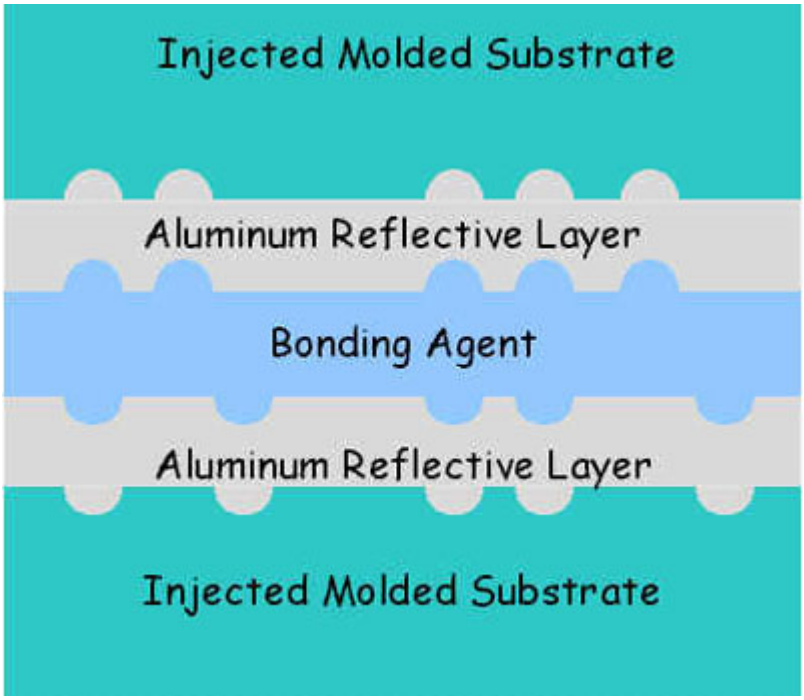

Figure 9. Bonding.

The above processes provide the DVD with a variable number of readable substrates, allowing a maximum of two substrates per side, with a maximum of two sides. This manufacturing process is not a large departure from conventional CD-ROM manufacturing processes, requiring higher tolerances

in the mastering phases of the process, addition of gold and silicon carbide in the sputtering process, and the addition of a bonding process.

Current Research

Ongoing research in Tokyo performed by the Agency of Industrial Science and technology has led to advances producing a DVD capable of holding 15 times as much data as current DVDs. This high memory density is achieved by adding an additional antimony film to the DVD, pinpointing the laser beam allowing up to 30 hours of moving images to be stored, using conventional DVD devices for playback [4:1].

IV. DVD APPLICATIONS

Given the technological advances made over CD-ROM, the applications for DVD are able to replace all conventional applications for optical disc use. Use of DVD is currently divided into five separate applications using six different DVD formats.

- *DVD-ROM.* High-capacity, high-throughput, read-only optical disc that can be used as a general-purpose computer storage device. This application is currently the most prevalent, with disc storage ranging from 4.7 to 17.0 GB, depending on format.
- *DVD-Video*. High capacity, high throughput, read-only optical disc that can be used for the interactive playback of high quality video, audio and graphic content. This application, similarly uses disc storage ranging from 4.7 to 17.0 GB, depending on the format.
- *DVD-Audio.*Similar to the DVD-Video, differing only in the compression and storage of audio, rather than video.
- *DVD-R.* High capacity, high throughput, write once, optical disc used as a general-purpose computer storage device. This application currently is formatted to hold 3.8 GB of storage per side, although current advances promise to achieve 4.7 GB per side.
- *DVD-RAM.* High capacity, high throughput, read-write, used as a highly versatile storage medium for computers and other devices. This application currently uses its own format, allowing 2.6 GB of storage per side.

V. DVD PROJECTED SALES AND REVENUES

The international Recording Media Association (IRMA) recently released its "Optical Media Intelligence Report" which forecasts annual worldwide DVD replication of 1.28 billion discs by the year 2002, including all of DVD's formats [7:12]. The following graph demonstrates the projected distribution of DVD playback devices, given the current trends and affordability of the devices.

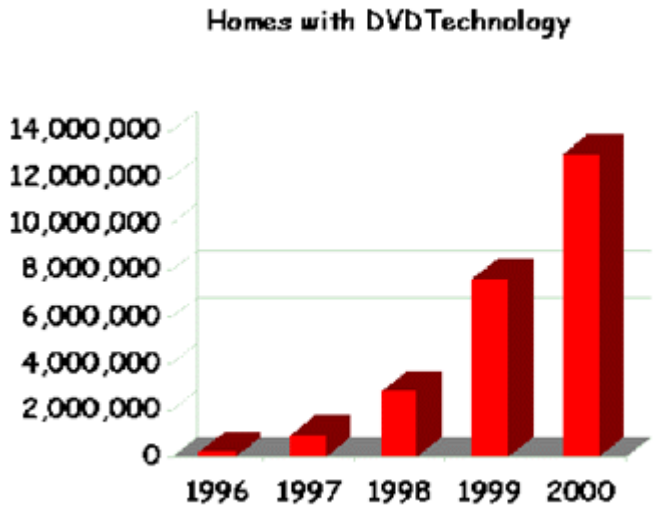

Figure 10. Homes with DVD Technology

As shown in figure 10, the distribution of DVD devices is growing exponentially, with the largest growth year occurring in 1999. A recent survey has found that DVD technology awareness in the public has grown from 18% in November 1997 to 49% in April 1998. This greater awareness has brought about large increases in player purchases followed by even greater sales of discs, primarily movies, as shown in the following graph, depicting DVD movie sales (yellow) combined with DVD-ROM sales (red).

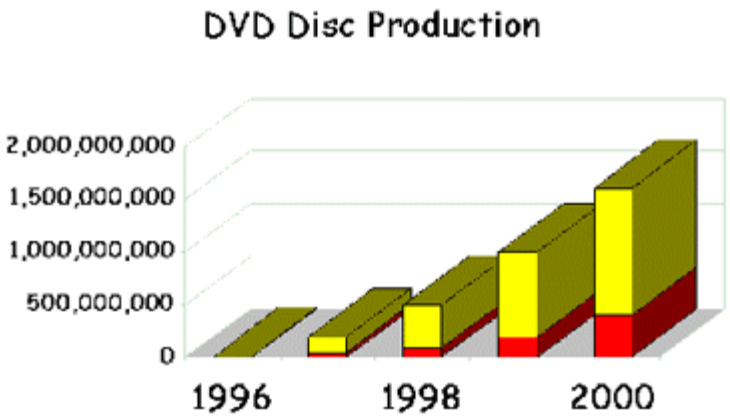

Figure 11. DVD Disc Production

In addition, the Electronic Industries Association of Japan forecasts the market for DVD movie players worldwide will expand to 11.53 million units in 2002 from the 796,000 units sold in 1997. This represents a 71 percent annual growth on average during the period [8:5] . The International Recording Media Association predicts this growth will also propel the demand for DVD-Video product, increasing the number of stores selling or renting the new format from 5,000 outlets at the end of 1997, to more than 32,000 by the end of 1999 [7:15].

A Forrester Research study recently reported that DVD technology could eventually turn the home PC into a primary home entertainment platform [4:12] . The report projects the DVD will displace the television as the focal point for electronic recreation. The study also predicts the PC industry growth to surpass the consumer electronics industry by the year 2000 [4:15].

The development of DVD technology requires a relatively small capital investment in comparison with the potential revenue, which could be generated through product sales, as shown in the table below.

Table 2. DVD Player Sales to Dealers.
Source: *Consumer Electronics Manufacturing Association DVD Report*, p. 35.

Year	Unit Sales (Thousands)	Dollar Sales (Millions)	Average Unit Price
1997	350	$170	$485
1998	750	$326	$435

VI. CONCLUSION

In conclusion, this report gives the initial introduction to DVD technology required to determine whether to implement the technology in Motorola products in the future. Given the ease of implementation of this technology and potential growth in sales and revenues, DVD technology promises to afford many avenues of implementation. These implementations range from current video, audio, and computer applications to household combination cable modem and large data storage units for combined application in multiple use consumer electronics devices. Beginning research as soon as possible could yield consumer product rollout in as soon as 12 months time. Given the expansion and partnerships forged by Motorola with other corporations and our current standing in the communications world, the implementation of DVD technology in our products beginning in 1999, will provide a large share of the market share during a period of extreme market growth.

INFORMATION SOURCES

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