Thin Film Technology for Optical Discs

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1.0 Introduction

1.1 Optical Disc Market

In the past decade, the market for audio CD has exceeded industry expectations as the most successful commercial application of optical disc technology. With the consumer base of installed CD players approaching 50% in the US, CD replication capacity is expected to reach one billion units in 1994 (1). Moreover, the merging of multiple formats in the computer software market is driving additional demand (CD-ROM). As technical advances continue, data compression techniques are expected to allow 74 minutes of full motion video on the 120mm CD format, creating additional and exciting new markets for multimedia applications.

Writable optical discs, such as the CD-R and the 140MByte MD-D (MiniDisc-data), have enormous applications and appeal as removable data storage media. It is in this segment, and not in competition with hard disc, that the best chances for commercial success of optical data discs reside. Floppy discs, which continue to be the dominant portable medium in the computer industry, are rapidly approaching obsolescence due to their limited data storage capacity, in light of ever increasing and larger software applications.

1.2 Thin Films for Optical Discs

For all these optical disc applications, thin film technology, in particular planar magnetron sputtering, has emerged as the key technology for disc production. Read only media such as the CD, CD-ROM, the prerecorded MD and Laser Disc (LD), and write once discs (CD-R), require an uncompromising reflection layer which is best achieved by techniques of physical vapor deposition.

Erasable optical discs, such as 3½" and 5¼" magneto-optical discs (MO) and the recordable MD, rely upon intrinsic storage layers and functional films (barrier and reflection-layers) which are likewise deposited using vapor deposition, primarily magnetron sputtering.

Hence, the evolution of thin film technologies for optical disc production shares three major driving forces:

1) a continuous growth of new formats and applications,
2) an ongoing trend towards process automation, and
3) a continuous demand for higher productivity

2.0 CD, CD-ROM, LD, prerecorded MD and CD

2.1 Evolution of the Technology

Ten years ago, in the beginning of high volume compact disc production, multi-purpose batch and evaporation systems were primarily used to apply aluminum coatings onto CD's. At that time, dedicated equipment was not available. In 1985, in response to growing customer and market demand, Balzers introduced the first single disc, in-line, planar magnetron sputtering system for CD-metallization. With this, the appropriate enabling technology needed to initiate industrial, in-line, production automation was created. This led to the first production monoline at KAO (formerly American Helix). Using programmable scara robots and dedicated equipment, integration of all production steps into a single, automated, clean room manufacturing line, became reality. Since then, a cascading trend from batch to in-line production has matured. Driven by customers and custom integrators, this phenomenon continues to exert a major impact upon metallizer design.

2.2 Changes in Hardware

The interdependence of replication cycle times with production concepts has created system designs which are smaller, faster and intimately adapted to all styles of manufacturing (batch, in-line, etc.) (Fig. 1). System foot print (Fig. 2) as well as the scheduled maintenance time required for target and mask change (Fig. 3) have decreased by a factor of 10. The general net result of these design improvements has increased cycle times, reduced unscheduled downtime and improved reliability.

In 1988, metallizer throughput for integrated lines were required to match the output of a single injection molder, having cycle times well above five seconds. With metallizer throughputs now twice as fast as the injection mold cycle, (1.8sec. vs. 4.5 sec respectively), dual line concepts using two injection molders to supply discs to a single metallizer have appeared. These combine the advantages of batch and

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monoline styles, providing greater throughput, uptime, and yields. Decreases in the price of vacuum metallizers have reduced the costs of capital investment by two fold, which when combined with enhanced performance, has led to marked increases in productivity, thus reducing manufacturing costs (Fig. 4).

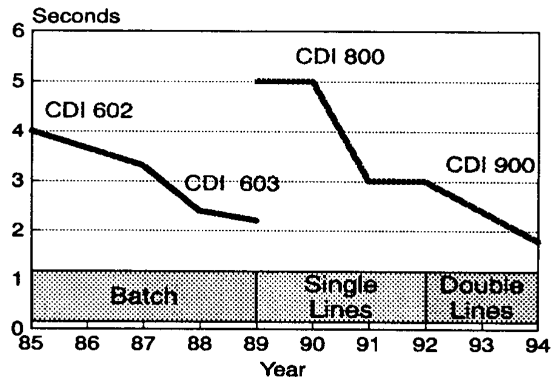

Figure 1: Cycle times of CD metallizers and CD production concepts

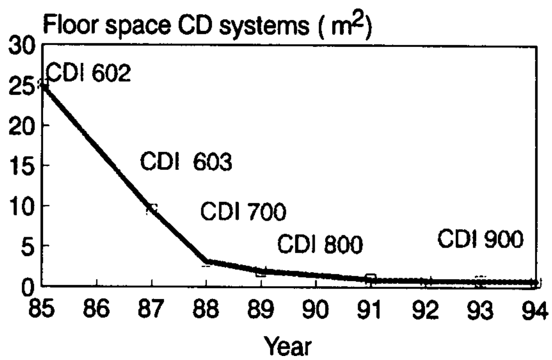

Figure 2: Floor space of CD metallizers

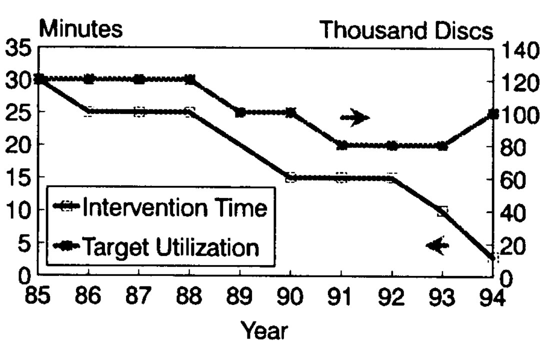

Figure 3: Intervention time for target or mask change and target utilization

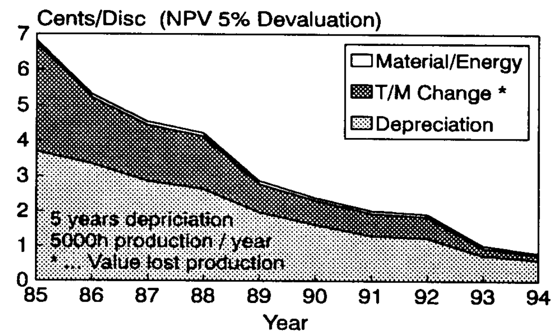

Figure 4: CD metallization costs

2.3 Latest Developments

Today, dedicated metallization systems (2) are greatly simplified, which makes them easy to use and more reliable. Throughputs of 2000 CDs per hour for double line metallizers and 1000 - 1500 CDs per hour for single line models are well established. Although demand for varied formats has been limited (LD, MD, etc.), today's metallizers will coat discs of 64mm to 300mm in diameter.

The desire for high rates (CD), better film uniformity (CD-ROM) and enhanced material utilization (Gold reflection layer on CD-R) has driven innovation in the area of planar magnetron technology. Our newly developed planar magnetron features full enclosure of the processing volume, thereby eliminating the need for sputter shields and liners. Additional design applications and new developments have produced a sputtering cathode of very high specific rate (6 nm/s kWcm3) for aluminum.

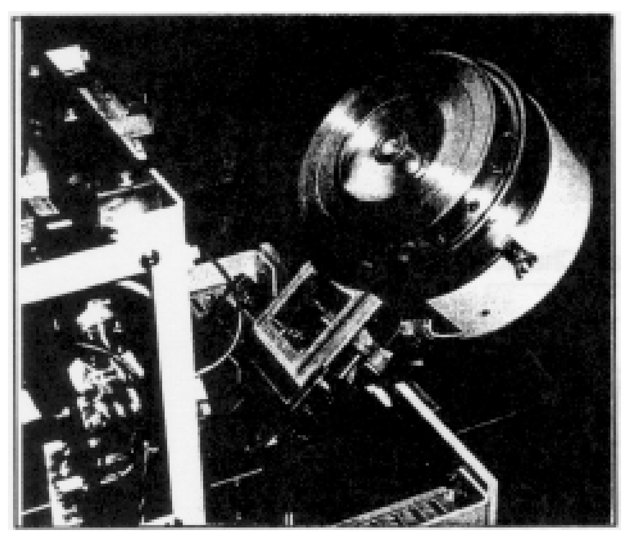

Figure 5: High efficiency planar magnetron

In the CDI 905, all maintenance parts can be replaced without the use of tools due to twist lock fixturing. Thus, the intervention time for target or mask change has been reduced to 3 minutes, since only the sputter chamber need be vented and not the entire vacuum system.

Taken collectively, the design gives a magnetron with a much higher efficiency of coating and conservation of sputtered material. In addition, an enhanced material utilization is realized, which is an important consideration when sputtering precious materials, such as gold for the manufacturing of CD-R.

3.0 Recordable MiniDisc, MO and other Multi-layer Optical Discs

3.1 Emergence of MO

To date, 5¼" MO disc has been the dominant format among erasable optical products. The number of discs produced annually has been on the order of ~one million/year, representing < 1% the number of CD's produced. Forecasts of MO-disc demand during the mid 80's did not reach expectations, and therefore production capacity, as well as production concepts, remained unchanged. Despite the fact that the processing technology for MO discs is exceedingly more demanding than CD, batch processing in large in-line coaters has, until 1994, remained the production technology of choice for the deposition of MO-layer structures.

The introduction of smaller, wider range formats, such as the 3½" MO-disc and the 2½" recordable MD, is driving change. The MD as audio carrier targets a consumer mass market; the MD-data, a market currently served by the floppy disc. In each, cost structures and volumes more closely parallel the CD than the professional 3½" and 5¼" MO disc, from which the technology is, in fact, derived. As consumer demand for the MD grows, a clear trend towards single disc sputtering systems for MD production using integrated production lines is being observed.

Single disc sputtering of magneto-optical layers is not a new approach. Such equipment (Balzers SDS 130) has been used successfully (3) for mass production of 5½" MO-discs for several years.

In production, the SDS 130 achieves throughputs of 180 MO-discs per hour despite its large footprint and hardware intensive design.

3.2 SDS 100

The mechanical transport concept of the SDS 100 was derived from experience acquired with the CDI 900. Processing technology was adapted from our SDS 130. By combining these elements, a marked improvement in performance, compared with previous generation equipment, has been achieved. (Table 1)

	SDS 130 86 - 92	SDS 100 since 93
Throughput	180 discs/h	360 discs/h
Floor Space	20 sqm	< 2 sqm
Nonproductive Time	6 h	1.5 h
Mask Change	on line	on line

Table 1: Performance improvements of MO sputter systems

SDS 100 throughput is doubled to 360 discs/hr; floor space is cut by a factor of 10; and investment is reduced by 50%. Target change intervention time, determined by the base pressure required to achieve the MO-deposition process, has been reduced by a factor of 4 as a result of equipment design . Only the sputter chambers, and not the entire vacuum system, requires venting on the SDS 100 to conduct scheduled maintenance.

Single Disk Sputtering System for MO-Disk SDS 100

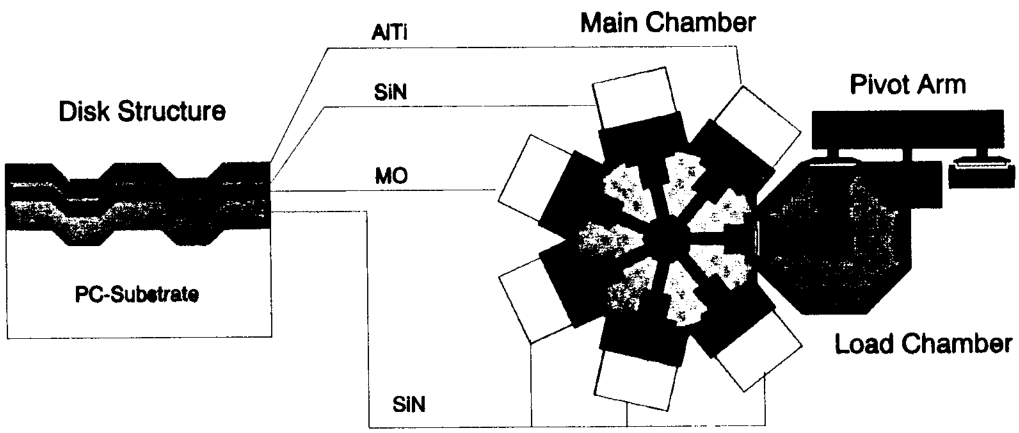

Figure 7: MO quadrilayer stack and SDS 100 system layout.

3.3 MO-process results

In contrast to aluminum sputtering, MO-disc technology demands a quadrilayer stack of dissimilar materials with very tight tolerances. The typical MO-stack of dielectric 1, MO layer, dielectric 2 and reflector is applied in sequential steps (Fig. 7). In the field, these systems have demonstrated their performance in reliable production world wide. Ultimately, the reproducible production of a quality disc is the primary yardstick of processing technology.

Among the most challenging issues of direct overwrite MO-discs, is the writing sensitivity. This dictates writing field strength and sets it within reasonable limits. We have measured Carriage to Noise Ratio (CNR) of samples as a function of external field strength. The results indicate that samples produced in SDS 100 systems are among the best discs commercially available.

- Process Results: Reproducibility

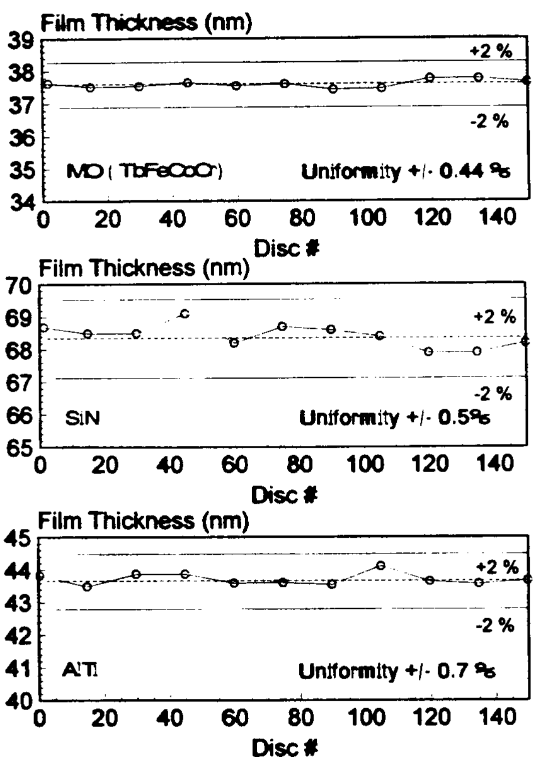

Figure 8: Reproducibility of sputter processes in the SDS 100

Excellent results are reproducibly obtained in high volume production with the SDS 100. Analysis of the film thickness of the various layers yields values of 0.44%, 0.5% & 0.77% for the critical films. These figures are well below ± 2%, which is assumed to be required uniformity for the MO, SiN and AlT layers, respectively (Fig. 8).

4.0 Summary

Thin film processes are an integral and essential applied technology in the effective production of high performance optical discs. Innovation in system design has been strongly influenced by three important factors: 1) A continuous demand for higher productivity, 2) An ongoing trend towards process automation, and 3) the emergence of new and exciting multimedia applications creating additional optical disc formats. Thin film processing of all existing optical disc formats, is an applied technology in mature manufacturing facilities used throughout the industry.

Literature

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