Due to the higher complexity and the tighter tolerances of high speed (16x) or Dual Layer discs, the pilot production of those media starts again with reduced cycle times. Bringing the productivity for these new high-end formats up to a level comparable to actual mass production of 4.7 GB media requires not only an extremely stable and reliable production line, but also the newest process know-how in all relevant fields. This knowledge reaches from mastering via moulding, dye technology, metallization and bonding towards suitable disc analyzing systems and, even beyond that, into the interaction of the discs with different recorders.

Today’s cost driven mass production of the recordable 4.7 GB media DVD-R (G) and DVD+R is performed on modern replication equipment designed for cycle times well below 3 seconds (Fig. 1, photo page 1). Already in May 2004, at the MediaTech Expo in Frankfurt, SINGULUS demonstrated a two-moulder STREAMLINE II DVDR inline system running with a cycle time of 3.0 seconds.

Most of the installed DVDR machines run today in mass production with a moulding and process cycle time in the order of 3.8 seconds.

While modern manufacturing equipment for recordable DVDs reaches cycle times of less than 3 seconds, both the recent high speed and the Dual Layer (DL) DVDR formats impose new technological challenges on the design of mass production lines. Tighter tolerance limits and more sophisticated disc layouts require superior machine technology which is based on proprietary know-how in every single process step, and on the successful application of new production technology. In addition, some of the new processes applied for high speed and DL DVDRs build a link towards future mass production of third generation optical discs.

STREAMLINE II DVDR-DL
The First DVDR Line with an Upgrade for Dual Layer Formats

[continued on page 2]
SINGULUS is a young company with a remarkable success story. Founded in 1995, producing only a stand-alone CD metallizer, the company grew to become the world’s leading supplier of CD metallizers.

SINGULUS’ profound R&D activities in all multiply interacting process fields generate the expertise to design reliable and highly productive machines, to react quickly to new technological challenges and to extract all necessary process know-how within reasonable time for the transfer to the users of our equipment. Competence in systems business is considered to be essential to cope with the challenges of new disc formats.

High speed DVDR
The process window shrinks for higher recording speeds; not only for the physical parameters of the disc, but also for the mechanical, optical and electrical properties of the recorder. As it is the case for 52 x CD-R, very subtle effects can decide about the success in recording a DVDR with 16 x speed.

Not only the thermal and the optical properties of the dye have to be well adjusted to achieve a wide power margin and a high recording sensitivity. The groove geometry and the pregroove information have to be precisely fitted to the physical properties of the dye. Pre-heating and post-heating effects make it necessary to refine the writing strategy, especially in the case of small pits or lands surrounded by long lands or pits respectively.

The moulding process, too, is one of the most decisive factors affecting high speed recording properties. Besides keeping a high replication rate, it is the challenge of moulding to produce substrates with lowest possible mechanical deformation. Repeatedly good tracking and focussing results presuppose tight and stable limits for variations in unbalance, eccentricity, tangential deviation and birefringence. It is essential to apply newest moulding technology and to co-develop mastering and moulding processes in order to maintain perfect substrate properties for high speed formats, even at reduced production cycle times.

After moulding, the thermal equilibrium within the STREAMLINE II, the fast mechanical substrate stabilization by means of the spin-coolers, an individual process air conditioning unit, a fast and homogeneous drying station with tilt control, uniform sputtering throughout the target lifetime, ample conditioning steps to relax tensions after drying and metallizing, a thermally balanced bonding station and a UV curing station with tilt compensation and eccentricity control all contribute to keep each substrate in shape; throughout the line and repeatably from disc to disc.

Dual Layer DVDR
DVD+R DL discs are presently produced only in limited numbers on pilot machine installations. The commercial success of 8.5 GB media depends strongly on the right choice, and on the industrial refinement, of the additional production steps.

"Reverse layer 1" vs. "layer-by-layer" process
The first discs available were produced in a "layer-by-layer" style, which is also referred to as 2P (photo polymer) process (Fig 2a and Fig. 3). A resin stamper made of polymer is bonded on top of the layer 0 (L0) substrate previously covered with dye and a semireflective metal film. After UV curing, the polymer stamper is separated from the resin, defining the groove structure for dye and metal coating of information layer 1 (L1). Finally, a 0.6 mm thick dummy substrate is glued on the Dual Layer substrate to stabilize the final disc.

A "reverse layer 1" type DVD+R DL, depicted in Fig. 2b and Fig. 4, makes use of a process comparable to DVD 9 production. Both polycarbonate substrates carry the groove information, one for L0 and one for L1. The L0 substrate is produced like in the "layer-by-layer" process, whereas the L1 substrate is covered with a reverse layer stack of metal and dye. To shield the dye layer of L1 from the bonding resin, a protective layer is deposited on top of the L1 dye layer before the two substrates are bonded with UV-curable adhesive. In spite of the equally oriented groove for both layers and therefore the better performance, the "reverse layer 1" type is becoming more popular due to its improved handling and mounting stability.
Supplier of CD and DVD inline manufacturing equipment. This success came from a dedicated focus on the optical disc market and innovative R&D leading to new proprietary technologies.

Signal compatibility of "layer-by-layer" type discs, we consider the physically more challenging "reverse L1" stack to be more economical for mass production. Particles produced during the separation of the resin stamper drastically restrict the yield of the "layer-by-layer" process. To generate optimum surface properties for that type of process, either the resin stamper material or the adhesive have to be carefully selected or treated, which generates additional material and machine costs, especially when the resin stamper cannot be used in a multiple way. Furthermore, in case of the "reverse L1" system, the machine layout is simpler, and proven standard components can be applied, which leads to higher production yield, increased reliability and a faster cycle time.

SINGULUS DL process development
SINGULUS TECHNOLOGIES develops hardware and functional layer stacks for both process types, however with a strong focus on "reverse L1" discs. To succeed with this process, special care has to be taken initially for the development of the layer stacks, but once achieved, the process can be reproduced quickly and with high productivity.

SINGULUS has optimized the layer stacks by tuning mechanical and material properties. The development of a special protective layer on layer 1 in combination with optimized groove geometries, dye materials and writing strategies already lead to very promising results. DL DVD+R samples could be recorded and replayed on commercial drives, where most of the electrical signals for L0 and L1 are within specification (Fig. 5 and Tab.1). Jitter values, for example, depend strongly on the write strategy, which is currently fine-tuned in close contact with the drive manufacturers, to enable full recording compatibility for L1 in different commercial writers.

STREAMLINE II DVDR-DL (Dual Layer)
Due to its modular design, the STREAMLINE II DVDR is already prepared to incorporate all new elements necessary for the production of Dual Layer discs according to both process types. A concept for a Dual Layer upgrade based on the "reverse layer 1" process has been worked out. The design consists mainly of an arrangement of additional thin film coating elements at different positions, which can be retrofitted to all existing STREAMLINE II DVDR machines.

The prototype of a complete Dual Layer system is installed, the final software and process adaptation will be finished by December, so that first production installations are expected for Q1/2005.

Based on a fast and reliable production system and the transfer of all process know-how necessary for any kind of recordable DVD, the new high-end formats 16x and Dual Layer DVDR are ready to go for mass production.

Fig. 5 RF signal of a DL DVD+R produced on a modified STREAMLINE II DVDR using a "reverse L1" process (Pulstec DDU 1000 tester)

Tab. 1 Electrical signals of a "reverse L1" DL DVD+R produced on the modified STREAMLINE II DVDR-DL version
“HDTV” and the 3rd Generation Optical Disc Formats

Introduced in 1982, the CD (Compact Disc) — the first generation of optical discs — has a data storage capacity of up to 700 MB using an infrared laser. In recent years, the market for prerecorded CDs (Audio CD, CD-ROM, Video CD) has grown to approximately 13 billion discs produced in 2003, while the demand for recordable formats (CD-R and CD-RW) remains strong and consistent at around 10 billion discs manufactured per year.

The desire for increased storage capacity led to the emergence of the Digital Versatile Disc (DVD). A red laser is used to read these discs, resulting in a capacity of up to 9.4 GB. Over the past few years, the DVD market has witnessed increasing growth due to the proliferation of DVD players in households everywhere.

While the market for DVD formats is still growing significantly, the next generation of formats is already on the horizon: Blu-ray Disc and HD-DVD (High Density DVD). In contrast to the red laser used for DVD, both competing next generation formats use a blue laser. The graph below illustrates the growth in million of discs produced worldwide from 2005 to 2010.

Source: Understanding & Solutions
The boom that began in the prerecorded DVD market last year continues unabatedly in 2004. Following the successful transition from CD to DVD in the global optical disc market, the renowned research firm “Understanding & Solutions” projects continued growth for DVD and DVD-R in the years ahead.

In 2003, 3.8 billion prerecorded DVDs were manufactured, and this number is projected to increase to 4 billion in 2004 and up to 7.8 billion by 2007.

The market for recordable/rewriteable DVDs (DVD±R, DVD±RW) has also grown rapidly. While only 207 million discs were produced in 2002, these numbers climbed to 908 million in 2003 and are expected to reach almost 5.2 billion in 2007.

SINGULUS TECHNOLOGIES will continue to reap above-average benefits from this sustained growth. In the first three quarters of fiscal 2004, the company has booked more orders for its SPACELINE replication machines than in the entire year of 2003, surpassing its own projections. Additional projects for this line are being negotiated.

Neither consumers nor replicators will ultimately decide the winner in this battle of emerging formats, but rather the content providers will — i.e., the Hollywood film studios. High quality and disc storage capacity along with superior copy protection will be key to the winner’s success.

SINGULUS TECHNOLOGIES is already well prepared for the emerging formats. Several strategic acquisitions have secured our exclusive access to components needed for this third generation of optical data storage. R&D efforts and investments in the new formats have been intensified in 2004, and efforts in the months ahead will be concentrated on the development of new in-line replication systems.

SINGULUS TECHNOLOGIES will continue to expand its leading position in the prerecorded DVD replication line sector. With a global market share of over 65 % and a clear lead over the closest competitor, the company is the undisputed market leader for this machine segment.

A shorter wavelength laser combined with a newly-developed data compression process results in higher storage capacity: 15 gigabytes per side for HD-DVD and up to 25 gigabytes per side for Blu-ray. However, the basic structure of the disc is different. HD-DVD, like conventional DVD, is made of two 0.6 mm disc halves, while Blu-ray combines discs that are 1.1 mm and 0.1 mm in thickness.

The market for the 3rd generation Optical Disc formats is not expected to take off before 2006. Market surveys project rapid growth for that year, with 53 million units of Blu-ray Disc and HD-DVD manufactured. It is anticipated that by 2010, the number of units will increase by over 1300 % to 779 million.

The introduction of Digital High Definition Television (HDTV) is a decisive development in the emergence of these two disc formats. With a resolution of 1920 x 1080 pixels, HDTV produces convincingly sharp images; red laser DVDs do not offer the storage capacity needed to record HDTV broadcasts or to play prerecorded HDTV movies.

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DVD & DVD- R/RW Market Continues to Grow

The boom that began in the prerecorded DVD market last year continues unabatedly in 2004. Following the successful transition from CD to DVD in the global optical disc market, the renowned research firm “Understanding & Solutions” projects continued growth for DVD and DVD-R in the years ahead.

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At the Replication Expo 2004 to be held in Guangzhou, China from November 8 - 10, SINGULUS MASTERING BV will introduce a number of new features to its DMS Evolution system, the latest generation of its inline mastering systems based on the DMS concept. The unique double Laser Beam Recorder capability remains central to the DMS concept and allows the system to be easily and quickly expanded for increased production capacity. Typical of its ‘workhorse’ capabilities, the DMS Evolution recording speeds have now been increased to 4R for DVD (from 2R) and to 10x for CD (from 6x). With this increase in speed, a DMS Evolution equipped with 2 LBRs can achieve an output of up to 140 DVD masters per day. Other new features to be presented at the Expo are the first order sensor and feedback loop which fine-tune the duration of the development process. This provides for an extremely high level of stability and reliability. A new Air Handling Unit (AHU) not only ensures that the air flow inside the DMS Evolution is maintained at class 100 clean room conditions, but also controls the temperature and relative humidity of the air. This will allow the DMS Evolution to operate in an office-type environment where there is considerable variation in temperature and humidity.

All DMS Evolution systems are supported by the Media Morphics encoding platform, offering a wide range of options and functionality – like the Mastering Super Highway (MSH) – for which this platform is renowned.

Apart from these new features, several less extensive technical upgrades have been implemented as well. More intelligent servomotors for the adhesive and photoresist spin-coaters have been incorporated, resulting in an ultra-precise control of the coating process.
SINGULUS EMOULD - The Advanced Moulding Competence

With more than 1,200 successful machine installations worldwide and eight years of experience, SINGULUS EMOULD GmbH represents the leader in all-electric injection moulding, one of the major technologies within the entire replication process of optical media.

As increasing writing speeds meet substantial reductions in cycle times, especially the production of recordable and rewritable formats require process reliability and precision exceedingly. By introduction of the new S2000/3 All-Electric Moulding Machine, SINGULUS EMOULD is keeping pace with the raising demands in optical disc moulding and well prepared for the permanently increasing requirements of the optical disc market.

New Machine Features
Based on our proven drive concept with servo motors and tolerance free timing belts now an advanced servo motor for the mould movement is implemented into EMOULD, which allows double the speed and maximum acceleration. This leads to best replication rates for high speed DVD R moulding and even for the smallest pit geometries found on the new high density formats.

The S2000/3 is equipped with up to four circuits Temperature Control Unit (TCU), designed by EMOULD. Minimized temperature variation for best reproducibility, advanced water flow for best heat transfer and new valve design for maximum lifetime are the main features of this unit.

Together with a more rigid machine frame, an advanced pneumatic valve board and the improved performance of our MITSUBISHI controller, stand out mechanical, optical and electrical disc properties can be achieved with EMOULD S2000/3.

1000. EMOULD Machine Delivered in June 2004 - More than 1,200 by Year’s End

The increasing demand of the EMOULD in the last years demonstrates the high acceptance of the well designed machine in the market worldwide. The reliability and performance due to the electric concept of the EMOULD is appreciated by customers worldwide. The demand for the machine has grown constantly from year to year since SINGULUS TECHNOLOGIES AG took over the all injection moulding producer company “e-mould” in 2002 and results in a production of about 1,200 machines up to date.

This enormous demand for the machine shows the huge technical capabilities of the EMOULD all electric molding machine for all optical disc formats for the benefit of the replicators. The replicators highly appreciate the possibility to install production lines for different formats from one manufacturer with one machine for all optical disc formats.

The well experienced engineering team of SINGULUS EMOULD GmbH guarantees the permanent optimization of the replication processes. The worldwide situated service departments with training centers enable a competent know-how transfer to the customers to produce high quality discs and to achieve profitable business.
Dr.-Ing. Axel Koster
Became SINGULUS TECHNOLOGIES’ new Technical Director

After completing his engineering studies at the University of Stuttgart and a subsequent doctorate at the Institute for Machine Tools, in 1987 Axel Koster joined the TRUMPF Group, a leading manufacturer of lasers and machine tools with an annual turnover of 1.2 billion Euro. After two years as assistant to the Managing Director of Operations he became head of production and material management for the CO2-laser subsidiary. In 2000 he was promoted to Plant Manager for HÜTTLINGER Elektronik GmbH+Co.KG, the electronics production center of the TRUMPF Group in Freiburg with 320 employees. Dr. Axel Koster was born in 1957. He is married and has two children.

Roberto Calleja
New Manager Customer Support

In May 2004, Roberto Calleja was appointed as new Manager Customer Support of SINGULUS TECHNOLOGIES.

After the completion of his mechanical engineering studies he began his professional career as a computer specialist for three years. He went on to become a mechanical engineer at Leybold AG where he gained first experience in the field of Optical Disc.

In 1997, Mr. Calleja started his career at SINGULUS TECHNOLOGIES as a commissioning engineer. In this position he was able to extend his knowledge in the area of pre-recorded CD and DVD formats. During that time, he established considerable customer contacts worldwide, particularly in Asia, South America and Europe, helping him to become Manager of Commissioning in the year 2000. Among his responsibilities was the planning of the commissioning engineers on site as well as for CD/DVD recordable and rewritable.

Now in his seventh year with the company, he was promoted to his current position as Manager Customer Support due to the detailed understanding of customers’ requirements and his well founded technical expertise.