FOCUS

Magneto-Optic Disks

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1. INTRODUCTION

Though the complexity of applications of information technology in various fields has grown, the consumer is demanding to process ever larger volumes of data. Magneto Optic Disk (MOD) technology is found to be the strongest candidate for supplementing if not replacing magnetic media for secondary removable storage in view of its low cost and large storage density (Figure 1 and Table 1). Though large scale production (and hence its low cost) is yet to take place, it is bound to do so by 2000 AD given the expansion rate of production and market penetration of magneto-optic recording. Schroff and Chakravarti had studied in detail the technologies and applications of optical memories (1). The present study addresses the advances which have taken place in the last two years specifically in magneto-optic disks.

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2. MAGNETO-OPTIC DISK TECHNOLOGY

Since the magneto-optic (MO) media is erasable and has high recording density, it is a very serious candidate for use as a secondary removable storage device. It has additional advantages of reasonably high data transfer rate; high tolerance to fluctuating ambient temperature, stray magnetic field and dusty environment. Among the various optical recording technologies, it is most advanced and has large scale usage possibilities. Several US and Japanese companies are now making MO drives and disks and some of the standard products marketed by them are given in Table 2. As can be seen, the cost of the MO disk storage varies between US$ 0.27 to 0.50 per MB of storage compared to the cost of floppy disk storage which is US$ 1 to 2 per MB. Storage costs of other competing media like Bernoulli magnetic cartridge (US$ 10/MB) are also higher than that of MO media. Therefore, MO disk storage at present offers the lowest cost of storage amongst all removable storage

production, the cost is bound to come down. Fujitsu plans to see MO recorders at an affordable US$ 400 per piece within a few years.

3.3 Applications

Due to its high access time and low data transfer rate, MO recording system cannot replace the magnetic hard disks for online direct-access-storage devices. However, where a large volume of data is to be handled and stored through removable medium or where data security is a must, the MO media is the most appropriate medium today.

With increasing use of faster computers having large semiconductor RAM size in industry offices and homes, stand-alone small computer systems have to handle large volumes of data and multimedia systems will be used for this purpose. Once that happens, floppy disks (as used presently) will not suffice to store this volume of data and transfer it to other computers. The MO recording system appears to be the obvious replacement for floppies in PCs and work stations. Potential application areas include strategic and military applications.

It is interesting to correlate the development of the MO recording technology with development of PCs. By 2000 AD, a PC is expected to have 1 GB of semiconductor RAM memory with a processing speed of 100 MIPS. However, this will not make secondary memories obsolete. It is well known that for efficient operation of a PC, a secondary storage ten times the size of the RAM memory is required. A window of opportunity exists for the MO technology to offer an appropriate secondary memory of the size of 10 GB in a PC.

3.4 Limitations

The main competitor to the MO technology is still the magnetic recording technology specially for the erasable and removable high density recording system. The magnetic recording seems to be a cat with nine lives. Since 1970s its demise has been predicted again and again by the 'experts'—first due to the advent of magnetic bubbles and now due to the optical recording. But each time the technology has fought back with improvements and cost reductions which the new challengers could not match. Today, it rules supreme for the direct-access-storage device applications, but is being challenged by optical disk technology in the removable media market. It is fighting back through attempts like floptical disks and newer developments can be expected in future.

4. CONCLUSIONS

As one can see, the various technologies are finding their niche in the memory technology scenario and each has its area of application. As direct-access-storage devices, hard disk drives based on longitudinal magnetic recording have no competitors mainly due to their short access time, a requirement essential for online operation. For offline secondary storage, CD-ROM, WORM, erasable phase change and MO disks are competing. Each is finding its own market segment. While CD-ROM and WORM disks are suitable for archival use, various cost and performance considerations show that magneto-optic disk is gradually winning the race for use as removable erasable secondary storage disk. However, it is still facing stiff competition from conventional magnetic tapes and disks. It must improve its cost/performance continuously in order to replace these

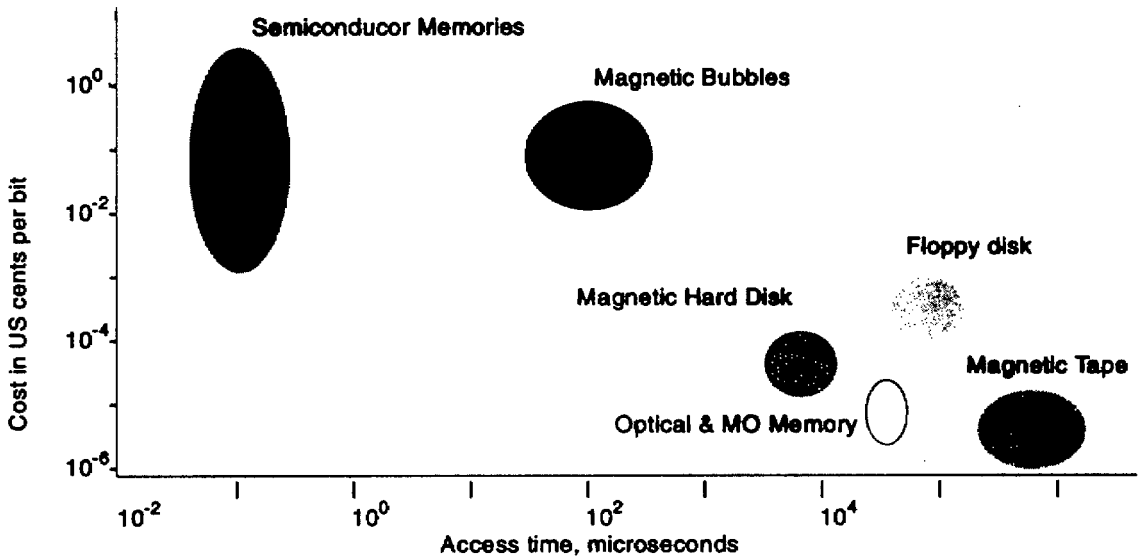

Figure 1. Chart Showing usage of different memories

media. Cost of the MO media is expected to go further down when it will be mass produced. However, the cost of the MO drive is still very high compared to other drives like floppy disk drives and is proving to be the main obstacle to attain a rapid expansion of usage of MO recording technology. However, the drive cost is also expected to go down in near future. Fujitsu is currently pricing a 128 MB 90 mm disk drive at US$ 696 and it expects its cost to go down to US$ 348 by 1995.

2.1 Application Areas

Commercialisation of MO storage technology depends upon opening up application areas where the medium has unique advantages. This alone can lead to the familiar cycle of higher demand ⇒ higher production volume ⇒ lower cost ⇒ higher demand. The application areas can be roughly divided into two categories, viz., (i) back-up for DASDs (Direct-Access-Storage-Devices) in large main frame

Table 1. Comparison of various commercial recording technologies.

Technology	Areal density, MB/cm^2	Bits per cm	Tracks per cm	Data transfer rate, KB/s	Access time
Digital Tape (1/2")	0.02	2500	7	550	minutes
Hard Disk (5 1/2")	8	12000	667	1373	20 ms
Floppy Disk (3 1/2")	0.32	6900	54	92	1 s
Video Tape (1/2")	1.8	6900	260	120	minute.
DAT-4mm	18	24000	748	183	20 s
CD-ROM (3 1/2"	70	11000	6000	1830	40 s
MO Disk (3 1/2")	40	10000	6000	4000	40 ms

Table 2. MO drives marketted by various companies.

Company	Disk size Inches	mm	Media size MB	Seek time, ms	Interface	Datatransfer, Rate MB/s	Drive cost US$	Disk cost, US$
Seiko Epson	3.5	90	128	38	SCSI	0.768	1000	64
Sony	3.5	90	128	40	SCSI-2	7.25	2295	64
Ricoh	3.5/5.25	90/130	128/650	35	SCSI	4.0/1.5	1500/2870	70/180
Nakamuchi	3.5	90	256		SCSI		3016	
Fujitsu	3.5	90	128	30	SCSI-2	2	696	50
Image Network Technology	3.5	90	128	45	SCSI-2	4	1699	70
Pinnacle Micro	3.5/5.25	90/130	128/650	38/19	SCSI	4/0.625	2395/4190	79/199
Relax Technology	3.5	90	128	39	SCSI	4	1299	49
Alphatronix	5.25	130	650	22	SCSI-2	1.6		

computers, and (ii) removable disks in workstations and PCs.

Although MO disks cannot be used as DASDs due to their slow access time and slow data transfer rate, they are being planned to be used as back-ups for the DASDs, an application which is ideal for the MO media. Such storage devices can have storage capacity of more than 10 GB using several MO disks in a juke box-like configuration. A single juke box made by Alphatronix USA can store upto 93 GB in random access mode for use in on-line, near- line or archival applications. NTT has made a DASD with 250 GB to 1 TB capacity using 130 mm (5.25") MO disks. Ricoh is supplying a 10 GB system with sixteen 130 mm size MO disks. Sharp is also offering a 2.2 GB system with six 130 mm size MO disks.

Table 3. Applications of MO Technology

Education	Course Material for Distance Learning Archival Storage Paperless Library Audio-visual Programmes
Health	Hospital Record Medical Image Storage
Engineering	CAD/CAM Stations Image Processing in Remote Sensing
Service	Bank Record Storage
Industry	Railways Reservation Data Storage Airline Reservation Data Storage Office Data Record
Defence	For Maintain image storage and processing during reconnaissance and other flights Satellite image storage On-board data storage in aircrafts

The main use of MO disks will be for workstations and PCs in applications requiring large secondary storage like in CAD/CAM and image processing. Some of the applications are listed in Table 3.

2.2 Demand Projection and Production of MO Disks

The demand for MO disks although modest at present is expected to reach about 23 million pieces (15 million 90 mm size disks and 7.5 million 130 mm size

disks) by 1995 and is expected to grow further at the rate of 50 per cent per year. In 1993, the demand was for about 5.5 million pieces costing about US$ 500 million. It is to be noted that although 130 mm size disks were first introduced into the market in late eighties, the demand for 90 mm size disks introduced later is more than that of the 130 mm size disks and it is increasing at a faster pace.

The production of MO drives and systems is mainly concentrated in Japan and USA. Although several US companies are providing MO disk drives, only one US company (3 M Company) is making the MO disks. The market is dominated by Japanese companies. Among the most notable developments is the plan of Fujitsu company to make 50,000 MO drives per month, which is five times the present capacity of the Sony Corp., one of the early starters of production of the drives. It is also selling 90 mm disk drives at the lowest cost of US$ 696 per drive and plans to bring down the cost to half by the year 1995. Fujitsu is offering 130 mm MO disk drive with 60 MB capacity for note book PCs and word processors to replace floppy drives. It can also be used in systems used for phones, facsimiles and electronic still cameras. Ricoh is increasing its production of MO drives. Toshiba is also increasing its capacity to 10,000 units/month. Idemistu Petrochemical, Japan is setting up a US$ 16 million facility to make 90 mm MO disks and drives. Sony is releasing a 90 mm MO drive which is less than half in size and twenty two per cent lighter in weight than current drives. Ricoh is marketing an optical filing system based on 90 mm MO drive.

Similarly most Japanese companies are extending their production capacities for MO disks. Some of these are pooling their resources to capture the world market.

2.3 Near Future Technology Development in MO Recording

MO recording technology is now attractive for several companies to go in for large scale production. Despite its limitations, various technological developments are taking place which show promise of improved MO disk production in near future. Some of these have increased capacity, new MO layer materials, direct overwrite capability and better production machines.

2.4 Improved Production Technology

For metallising CDs CD-ROMs and MO disks, DC/RF sputtering with or without magnetron is usually used. For productionising this multi-layer thin deposition process, initially large systems with large multiple targets were used and several disks were coated simultaneously to increase the production rate. However, in-line coating facility where single disk is coated in a series of small sputtering units is now available. This is more cost effective. Such a system facilitates optimisation of deposition conditions of each layer in isolated vacuum systems and leads to better reproducibility. The cost of the system also goes down since each individual system is small.

3. STATUS OF MO RECORDING TECHNOLOGY

In order to understand the status of MO recording *vis-a-vis* other technologies available today, an analysis of strengths, weaknesses, applications and limitations is given below:

3.1 Strengths

The obvious strength of the MO technology is that it is an erasable recording technology with a high areal recording

density of 40 MB/cm^2 and with good prospects of increasing the areal density to 400 MB/cm^2 using blue lasers. The only technology which can compete with this capability is the longitudinal magnetic recording (LMR) media with fixed heads (hard disks). Although a decade back it was thought that the areal density in LMR media will saturate around 5 MB/cm^2, today IBM is offering commercial system (IBM 33900) with areal density of 10 MB/cm and media with areal densities of 300 MB/cm^2 have been demonstrated. As these media are longitudinal, serious noise problem is encountered at high recording densities with the bit size approaching the grain size. Typically it shows a CNR of 20-30 dB at such high areal density. On the other hand, MO media supports perpendicular domains and is amorphous in nature and closer domain spacing becomes more viable and, therefore, the MO media shows a CNR of 45 dB even at a high recording density.

The second strength of the MO media is the larger head-to-media distance, which makes head crash almost impossible. It also tolerates dusty conditions due to the use of a focused laser beam for read/write action. This media has a very high coercivity and as the domains are perpendicular to the plane of the media, it faces a smaller demagnetising field. Therefore, it can resist demagnetisation due to stray magnetic field, a common problem in magnetic media.

Perhaps the main strength of the MO media is the low cost of storage. It now costs about US$ 0.27 per MB of storage using a 130 mm MO disk and is the cheapest of all removable recording media. With mass production yet to come, prospects of still lower cost of storage are bright.

3.2 Weaknesses

The MO media is facing hurdles for wider application due to several weaknesses. The media has a longer access time (40 ms) than that of magnetic hard disk (10 ms), but it is comparable to that for the floppy disks and other optical recording media. The second weakness is the slow data transfer rate of about 4 MB/s for recording. The main reason for this is the heavy read/write head which can be improved by placing multiple disks in parallel. Another reason is the slow overwrite speed resulting from the two passes required for rewriting in MO media. As explained above, directly overwritable disks are now possible albeit with multiple layer magnetic thin films, which make production a little more complicated and a data transfer rate as high as 64 MB/s has been achieved.

Being a *Tm-Re* (Thulium-Rhenium) alloy, the active magnetic layer in MO media is susceptible to oxidation. Although efforts such as coating with a protective non-oxide dielectric over the layer followed by lacquering the layer, adding dopants like *Ti* to the layer to increase its oxidation resistance have been made, the long term reliability of the media is not yet fully proven. However, the lifetime of the media is predicted to be about 10 years, a figure comparable to the lifetime of the magnetic media, but somewhat inferior to that of the CD-ROMs. The MO recording system generates relatively a higher amount of heat during operation and its internal mounting inside PCs will require extra cooling. At present external mounting is preferred.

Although the cost of MO media is low, MO recorders are expensive (at US$ 2000) and there is customer resistance to go in for an expensive hardware. With mass

conventional technologies especially since the conventional magnetic recording technology is also improving its cost/performance. As Gote, Lab Editor of BYTE Magazine, states, "For many applications, MO is now the way to go", MO looks to be the wave of the future. At the same time, there are improved MO technologies over the horizon capable of giving a recording density of 400 MB/cm, data transfer rate of 64 MB/s and direct overwrite capability. If this can be achieved in production, magnetic hard disk will have a fight in hand even for the direct-access and storage application.

5. REFERENCES

1. Shroff, N and Chakravarti, AK. Optical Memories: Technologies and Applications. September 1991, 673-701).