DEVELOPMENT OF DVD-R PROCESS BASED ON ORGANIC MEDIA

A Major Project submitted in the partial fulfillment of requirement
For the award of the Degree of

MASTER OF ENGINEERING
IN
POLYMER TECHNOLOGY

Submitted by

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CERTIFICATE

This is to certify that Mr. Alok Kumar Bhatt has satisfactorily completed the project work entitled **"Development of DVD-R process based on organic media"** in the partial fulfillment of the requirement for the award of the degree of Master of Engineering in Polymer Technology from Delhi College of Engineering, University of Delhi, Delhi during the session of 2006-2009. The matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

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CONTENTS PAGE NUMBER

ABSTRACT

Polymers seem to provide a solution to almost every deed in life, from preparing daily commodities to the highly sophisticated, artificial heart valve. Due to the availability of such special kind of properties including high heat strength, very high refractive index and excellent mechanical properties in polycarbonate, it is possible the existence of optical disc.

Till the date the performances and the applications point of view there are lots of study done in this field but the processing technicality involve in the manufacturing of DVD-R via various processes still to revealed.

The injection moulding of digital video disk substrates requires the selection of over forty process parameters to ensure the satisfaction of over twenty quality attributes. The present work develops a methodology for process characterization through empirical models, termed transfer functions. The transfer functions can then be used to optimize a process, compare different processing systems, or predict the output quality from input processing conditions and also serves detailed study of the processing of optical discs, the material, technologies and engineering behind the manufacturing or processing of the world's most reliable source of storage media.

CHAPTER-1

INTRODUCTION

INTRODUCTION ABOUT DVD-R

The optical disc was invented in 1958. In 1961 and 1969, David Paul Gregg David Paul Gregg was the inventor of the laserdisc. Gregg was inspired to create the laserdisc in the late 1950s. He originally had it patented as the "Videodisk" in 1961....Registered a patent for the analog optical disc for video recording, (US Patent 3,430,966). It is of special interest that US Patent 4,893,297 filed 1968, issued 1990, and generated royalty income for Pioneer Corporation’s department of veteran’s affairs.

Until 2007 encompassing the CD, DVD and Blue-Ray disc systems. In the early 1960s, the Music Corporation of America bought Gregg's patents and his company, Gauss Electro physics.

Likewise, in 1969 Holland, Philip Research physicists began their first optical videodisc experiments at Eindhoven. In 1975, Philips and MCA join efforts, and in 1978, commercially much too late, they presented their long-awaited laserdisc in Atlanta, Georgia, USA MCA delivered the discs, Philips the players; the presentation was a technical and commercial failure; the Philips/MCA cooperation ended.

In Japan and the U.S., Pioneer succeeded with the videodisc until the advent of the DVD. In 1979, Philips and Sony, in consortium, successfully developed the Compact Disc in 1983.

FIRST-GENERATION

Initially, optical discs were for storing music and computer software. The laser disc format stored analog video signals, but, commercially, lost to the VHS videotape cassette, mainly its high cost and non-record ability; other first-generation disc formats are designed solely to store digital data.

Most first-generation disc devices had an infrared laser reading head. The minimum size of the laser spot is proportional to its wavelength, thus wavelength is a limiting factor against great information density, and too little data can be stored so. The infrared range is beyond the long-wavelength end of the visible light spectrum, so, supports less density than any visible light colour. One example of high-density data storage capacity, achieved with an infrared laser, is 700MB of net user data for a 12 cm compact disc.

NOTE: other factors affecting data storage density are, for example, a multi-layered infrared disc would hold more data than an identical single-layer disc; whether CAV, CLV, or zoned-CAV; how the data are encoded; how much clear margin at the centre and the edge.

- ❖ Compact Disc
- ❖ Laser Disc
- ❖ Magneto-Optical Disc
    - Mini Disc

SECOND-GENERATION

Second-generation optical discs were for storing great amounts of data, including broadcast-quality digital video. Such discs usually are read with a visible-light laser (usually red); the shorter wavelength and greater Numerical aperture allow a narrower light beam, permitting smaller pits and lands in the disc. In the DVD format, this allows 4.7 GB storage on a standard 12cm, single-sided, single-layer disc; alternately, smaller media, such as the

A Mini disk is a magneto-optical disc-based data storage device initially intended for storage of up to 80 minutes of digitized sound. Today, in the form of Hi-MD, it has developed into a general-purpose storage medium in addition to greatly expanding its audio roots.

Data Play is an optical disc system developed by Data Play Inc. and released to the consumer market in 2002. Using very small disks enclosed in a protective cartridge storing 250 MB per side, Data Play was intended primarily for portable music playback, including both pre recorded disks and user-recorded disks formats, can have capacity comparable to that of the larger, standard compact 12 cm disc.

- ❖ HI-MD
- ❖ DVD And Derivatives
    - DVD-Audio
    - Dual Disc
    - Digital Video Express
- ❖ Super Audio CD
- ❖ Video CD

- Super Video CD
- Enhanced Versatile Disc
- GD-Rom
- Data Play
- Phase-Change Dual
- Universal Media Disc
- Ultra Density Optical

MAJOR EVENTS IN FIELD OF DVD-R (OPTICAL MEDIA)

- 1972 First demonstration of an Optical Disc
- 1980 Standards for CD were fixed by Sony and Philips
- 1982 First CD-Player; First CD: Billy Joel's 52 nd Street
- 1985 CD-ROM Drives come to the market
- 1992 Sony and Philips starts developing the DVD
- 1995 All important companies declare one DVD standard
- 1996 Introduction of the DVD in US and Japan
- 1997 Introduction of the DVD and CD-RAM in Europe
- 1998 Introduction of DVD-RAM / DVD-R are expected
- 2002-2007 Format war continues between DVD+/-R/RW/RAM
- Two major competing formats; DVD-R (Fuji) and DVD+R (Philips)
- Future discs HD-DVD (Toshiba) with the capacity of 20-25 GB
- But 2007-08 Toshiba lost the race in the DVD forum (due to complication at the customer and drive manufacturer ends) to establish the HD-DVD as the future storage media.
- DVD forum unanimously agreed for the DL and BD-R will be the future storage media due to simplicity at the user ends while their processing is too tough as compare to HD-DVD.
- DVD forum, the details about the DVD forum are given in annexure-1

WHAT IS DVD?

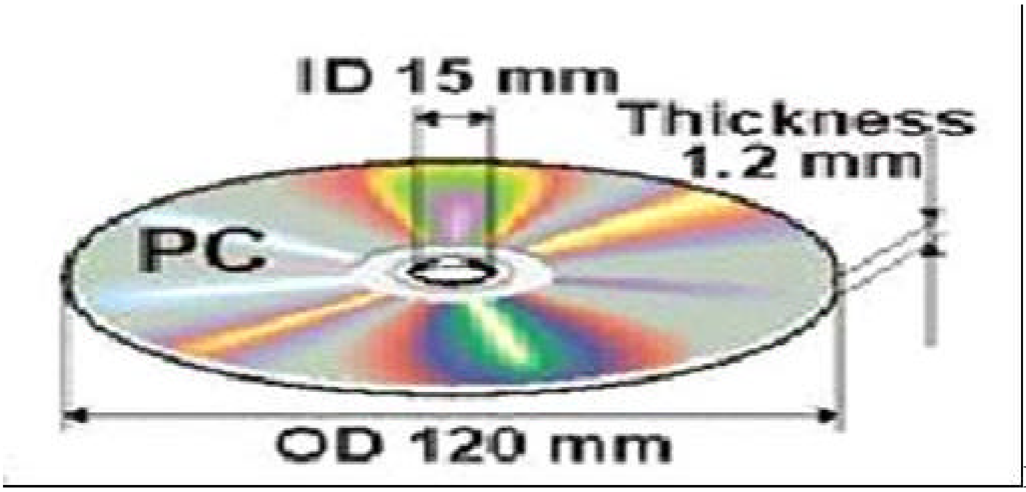
DVD also known as "Digital Versatile Disc" or "Digital Video Disc," is an optical disc storage media format. Its main uses are video and data storage. DVDs are of the same dimensions as compact discs (CDs), but store more than six times as much data.

Variations of the term DVD often describe the way data is stored on the discs: DVD-ROM (Read Only Memory) has data that can only be read and not written; DVD-R and DVD+R can record data only once, and then function as a DVD-ROM, DVD-RW, DVD+RW, and DVD-RAM can both record and erase data multiple times. The wavelength used by standard DVD lasers is 650 nm.

DVD-R is a DVD recordable format a DVD-R typically has a storage capacity of 4.71 GB (or 4.38 GB), although the capacity of the original standard developed by Pioneer was 3.95 GB (3.68GB) Both values are significantly larger than the storage capacity of its optical predecessor, the 700 MB CD-R – a DVD-R has 6.4 times the capacity of a CD-R. Pioneer has also developed an 8.54 GB dual layer version, DVD-R DL, which appeared on the market in 2005.

DVD IN TERMS OF MANUFACTURING

A DVD is composed of an optically transparent substrate (typically polycarbonate), with injection moulding as the primary manufacturing process. For pre-recorded media, the data stored on a disk in the form of pits, is moulded into the disk during the injection moulding process, as shown in Fig.1.



Disc

Pits

Fig.1 Outer geometry and pits of the DVD-R

All formats of DVD require the bonding together of two 0.60 mm polycarbonate substrates. One half known as active and other half is called as dummy. Active having track in which data stored via formation of pit and lands at the time of burning process. Data stored in the pits while lands are empty. Dummy is for providing the mechanical, dynamic strength to the disc.

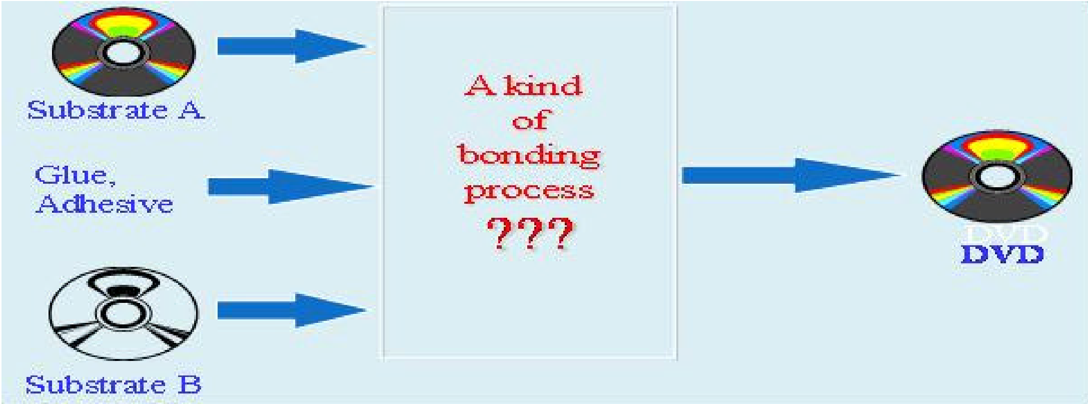


Fig. 2 Bonding of two halves of the DVD

PITS AND LAND RECORDING

The phenomenon of formation of pits and land has been shown in fig.3

- ❖ The data to be stored on the disc which is modulated into a long bit stream of ones and zeros
- ❖ After EFM + modulation there are 2 min. and 10 max. zeros between the ones
- ❖ Recording Phase (mastering): Bit stream=> Pits and lands
- ❖ The ones in the bit stream toggle the recording laser on /off
- ❖ Reading Phase (Reading disc): Pits and lands=> Bit stream.

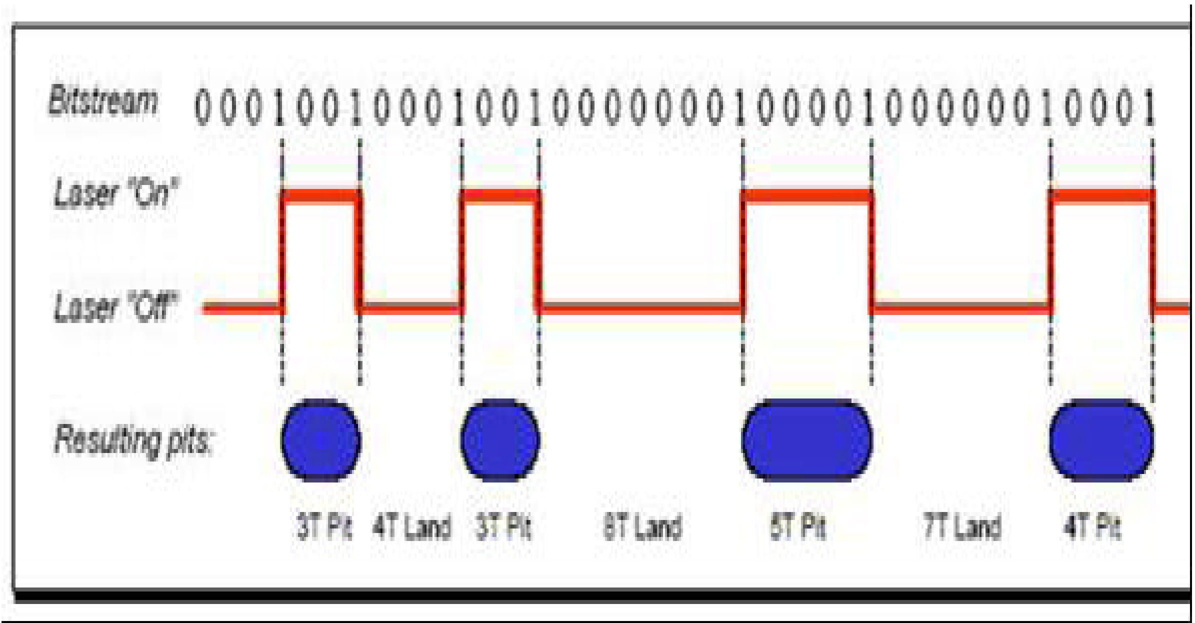


Fig 3 Phenomenon of formation of pits and lands

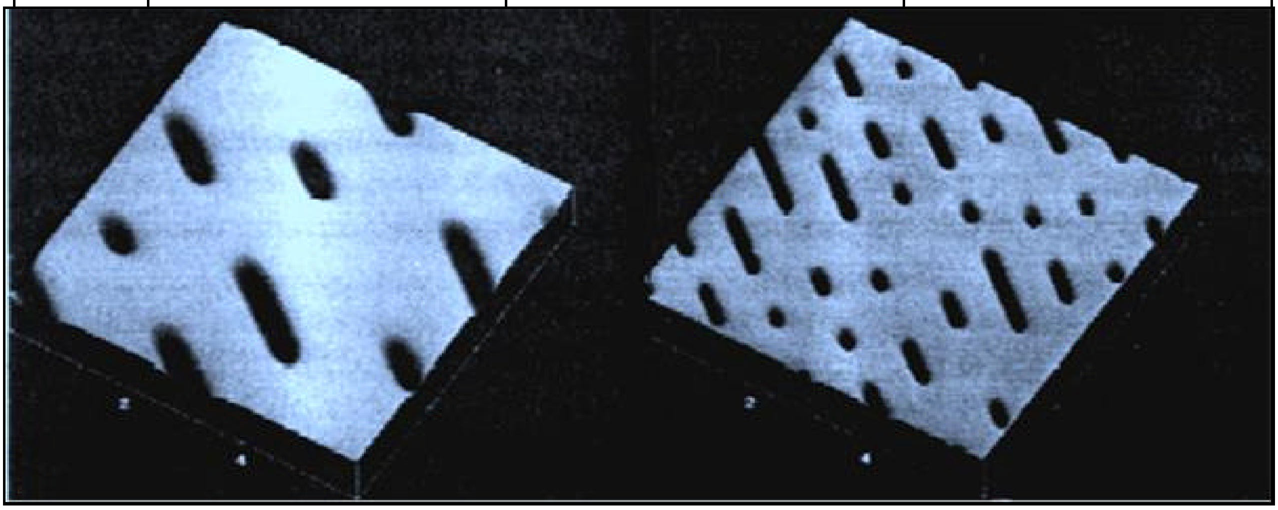
DVD vs CD

The main characteristic difference in DVD as compare to CD is their storage capacity.

The higher storage capacity occurred due to their track pitch is just half of the CD that means formation of no of pits and land are more in the DVD.

Table 1 Comparison between DVD and CD

S. No.	Characteristic Feature	DVD	CD
1.	Disc Diameter	120 mm (5 inches)	120 mm (5 inches)
2.	Disc Thickness	1.2 mm (2 bonded discs)	1.2mm
3.	Track Pitch	0.74um	1.6um
4.	Laser Wave Length	595 nm	780 nm
.	Numerical Aperture	0.6	0.45
6.	Minimum Pit Length	0.4 nm	0.834
7.	Error correction	Red Solomon product code	CIRC
8.	Signal Modulation	8-16 Modulation (EFM+)	8-14 Modulation (EFM)
9.	Reference Scanning	3.49 m/s Single Layer	1.2-1.4 m/s
10.	Velocity	3.84 m/s Dual Layer	
11.	Data Capacity	4.7-17 GB	650 MB
12.	Max Data Rate	10.08 Mbps	1.4112



OBJECTIVE

Production of DVD-R or any optical disc required a huge utility set up due their various quality check points, and the raw material used derived from the petroleum. Energy as well as raw material cost keeps on increasing day by day because energy also derived from the petroleum, in spite of that customer wants quality product in low price. In this scenario manufacturer can only survive when he produces quality product in volume, therefore the per disc cost will minimize.

In order to stay competitive, improvement in productivity through reduction in process cycle time and improved yield is required. This can be done by understanding how each input material and process parameter affects each quality output. This would leads to productivity and yield gains.

So the objective of this project work is to develop such processes for DVD-R that are applicable at each and every stage of production in terms of raw material, processes and machine characteristics. With such developments we achieve specific properties and processing conditions that are able to produce quality product according to quality index set by the DVD-forum.

CHAPTER-2

EXPERIMENTAL WORK

PROPERTIES REQUIRED IN THE MATERIAL BEING USED FOR THE BLANK SUBSTRATE OF DVD

The material used (PC) for the substrate must offer the following combination of properties.

- High light transmittance in the diode laser operating range
- High dimensional stability
- High heat stability
- Accurate mould surface reproduction
- Low birefringence
- Good level of mechanical properties
- Melt process ability
- Exceptional purity
- Become liquid at 280°C, intrinsic viscosity
- Broad processing window

Important properties of polycarbonate which are being used in the processing of the DVD-R blank substrate are presented in Table 2.

Table 2 Properties of polycarbonate desired for the processing of the DVD-R blank substrate

POLYCARBONATE (PC)	PC CD 2005	PC DP1-1265
Glass Transition Temp (T_g)	145°C	143°C
Melt Flow Index(MFI)	60 g/10 min	71 g/10 min
Transmission	90 - 91%	
Moisture Absorption	0.15% (20°C, 50% RH)	

Recommended moisture content for processing = 0.02%.

SYNTHESIS OF POLYCARBONATE

The interfacial polymerization method for the synthesis of PC known as, **Solvent or Phosgene process** has been given as below in Fig 4 while an ester-exchange polymerization method used for the synthesis of PC known as **Melt Process or Non-Phosgene Process** in Fig. 5

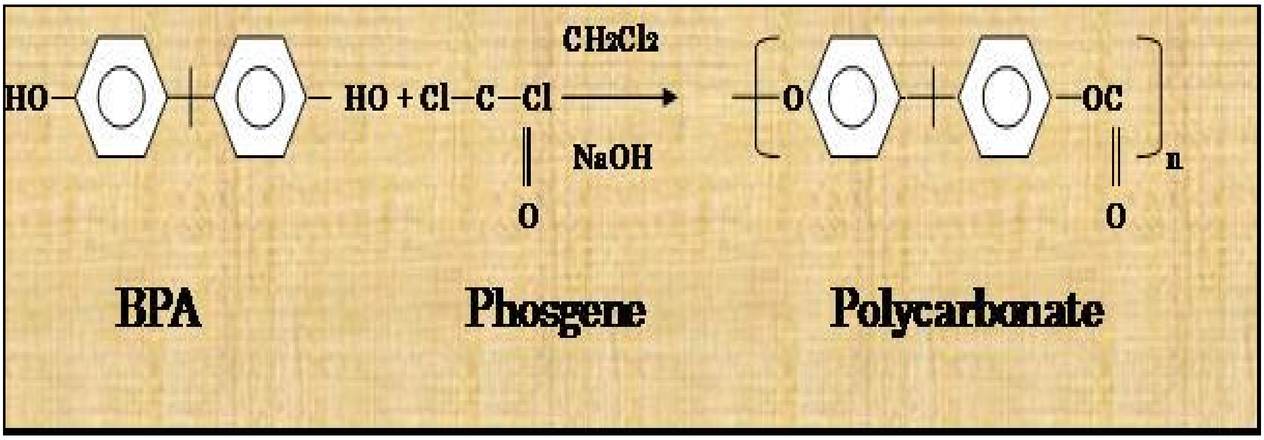


Fig 4 Solvent or Phosgene Process

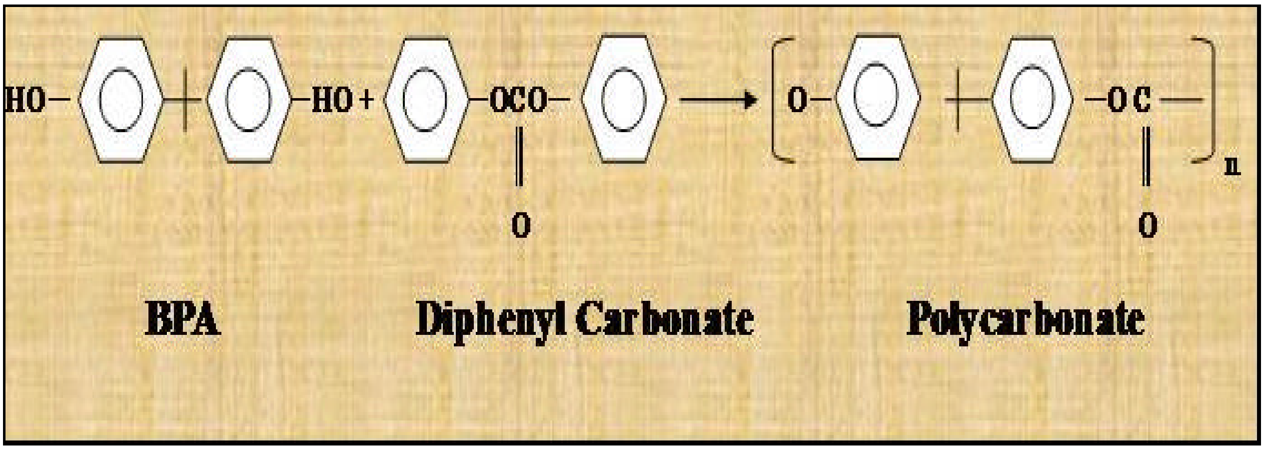


Fig. 5 Melt Process / Non-Phosgene Process

PROPERTIES OF DVD-R GRADE POLYCARBONATE

This material we haven't developed in our laboratory as it is already available in the market. So we validate all the requisite properties for the DVD-R production. The observed detailed properties for the DVD grade polycarbonate are listed in **annexure-2.** All the Commercially available DVD-R grades of polycarbonate and their manufacturer which are being used for the processing of DVD-R blank substrate are presented in Table 3.

Table 3 Commercially available DVD-R grades of polycarbonate and their manufacturers

MANUFACTURE AND SUPPLIER	TRADE NAME	GRADE NAME	TYPE OF GRADE
BAYER	MAKROLON	DPI-1265,	High Flow
		DPI-1189	High Flow
		2085CD	High Flow
		1080DVD	High Flow
GE	LEXAN	OQ1030(L)	High Flow
		OQ1020(C)	Moderate flow
		OQ1020(L)	High Flow
		OQ1030(C)	Moderate flow
TEIJIN KESI	PANLITE	AD5503	High Flow

CHAPTER 3

RESULTS AND DISCUSSION

DVD-R CONSISTS MAINLY SIX PROCESSES AS GIVEN IN THIS CHAPTER

3.1 MOULDING PROCESS

3.1.1. Pre-drying of polycarbonate

3.1.2. Moulding of polycarbonate

3.1.3. The way to a good substrate in terms of the performance

3.1.4. Properties which affects the performance of the blank substrate

3.2 DYE PROCESS

Media (Azoic based dye)

3.3 ANNEALING PROCESS

Removal of residual stress present in the moulded substrate as well as removal of solvent remains in the surface of the disc after dye dispensing process

3.4 SPUTTERING PROCESS

Deposition of reflecting layer via formation of plasma

3.5 BONDING PROCESS

Joining of active and dummy discs by acrylics base resin

3.6 UV CURING PROCESS

Due to UV light acrylics resin convert in to polymer with the help of photo initiators

MOULDING PROCESS

Injection Moulding of validated polycarbonate resin in the form of blank substrate (active and dummy) can be divide in to following categories.

- ✓ **PRE DRYING OF POLYCARBONATE**

Before the moulding of the substrate, it is necessary to eliminate all the moisture present in the material. Moisture present in the granule will convert in to gaseous state by high processing temperature which leads to the formation of bubble and streak as shown in Fig. 6. The presence of moisture also triggered chemical reaction in hydrolysis sensitive plastics which leads to the material degradation.

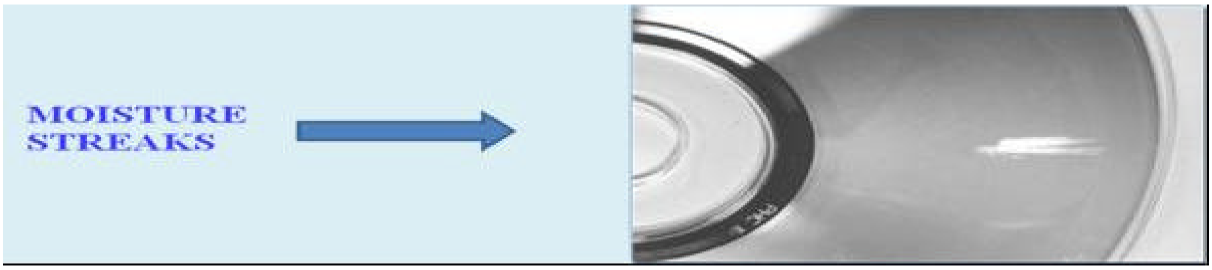


Fig 6 Moisture streak in DVD

To eliminate the entire problem or remedy for all the above problems is pre-drying or dehumidification of the material before the process.

PRE HEATING/DEHUMIDIFICATION PROCESS OF POLYCARBONATE

The dehumidification process eliminates the moisture from granules as shown in Fig 7

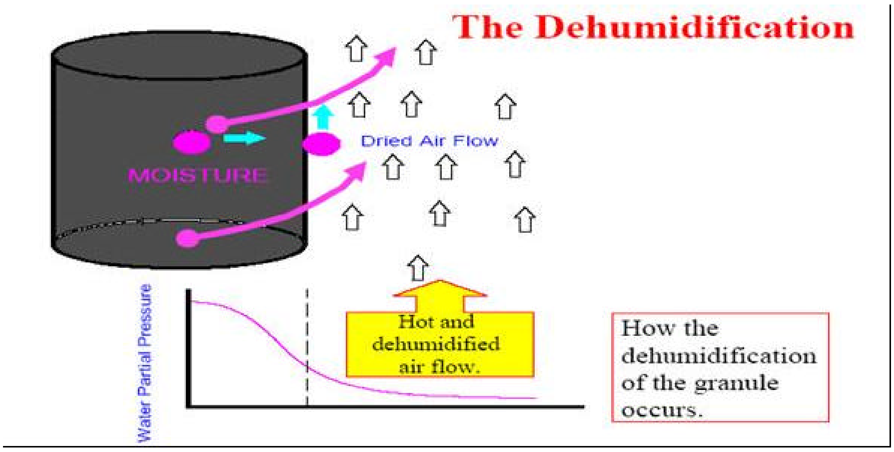


Fig7 Dehumidification process

To prevent the formation of moisture/silver streak, adequate material drying is essential for the production of DVD-R. Drying is normally performed with dry-air driers. The capacity of the driers should be such that proper drying may be ensured with an average pellet residence time of at least 2 h. It is particularly important that the pellets should be heated up rapidly by the dry air. Once the material has been dried, it should not be allowed to come into contact with the ambient air again. A similar condition is also applied for the transport of the material from the drying hopper to the injection moulding machine. The designed dryer set up of for the drying of poly carbonate presented in the following Table 4.

Table 4 Dryer setup w.r.t. types of air used, drying time and the temperature

DRIER TYPE	DRYING TIME (h)	DRYING TEMPERATURE (°C)
Circulating air drier (50 % Fresh air)	4 – 12	120
Fresh air drier	3 – 4	120
Dry air drier	2 – 3	120

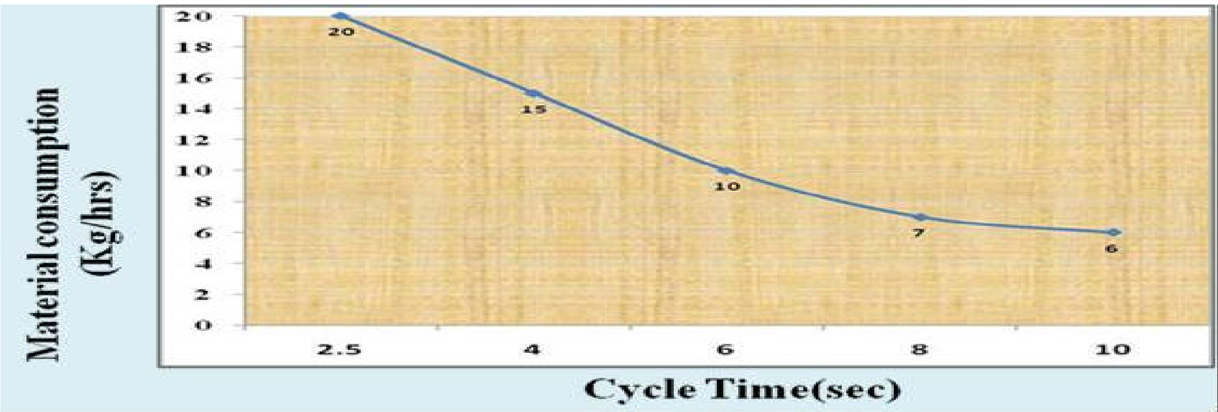
The drying temperatures as specified in the Table 4, should not be exceeded by any considerable margin, otherwise there will be a danger of conglomeration. Observing these recommendations and employing a drier of the correct design (performance data), a residual moisture content of no more than 0.01 % will be guaranteed in the pellets.

The capacity of a drier is characterized by size of the drying hopper and the air throughput of the dry air generator. The drier should be designed in such a way that the pellets remain inside the drier for at least 2 h. The size of the drying vessel should be determined on the basis of the moulding weight, cycle time, number of injection moulding machines linked to the drier and the residence time of the material in the drier.

The size of vessel required for an injection moulding machine with a cycle time of 6 s (material throughput approx. 10 kg/h), a bulk density of 0.6 kg/dm^3 and a residence time of 2.5 h in the drier is worked out as follows.

Minimum volume = material throughput * residence time / bulk density.

Minimum volume = 10 kg/h * 2.5 h / 0.6 kg/dm^3 = 41.7 dm^3

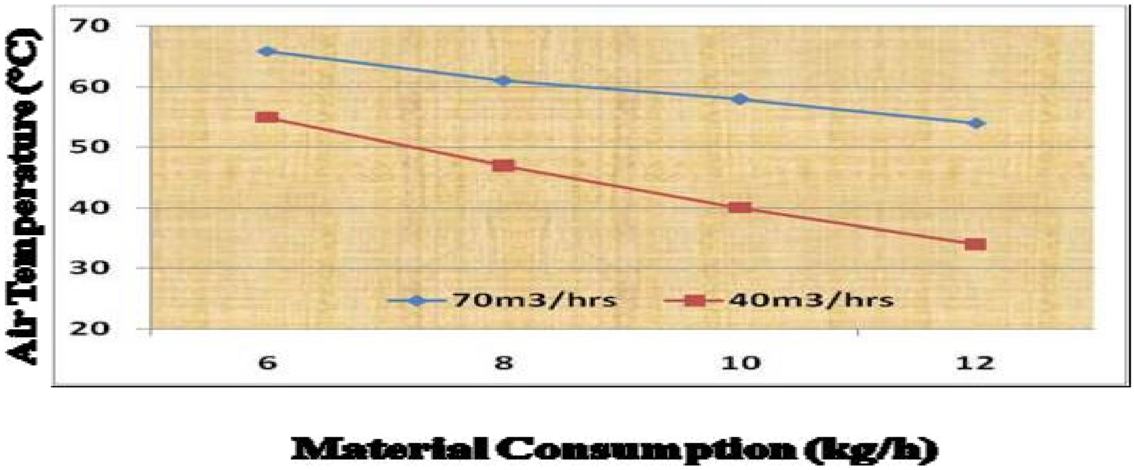


Graph 1 Relation between the machine cycle time and material consumption

This graph clearly shows that the output/ material consumption depend on the machine cycle time. As the cycle time decreases, material consumption increases.

REQUISITE AIR THROUGHPUT

The dry air serves first and foremost to heat the material to the target drying temperature (120°C) as rapidly as possible. The necessary air throughput is a function of the material throughput. The line Graph 2 as given below shows a relation between the material consumption and the air temperature used for drying the material.



Graph 2 Relation between material consumption and the air temperature used for drying

This graph shows that when material consumption is high then higher dry air temperature is required for drying.

TEMPERATURE EFFECTS

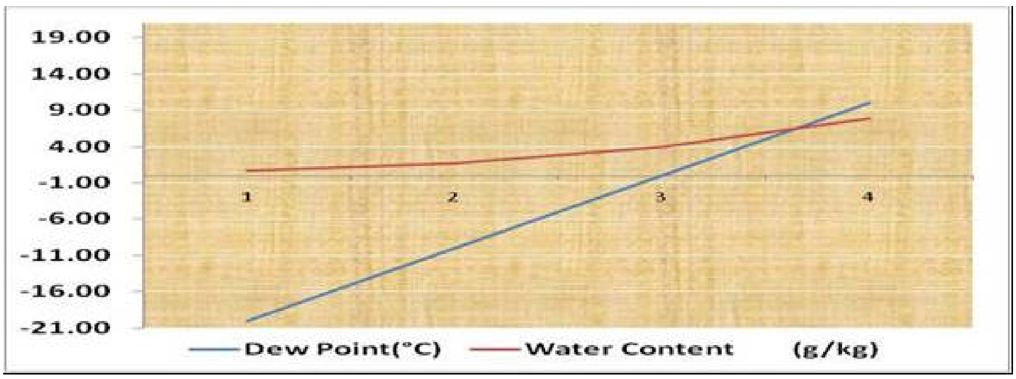
Increasing the temperature from 90 to 120°C will have the effect of doubling the diffusion rate of water in PC and thus of divide in two the requisite drying time. It would be possible to reduce the drying time still further by increasing the drying temperature again, but there are limits on this due to the softening of the material. That is why the actual temperature prevailing at the entry to the drying hopper should be between 120 and 125°C. The requisite drying time is also a decisive function of the drying temperature.

DEW POINT

The dew point is the temperature at which the moist air is saturated with water. As far as the drying process is concerned, a low dew point means low water content in the dry air. A correlation between the dew point and relative humidity data have been presented in Table 5 and graph.3 relation between dew point and the amount of water content present.

Table 5 Correlation between the dew point and relative humidity

DEW POINT (°C)	WATER CONTENT (G/KG)	PARTIAL PRESSURE (BAR)	RELATIVE HUMIDITY AT 120 °C (%)
-20.00	0.65	0.0010	0.05
-10.00	1.65	0.0026	0.13
0.00	3.95	0.0062	0.31
10.00	7.88	0.0125	0.62



Graph 3 Relations between dew point and the amount of water content present

This graph clearly shows that percentage of water content depend upon the dew point. If the dew point would rise, water content present would also rise.

- ✓ **MOULDING OF POLYCARBONATE**

The injection moulding of digital video disk substrates requires the selection of over forty process parameters to ensure the satisfaction of over twenty quality attributes. There are many quality measurements for DVDs, with most processing parameters affecting multiple product attributes. For example, increased cooling time has a desirable effect on most quality characteristics, yet it has a negative impact on production efficiency.

For stabilizing these parameters, it is necessary to have such a moulding machine which is capable of providing the all the controls.

There are very few injection moulding machine makers which are capable of providing quality of the products with improved productivity. The injection moulding machines used for the producing the blank substrate are given as below.

- ❖ Sumitomo S-D series-Japan
- ❖ Net stall –Germany
- ❖ JSW-Japan

The widely used molding machine in the optical industry is Sumitomo SD-series.

SUMITOMO (Japan) SD.35-40

The Fig 8 has been shown complete set-off injection moulding machine.

PARTS OF AN INJECTION MOLDING MACHINES

Injection molding machine divided in to two parts.

- ❖ Injection Unit
- ❖ Clamp Unit

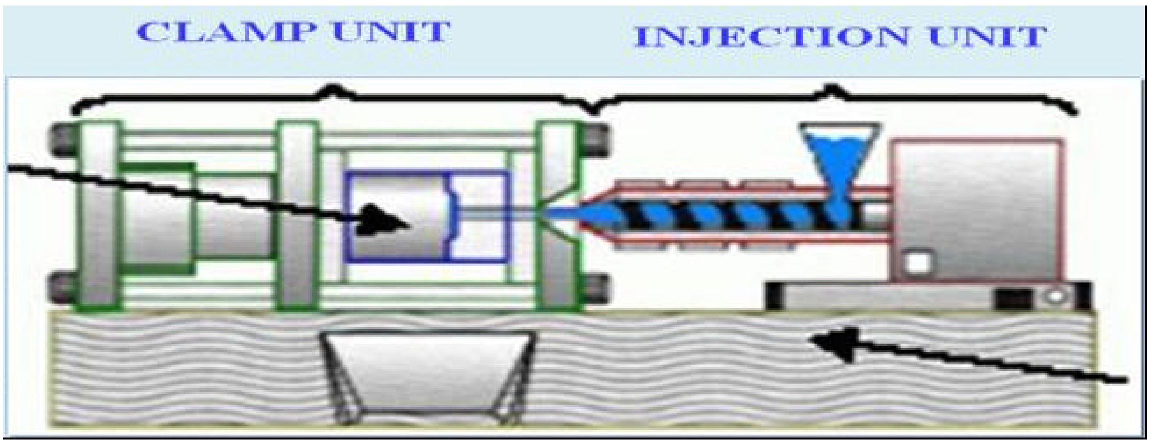


Fig 8 SUMITOMO injection molding machine

INJECTION UNIT

Injection unit consist of the three major parts, which are as follows.

- ❖ Hardened and coated surface barrel
- ❖ Nozzle
- ❖ Injection screw

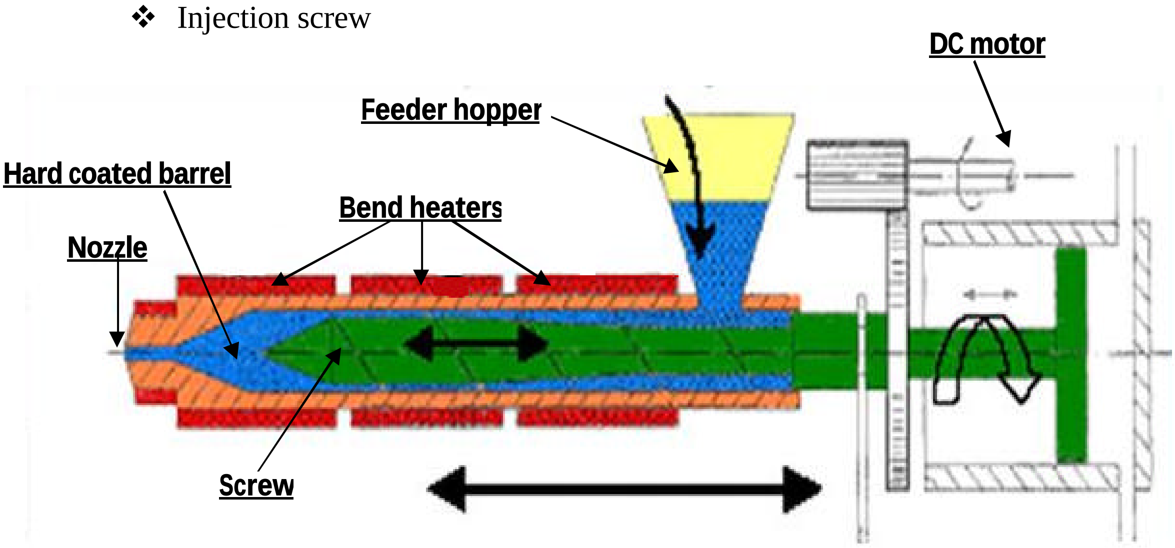


Fig 9 Parts of injection unit

INJECTION SCREW HAVING THREE ZONE (SCREW)

- ❖ Feed zone - Soaks in material
- ❖ Plasticizing Zone- Material start softened due to heat and shear force developed due to inner dia changes
- ❖ Metering zone - Homogenizing the melt

All three zones of injection screw are depicted in Fig.10.

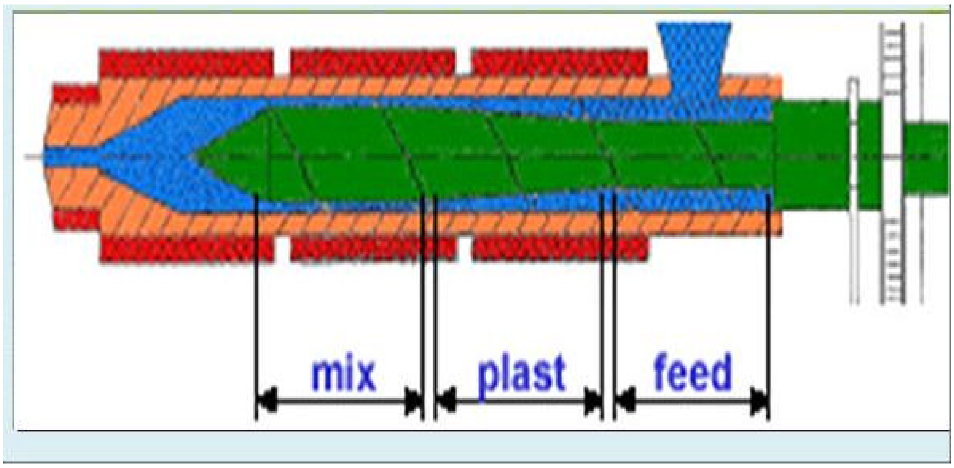


Fig 10 Injection screw

TYPES OF NOZZLE USED IN DVD-R PROCESSING

- Open –Nozzle
- Shut Off Nozzle

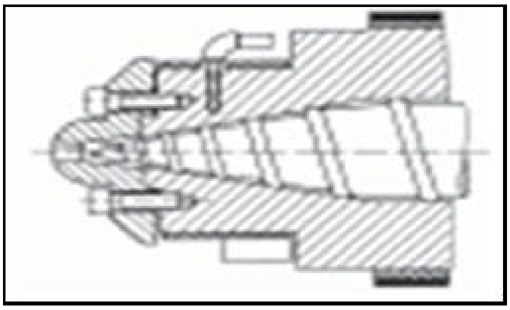


Fig 11 (a) Open nozzle

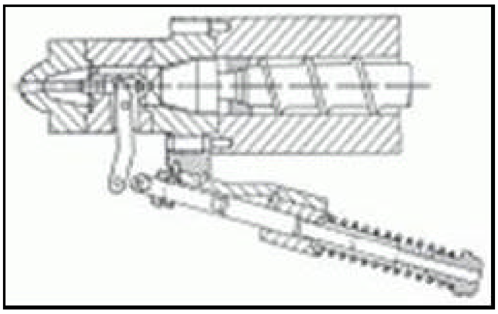


Fig 11 (b) Shut off nozzle

Shut off nozzle is preferable to avoid the drooling.

CLAMP UNIT

Toggle type clamping system used to clamp the moving half.

DVD-R MOULD

DVD-R mould consists of …

- **MOVING HALF**

In the moving half, mirror is mounted through cavity ring and..

- **STATIONARY HALF**

In this half stamper is mounted with the help of vacuum and stamper holder. The two half of the mould has been described in Fig12.

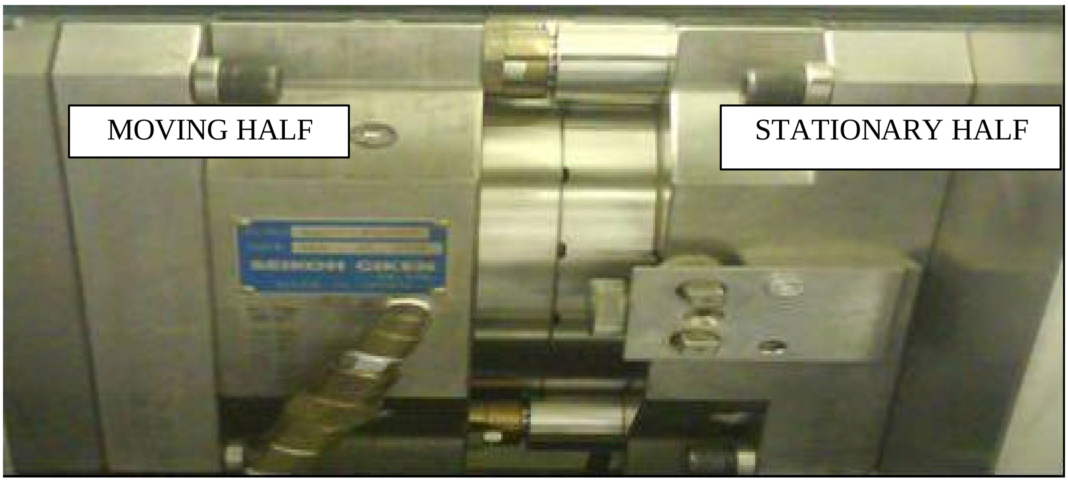


Fig. 12 Two half of the DVD-R mould

STAMPER

DVD-R stamper is a metallic disc in which circular track engraved via mastering and galvanic process. The engraved tracks transfer or embossed in to the molten polymer at the time of molding. Therefore stamper is prime responsible for the formation of tracks on active disc.

The final processed DVD-R stamper is depicted in Fig 13.

Fig 13 DVD-R stamper

MIRROR

Mirror provides the smooth supports for the other sides of the disc. It also acts as a cavity. Mirror is responsible for the mechanical supports which controls the eccentricity tracking error and focusing error.

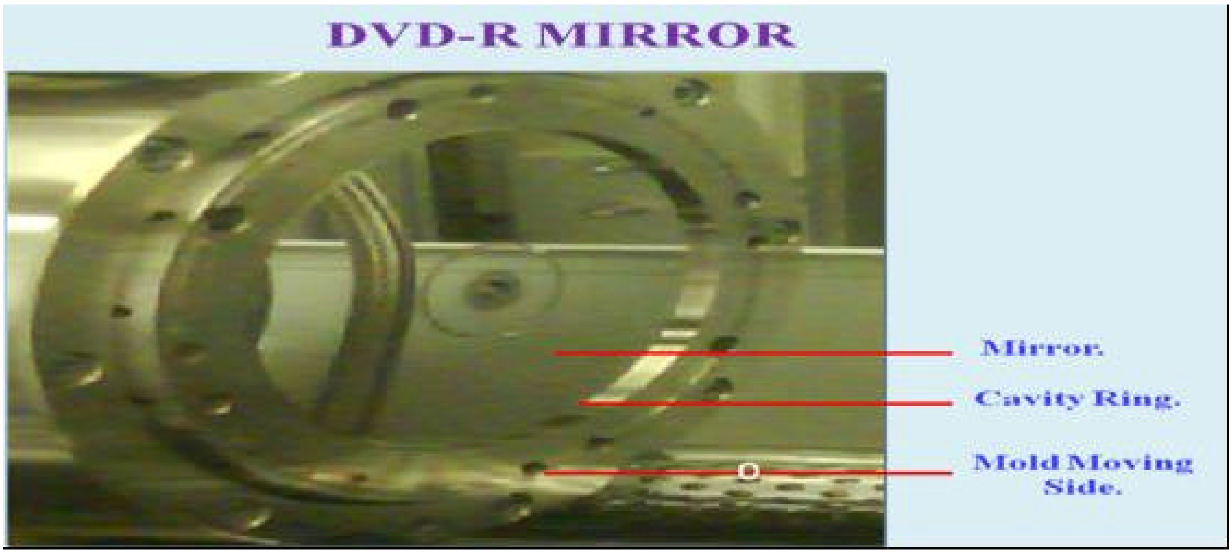


Fig. 14 DVD-R mirror

COMPLETE MOLDING CYCLE FOR THE DVD SUBSTRATE

Injection molding of DVD-R is completely different than the conventional injection molding in conventional molding mold is closed with full clamping tonnage and then filled the cavity but here in DVD-R cavity is partially filled in a closed mold and clamping tonnage will apply in a series of steps known as coining profile. The Complete schematic **of injection molding process** of DVD-R has been shown in Fig.15

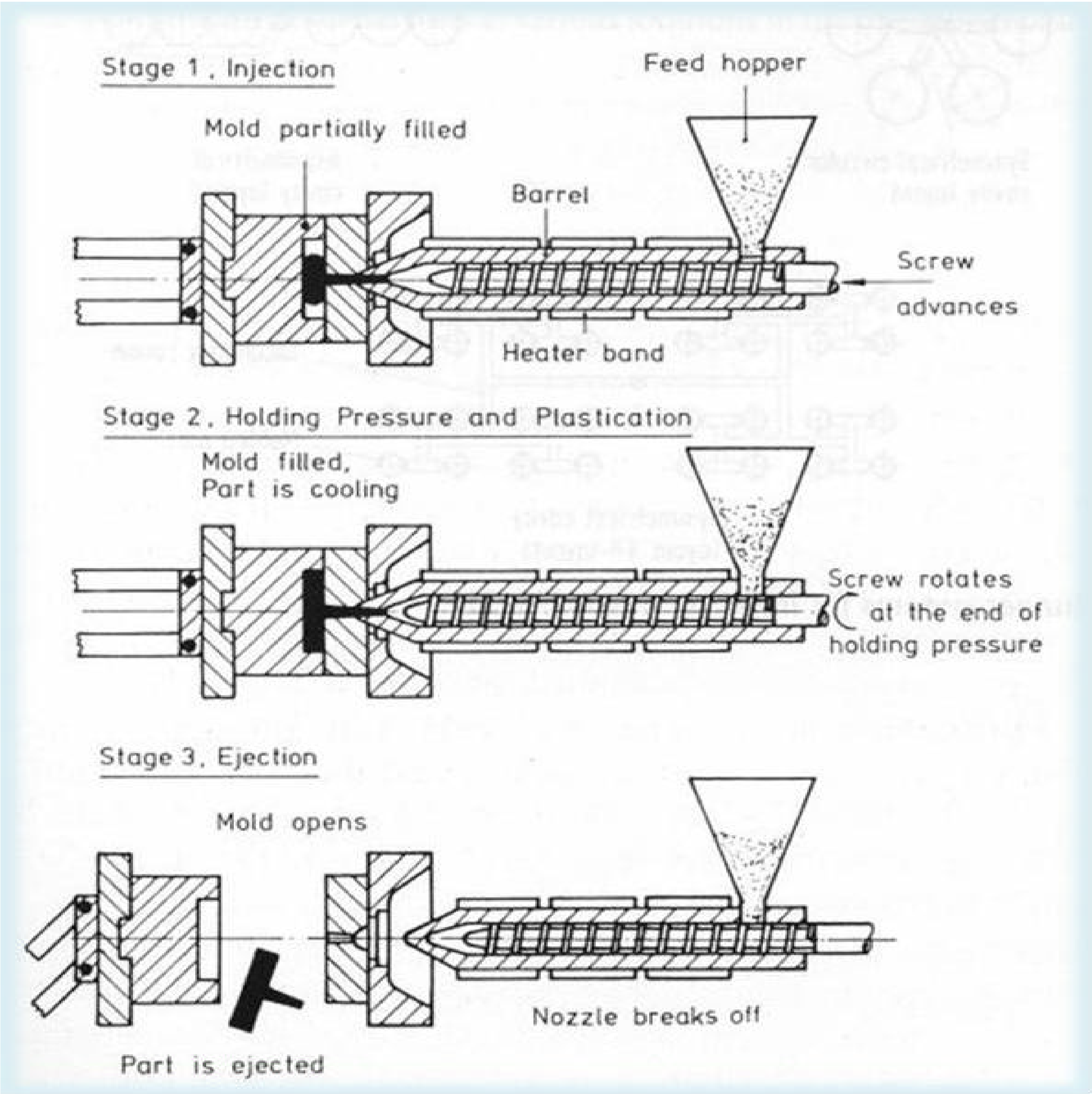


Fig 15 Complete molding cycle for the DVD substrate

CLAMPING MECHANISM

DVD produced by direct injection but by the injection compression technique whereby melt is injected at a pre-defined point before the mould is fully closed. This method ensures excellent groove reproduction and dimensional accuracy within nanometres as well as low birefringence and high deflection temperature.The clamping mechanisms used in the making of blank substrate are ICM and coining.

The clamping mechanism used in the making of blank substrate is ICM and coining. The clamping mechanism for molding of blank substrate, used in various forms of optical media is explained in Fig16.

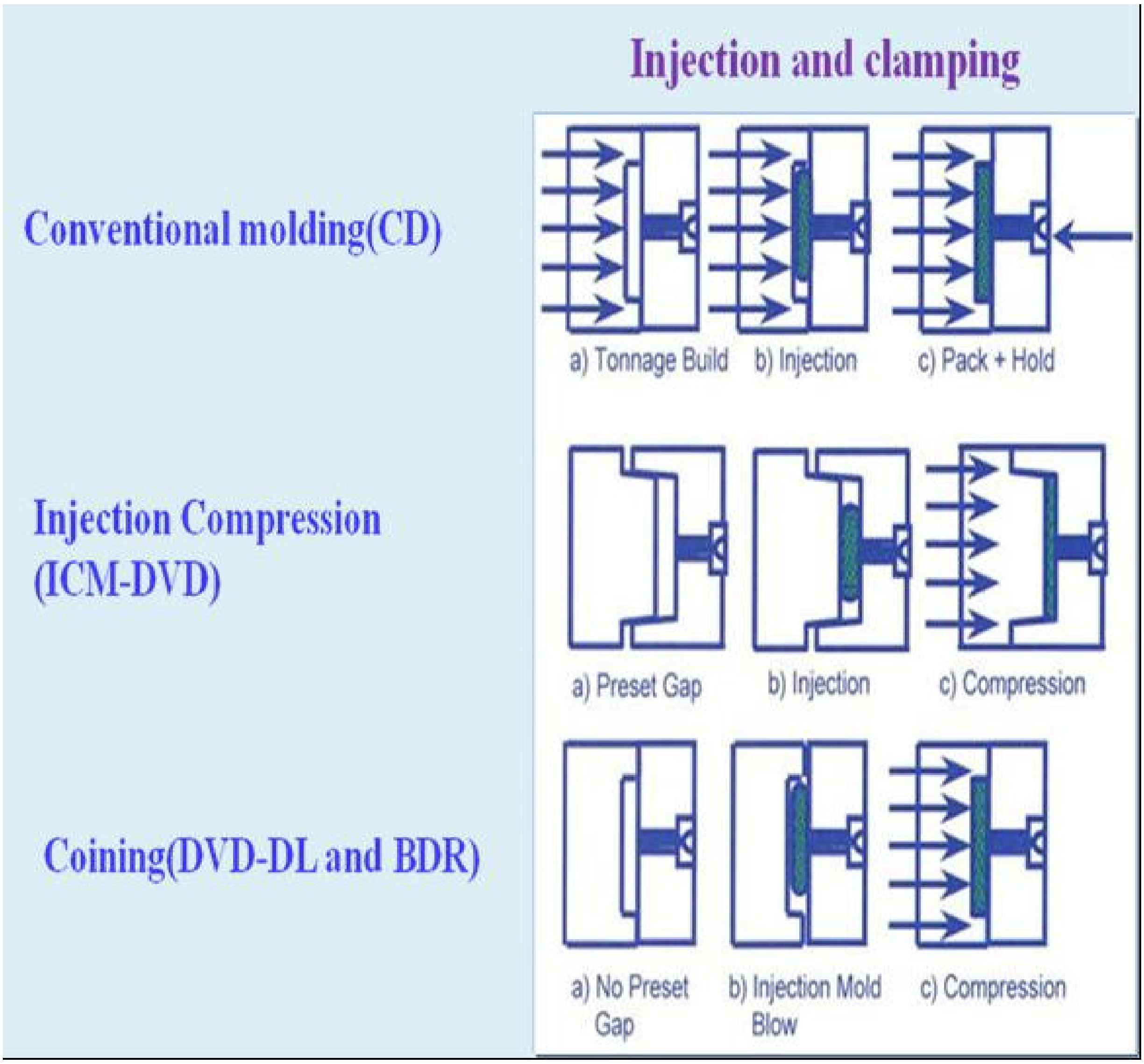


Fig. 16 Clamping mechanism of molding process

MOLDING PROCESS STABLISATION

There are more than 40 recorded and unrecorded parameters which are needed to qualify and 90% of the disc performance depends upon molding quality of the blank substrate. The performance of the discs depends upon the following discs parameters.

- Proper formation of Grove depth (GD) or Replication of grove geometry from stamper
- Birefringence
- Radial Tilt and Tangential Tilt

All the above properties depend upon the:

- Clamping profile of mould
- Temperature profile mould and barrel
- Injection velocity
- Pressure profile
    - Filling pressure or injection pressure
    - Hold Pressure of mould

CLAMPING PROFILE OF MOULD

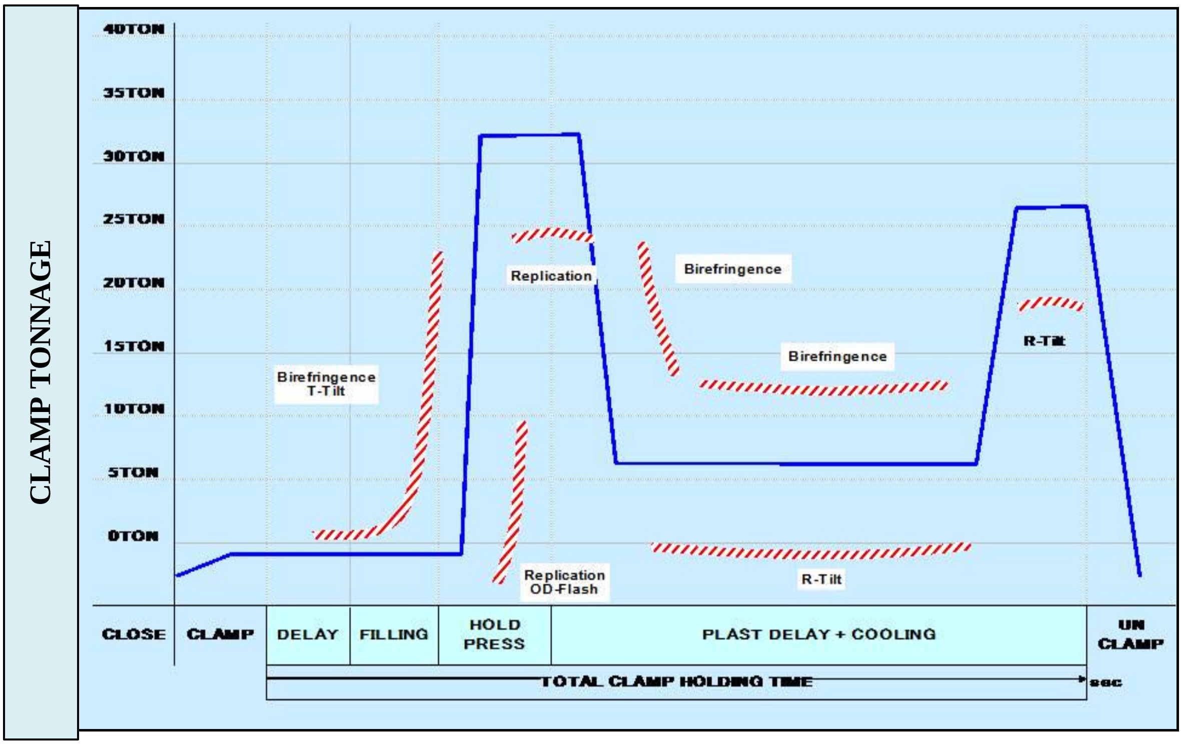


Fig. 17 Clamping profile for the SD-40/FR type mold

The above graphical figure shows that how the clamping tonnage profile affects the various moulding parameters such as replication, birefringence, R-tilt. It shows that little variation in clamping profile affects the one of the property or all. It shows that clamping window is too short.

TEMPERATURE PROFILE OF MOULD AND BARREL

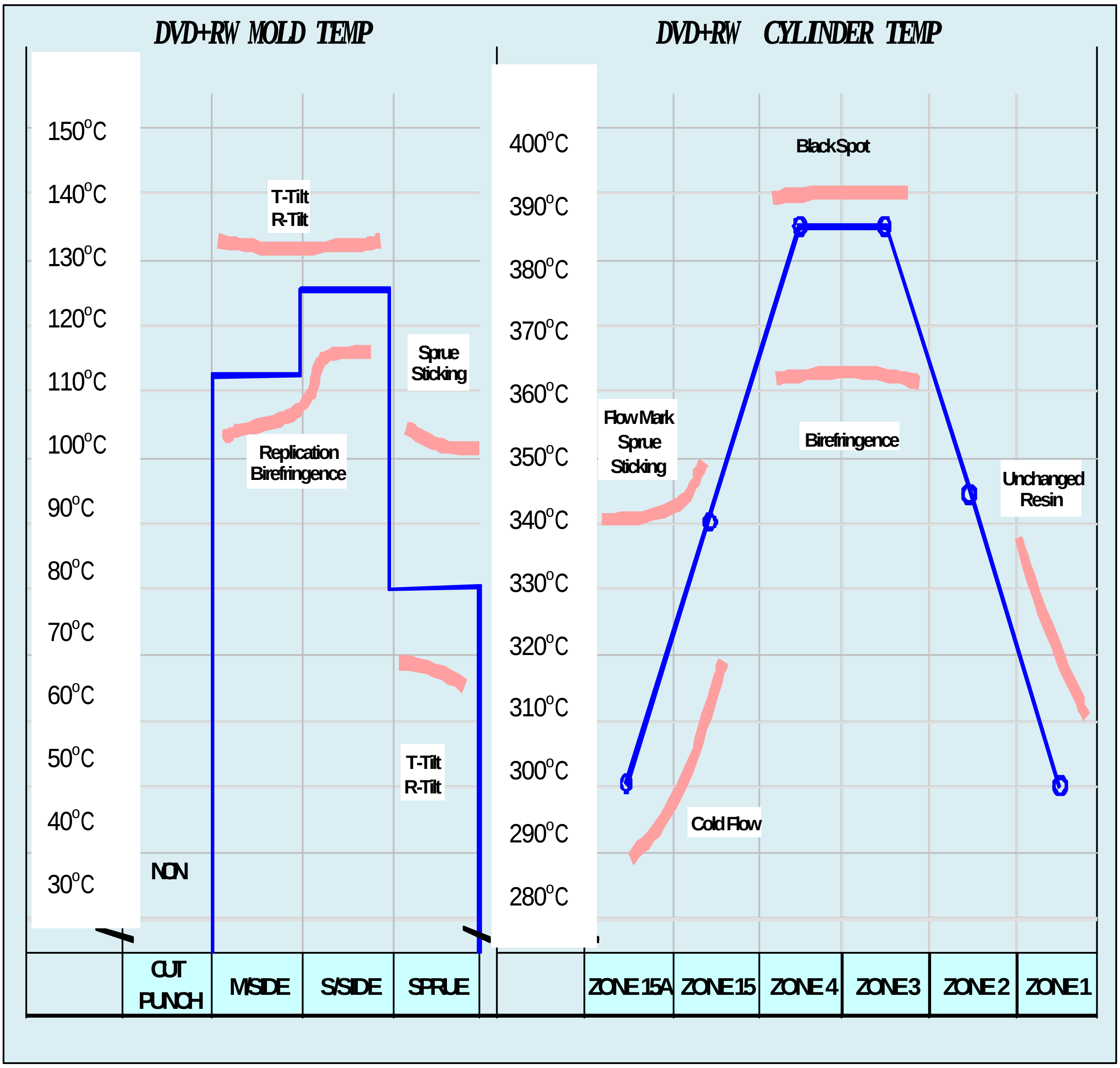


Fig. 18 DVD-R mold and barrel (cylinder) temperature

Above graphical figure shows the effect of mould temperature on replication, birefringence, R-tilt and sprue sticking whereas the barrel temperature shows the affect on cold flow, flow mark sprue sticking, birefringence and unchanged resin.

INJECTION VELOCITY AND HOLD PRESSURE PROFILE

The filling pressure or injection velocity and hold process map is explained in Fig.19.

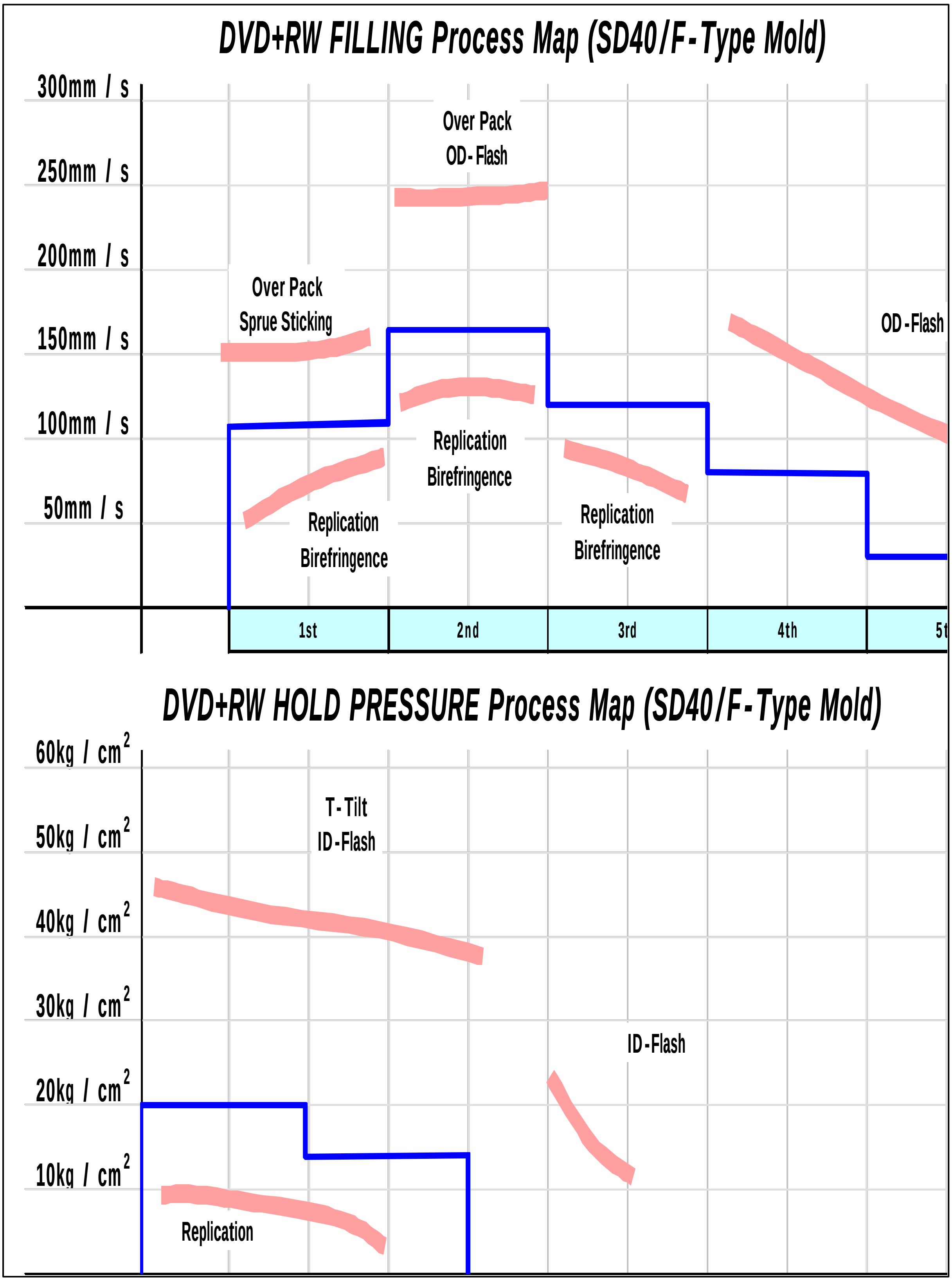


Fig. 19 Pressure profile

Above graphical figure shows the effect of filling velocity on replication, birefringence, over pack OD-Flash whereas the hold pressure shows the affect on replication, T-tilt and flash.

FLOW OF POLYMER MELT

Flow of polymeric melt in a cylindrical barrel is as follows. Due to this nature of polymer melt flow; there are lots of chances to develop the weld lines in the substrate.

Orientation and weld lines in plastic parts evoked….

- ❖ By shear and stretch.
- ❖ Weld lines in drawing jigs.

The melt flow direction in mold and barrel is depicted in Fig 20.

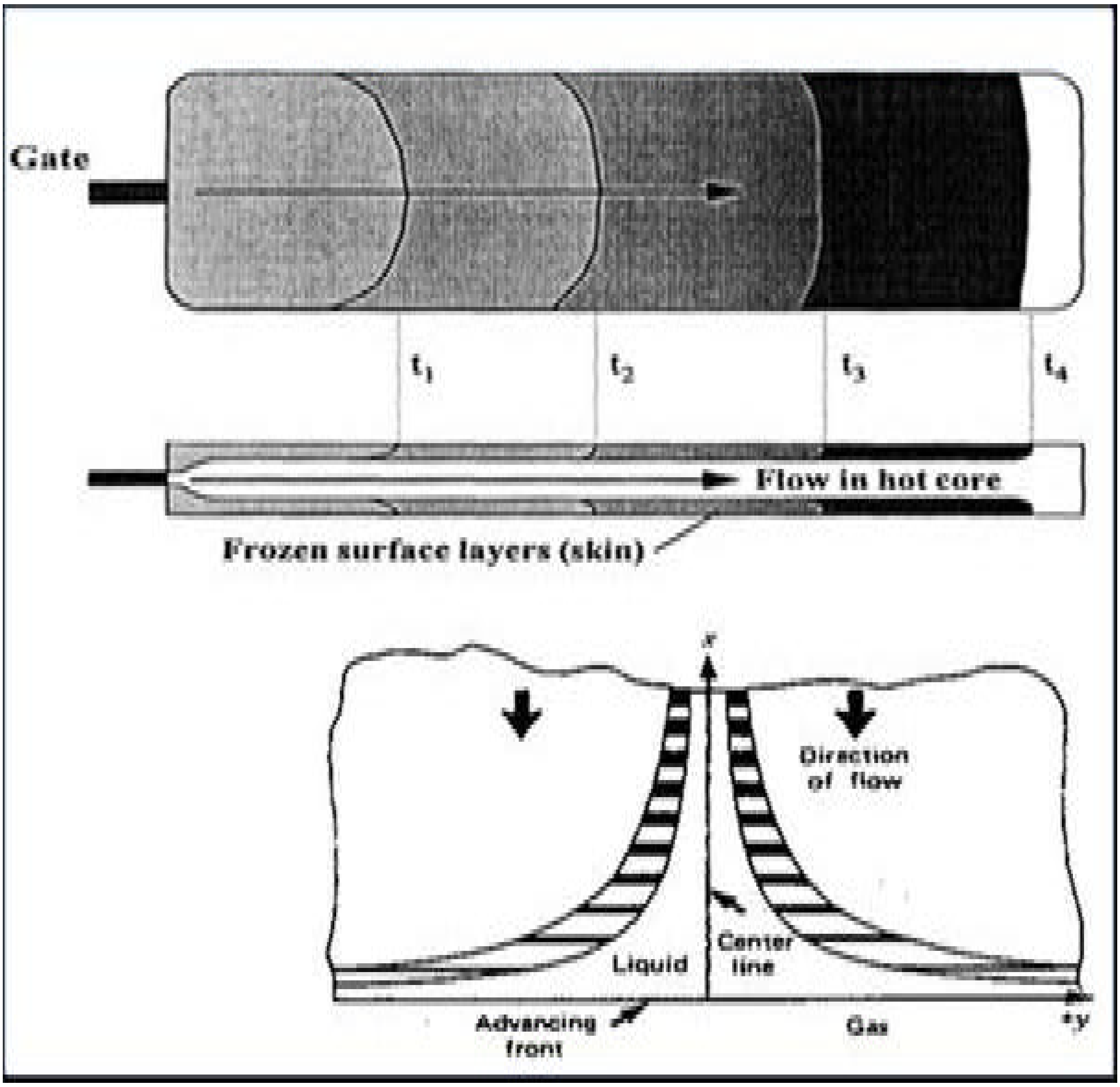


Fig.20 Flow of polymeric melt in barrel and mould

FLOW OF POLYMER MELT IN NORMAL MOULD

Here the molten flow direction or orientation of polymeric chains occurred from side to center.

The flow directions of molten polymer inside the normal mould are as follows.

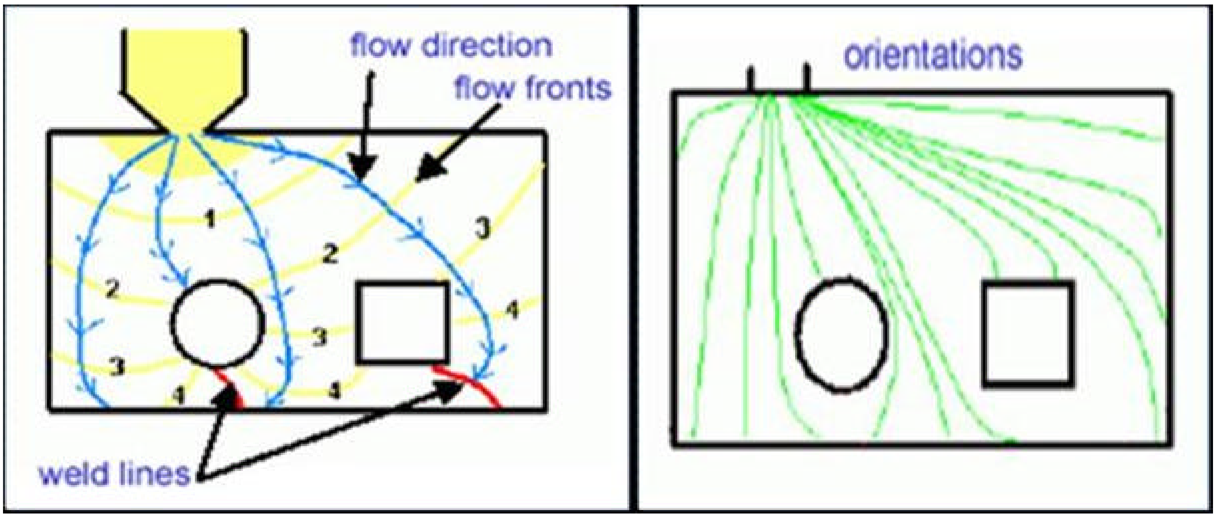


Fig. 21 Directional flow of molten polymer in the normal mould

FLOW OF CD/ DVD MELT

The directions of CD/ DVD melt flow are completely different from the normal melt flow occurred. Orientation in a disc substrate ….

- ❖ Flow direction from center to the outside
- ❖ Circular flow front
- ❖ No weld lines possible due to fill properties

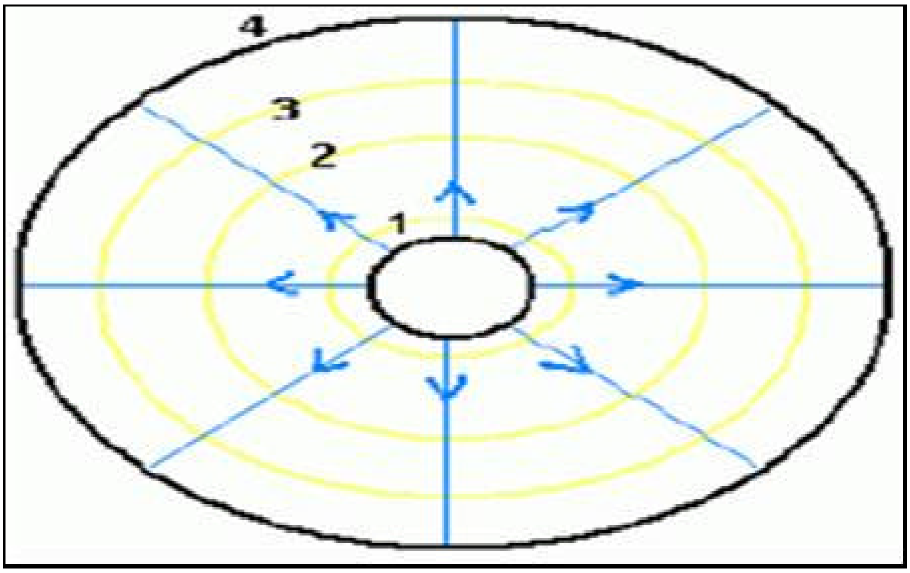


Fig. 22 Melt flow of CD/DVD

But, other properties also very important which are given as below.

- Optical properties very important
- Stress causes birefringence
- Stress causes changes when…
  - Discs Sputtered
  - Cured after lacquering or
  - Bonding

BLANK DVD SUBSTRATE

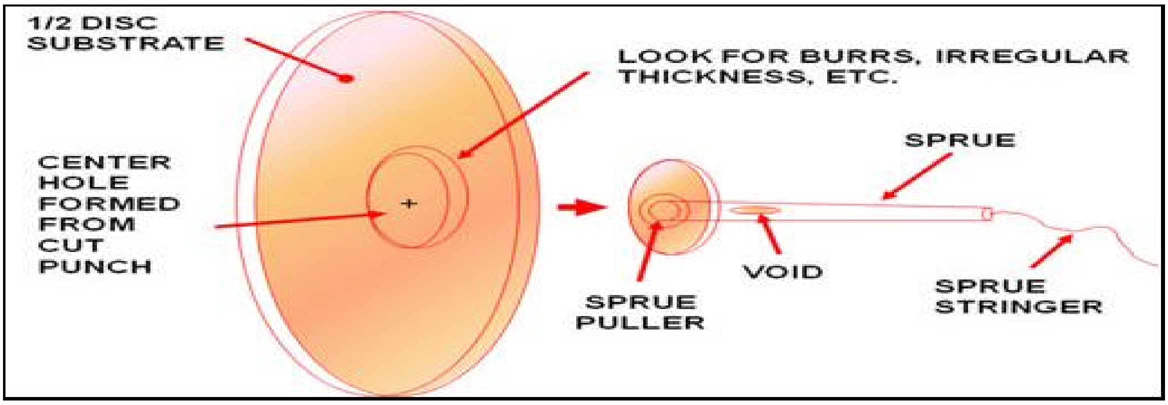


Fig. 23 Blank substrate with sprue and sprue puller

PROCESS WINDOW FOR DVD-R PRODUCTION

Processing of DVD-R is a very critical you have very narrow process window so you have to optimized the molding process window in which can able to achieve desired replication and at the same time dishing and birefringence should control.

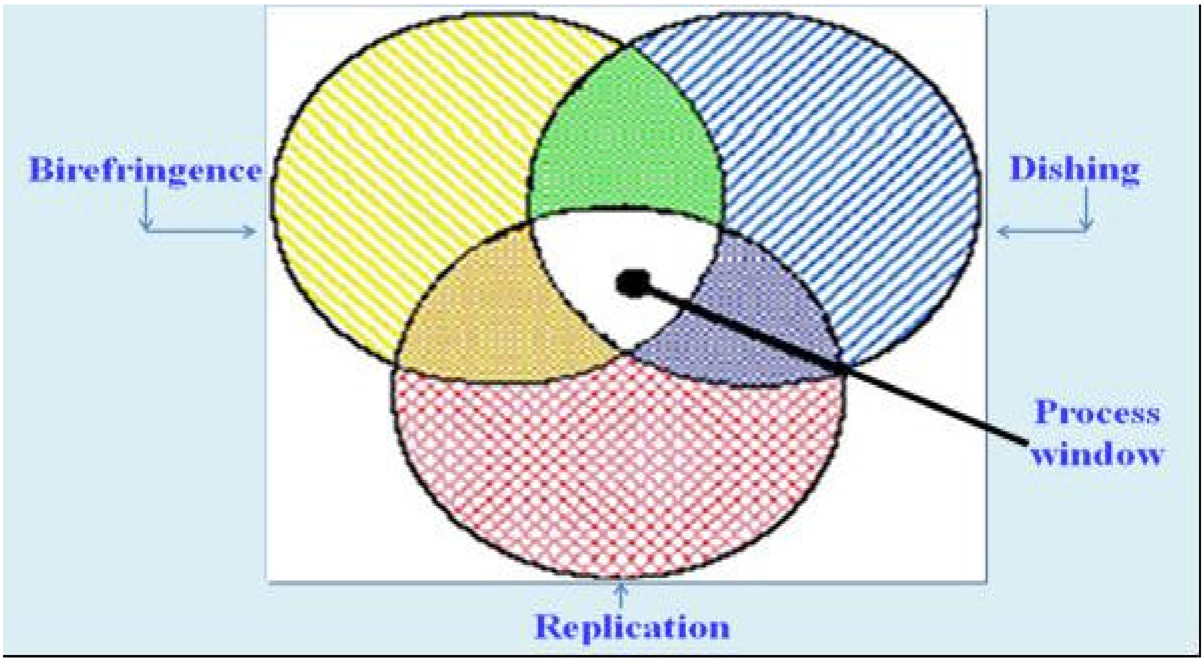
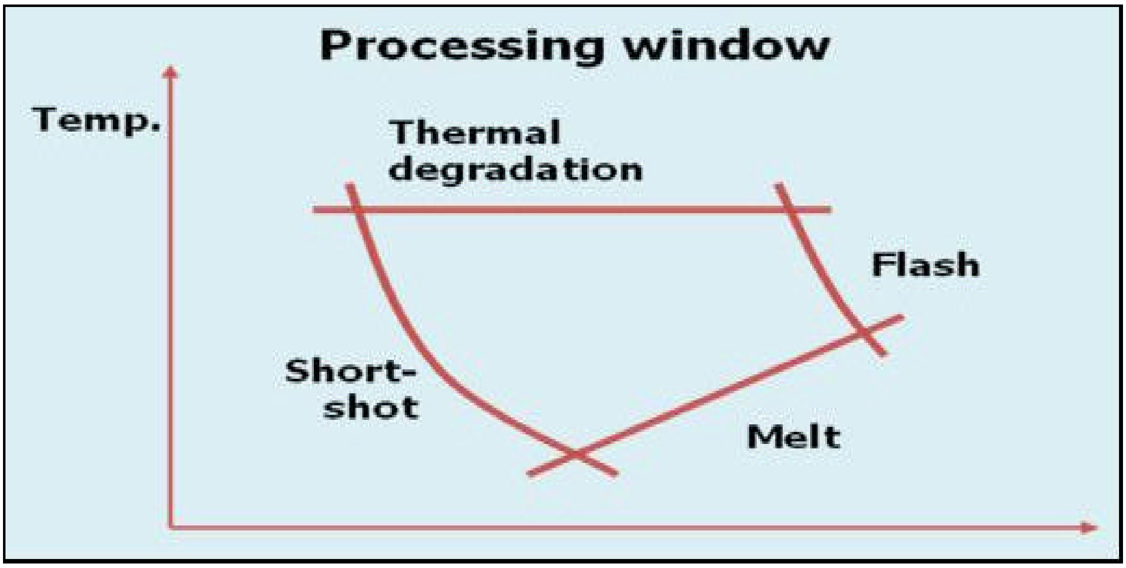


Fig. 24 Process window for DVD-R production w.r.t. mechanical properties



Graph 24 (a) Temp process window for DVD-R melt behaviour

PROCESS WINDOW PARAMETERS

For stabilizing the molding process and producing the disc free from all the defects, there are more than 35 molding m/c parameters which are responsible for the discs quality.

Detailed designed process window of DVD-R for low cycle time which is qualifying all the quality parameters required in blank substrate. For detailed refer **annexure 3 and 4 for active and dummy, respectively.**

THE MOST COMMON MOLDING DEFECTS DURING PROCESSING AND THEIR REMIDIES

DEFECT 1 FLOW MARK

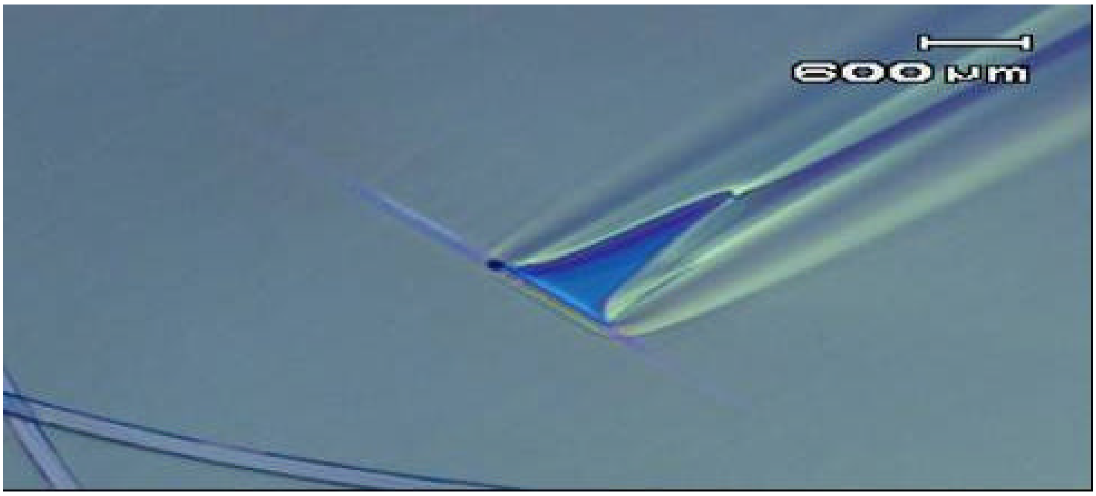


Fig. 25 Flow marks

Table 6 Root cause of flow marks and their probable corrective action

ROOT CAUSE	CORRECTIVE ACTION
❖ Trapped air on mirror side ❖ Trapped air on stamper side	❖ Reduced Injection speed at beginning of filling ❖ Check clamping ring

DEFECT 2 BLACK SPOT

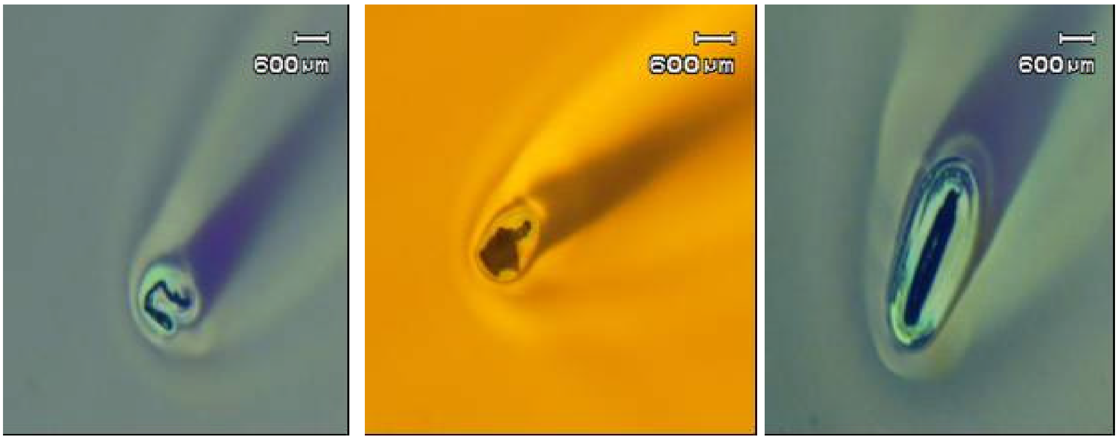


Fig. 26 Black spot

Table 7 Root causes of black spot and their probable corrective actions

ROOT CAUSE	CORRECTIVE ACTION
❖ Peeling of built up material in the screw ❖ Hang up spots due to sealing faces ❖ Incorrect procedure for heating up and cooling down the injection unit ❖ Sometimes at material change	❖ Purge with lower temperatures ❖ Check relevant sealing ❖ Correct the procedure (not too fast) ❖ Run extra shots between materials

DEFECT 3 MOUNT FUJI

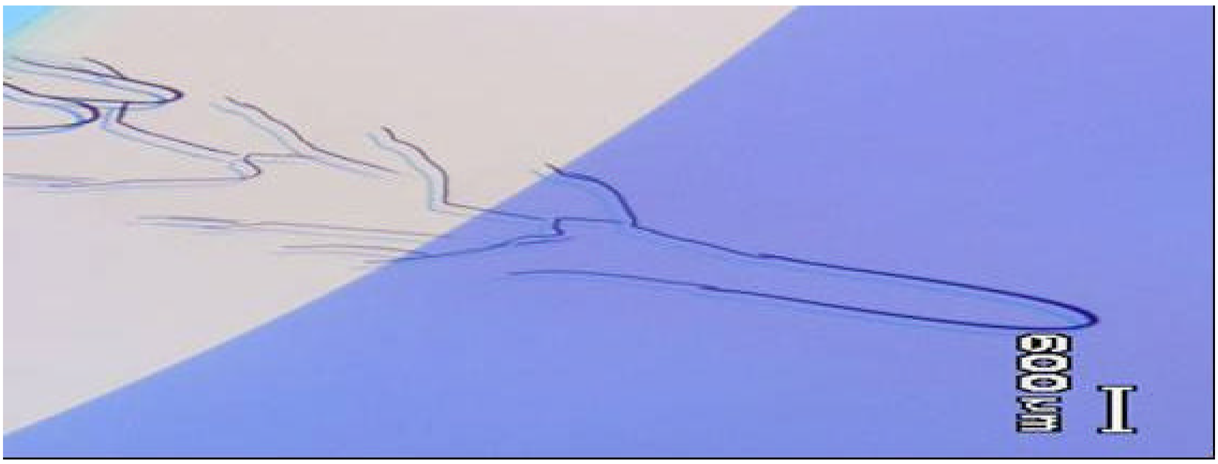


Fig. 27 Mount Fuji

Table 8 Root causes of Mount Fuji and their probable corrective actions

ROOT CAUSE	CORRECTIVE ACTION
❖ Improper temp (nozzle profile-low temp) ❖ Low back pressure ❖ Less injection velocity	❖ Nozzle temperatures increase ❖ Back pressure increases ❖ Injection velocity should be increase

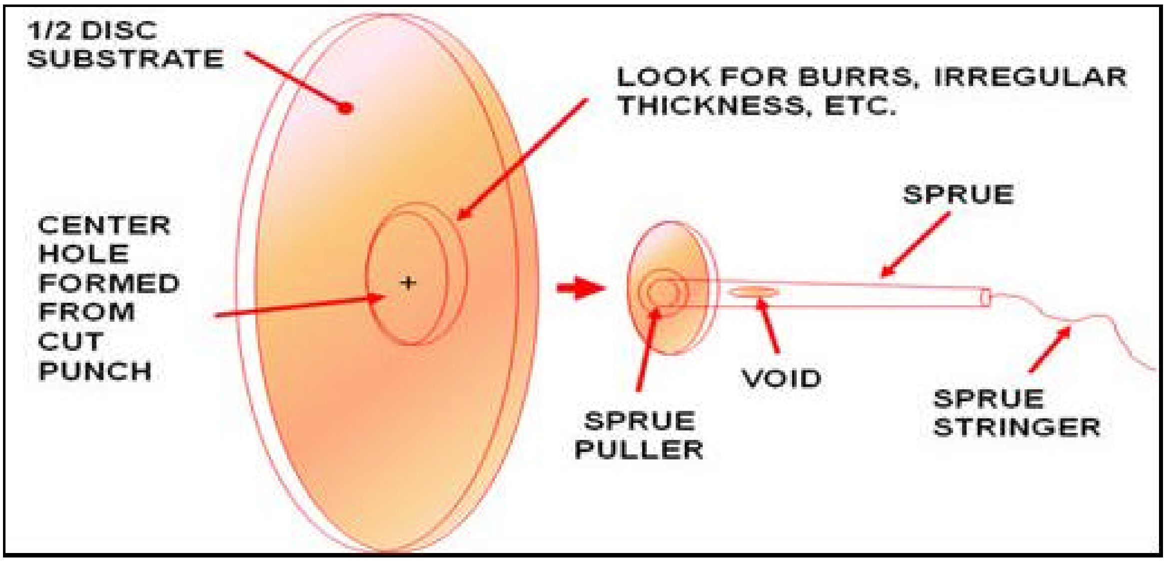
DEFECT 4 SPRUE TAIL

Fig 28 Sprue tail

Table 9 Root causes of SPRUE TAIL and their probable corrective actions

ROOT CAUSE	CORRECTIVE ACTION
❖ Improper temp nozzle profile-High temp) ❖ High back pressure ❖ High injection velocity	❖ Nozzle temperatures lowered ❖ Back pressure lowered ❖ Injection velocity should be lowered

✓ THE WAY TO A GOOD SUBSTRATE IN TERMS OF THEIR PERFORMANCE



The performance of DVD-R depends upon the quality of blank substrate while the quality of blank substrate depends upon following factors.

- ❖ Influence of facilities-------------Temp, Humidity, and dust count
- ❖ Influence of Line -----------------Influence of machine
- ❖ Components----------------------Influence of molding parameters
- ❖ Influence of stamper. -------------Type of galvanic process

✓ PROPERTIES WHICH AFFECTS THE PERFORMANCE OF THE BLANK SUBSTRATE

- ❖ Electrical Properties
- ❖ HF signal

The above properties depend upon the following mechanical properties of the blank substrate.

- ❖ Dishing
- ❖ Tilt Radial and Tangential
- ❖ Birefringence

- ❖ Grove geometry and replication

DISHING

- ❖ Molecular chains on the hotter surface able to relax
- ❖ Causes more shrinkage compared to colder side
- ❖ Uneven shrinkage on the two sides causes disc to warp

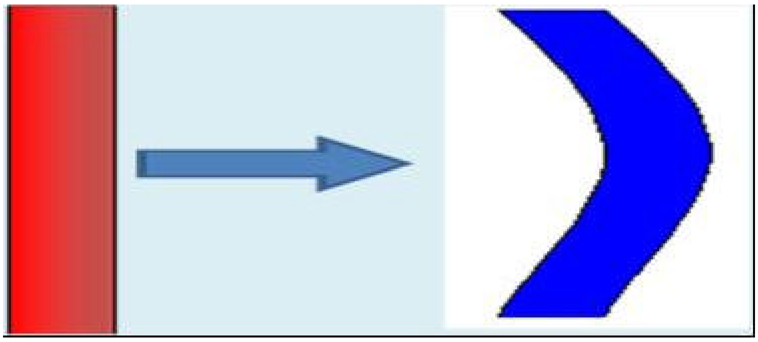


Fig 29 Dishing

- ❖ Dishing caused by asymmetric disc structure and moisture absorption of finished disc.
- ❖ Moisture is absorbed by the PC side of a disc while lacquer and reflective layer hinders moisture absorption.
- ❖ The absorbed moisture caused volume expansion which leads the warping of disc.
- ❖ Once the moisture content reaches equilibrium across the whole thickness of the substrate, the disc straightens.

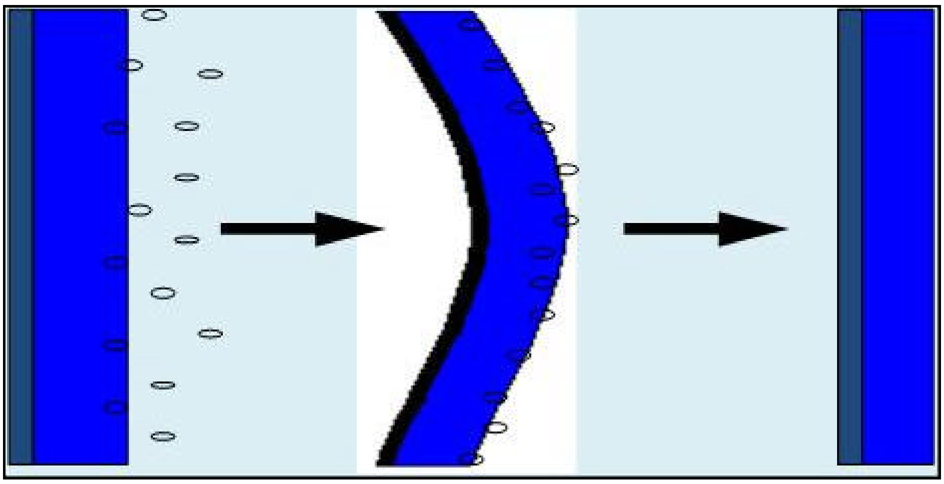


Fig 30 Disk straightening

DISC TILT (RADIAL AND TANGENTIAL)

Leads to deformation of spot and wave front which results to

- ❖ Loss of modulation depth
- ❖ Increase of inter-symbol interference
- ❖ Increase of cross talk

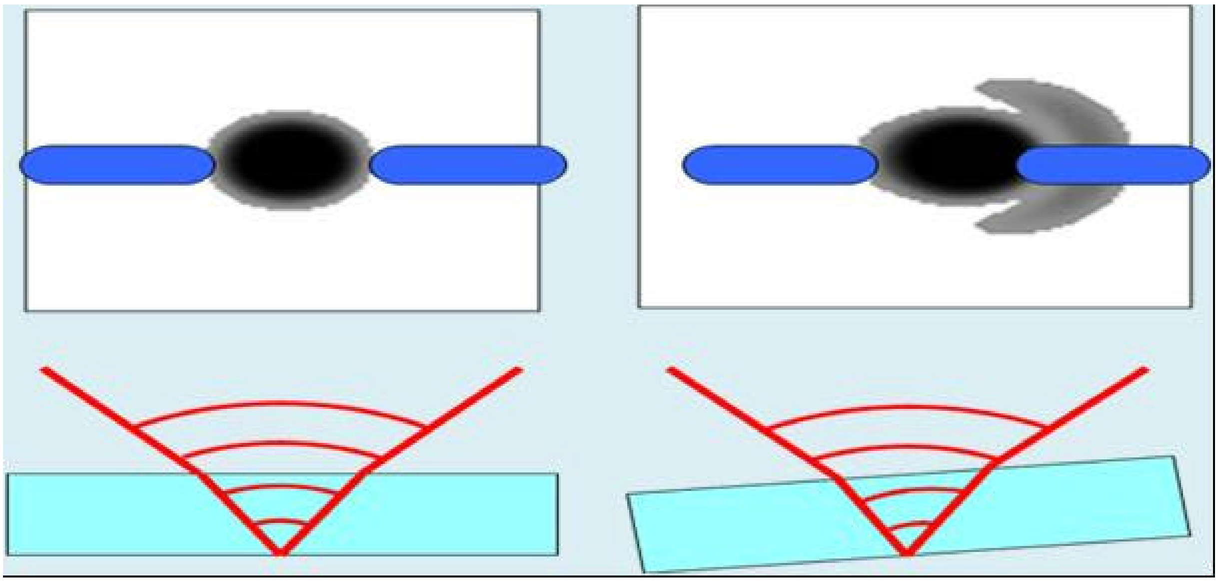


Fig 31 Disc tilts on the laser beam

RADIAL TILT (R.T.) AND THEIR REMEDY

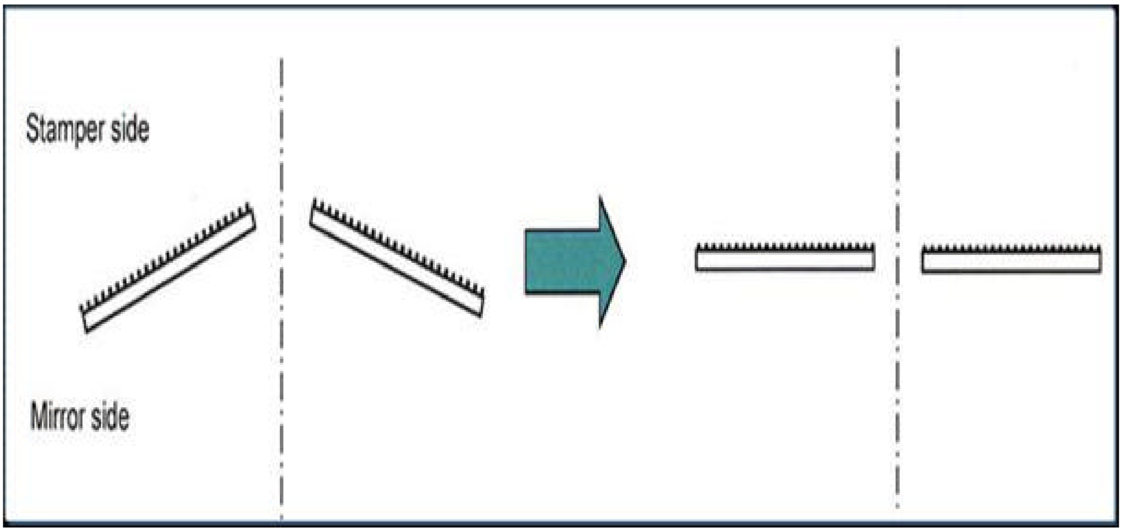


Fig 32 Negative (-ve) radial tilt

Table 10 Root causes of negative (-ve) RT and their probable corrective actions

ROUTE CAUSE	CORRECTIVE ACTION
❖ Tilt is generally caused by cooling rate imbalance between stamper and mirror side of mold. ❖ Generally the mold temperature on the stamper side is lower than the mirror side of the mold.	❖ Cooling rate should be balanced ❖ Stamper side mold temperature increases while lowered the mold temperature on mirror side
❖ The disc maintains contact with the mirror side/moving half of the mold as the tool opens. ❖ This additional contact time contributes more thermal imbalance between mirror and stamper side of disc.	❖ Lower mold temperature on mirror side ❖ Lengthening the cooling time and start air blow on moving side. ❖ Increase air flow on moving side

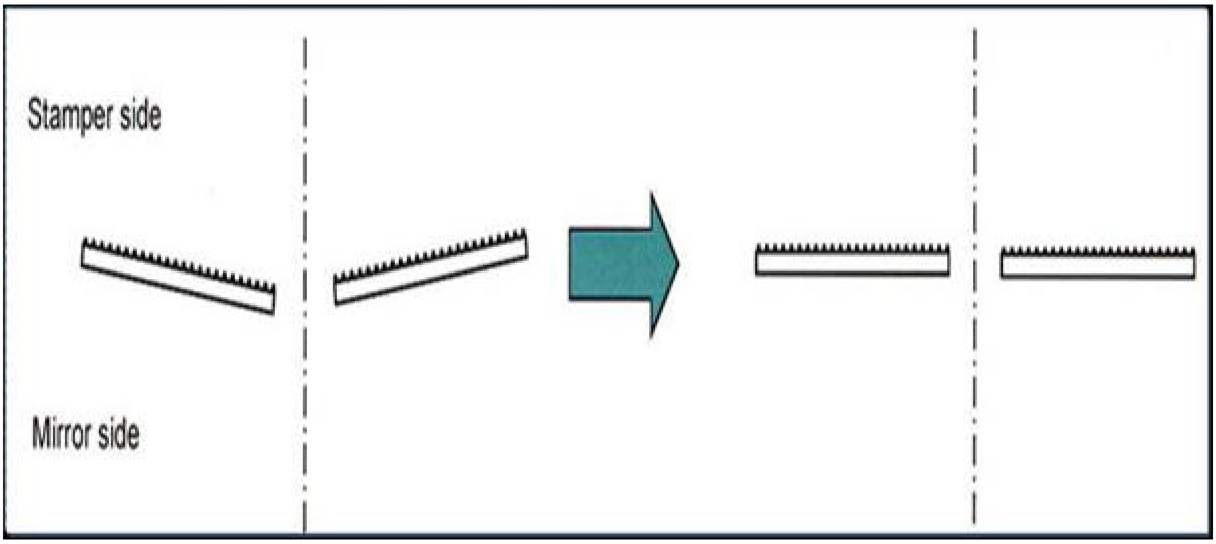
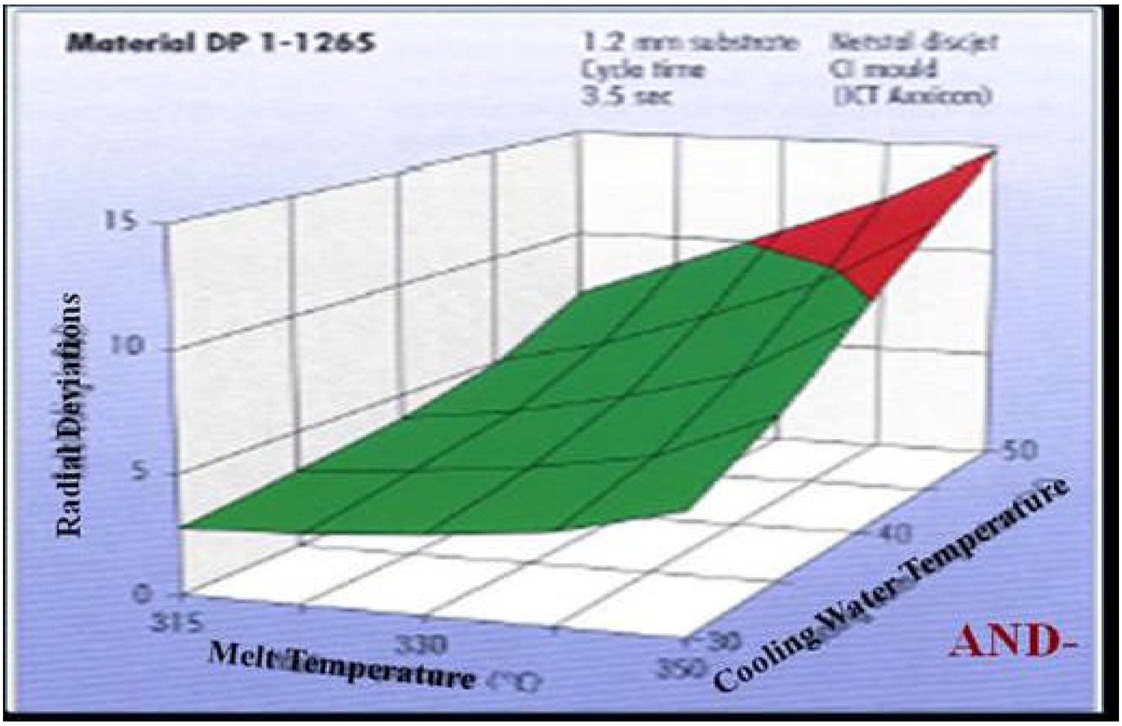


Fig.33 Positive (+ve) radial tilt

ROUTE CAUSE	CORRECTIVE ACTION
❖ Radial Tilt is generally caused by cooling rate imbalance between stamper and mirror side of mold. ❖ Generally the mold temperature on the stamper side is lower than the mirror side of the mold.	❖ Raise mold temperature on mirror side ❖ Lower mold temperature on stamper side
❖ The disc maintains contact with the mirror side/moving half of the mold as the tool opens ❖ This additional contact time contributes more thermal imbalance between mirror and stamper side of disc.	❖ Start air blow on stamper side earlier ❖ Delay start of air blow on mirror side ❖ Increase air flow on stamper side ❖ Shorten the cooling time

Table 11 Root causes of negative (+ve) RT and their probable corrective actions

RADIAL DEVIATIONS vs MELT AND COOLING WATER TEMP



Graph 5 Effect of temp on the radial deviations

TANGENTIAL TILT (T.T.) AND THEIR REMEDY

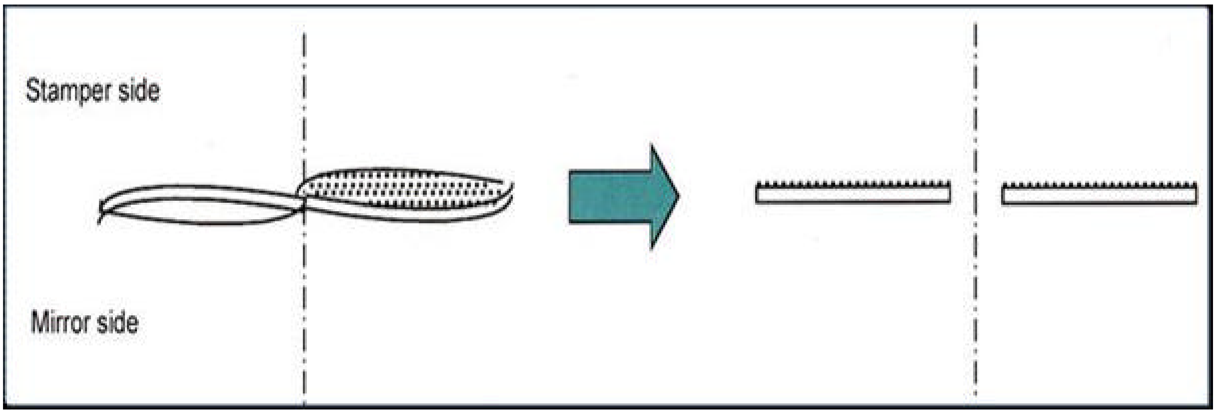


Fig 34 Tangential tilt phenomenon

Table 12 Route causes of tangential tilt and their probable corrective action

ROUTE CAUSE	CORRECTIVE ACTION
❖ Tangential tilt is generally caused by insufficient cooling of the substrate has occurred and disc removed too soon.	❖ Lengthening the cooling time. ❖ Lower mold temperatures. ❖ Lower clamping force (latter half multi-stage)

BIREFRINGENCE

Optical distortion caused by different indices of refraction for separate directions of polarization, often caused by stress in the optical medium produced during CD or DVD injection moulding by shrinkage, flow lines, and inclusions in the substrate. Usually more severe near the outer diameter. Thus birefringence is the phenomenon of destruction of incident laser beam. Fig.35 shows birefringence is the phenomenon of destruction of incident laser beam.

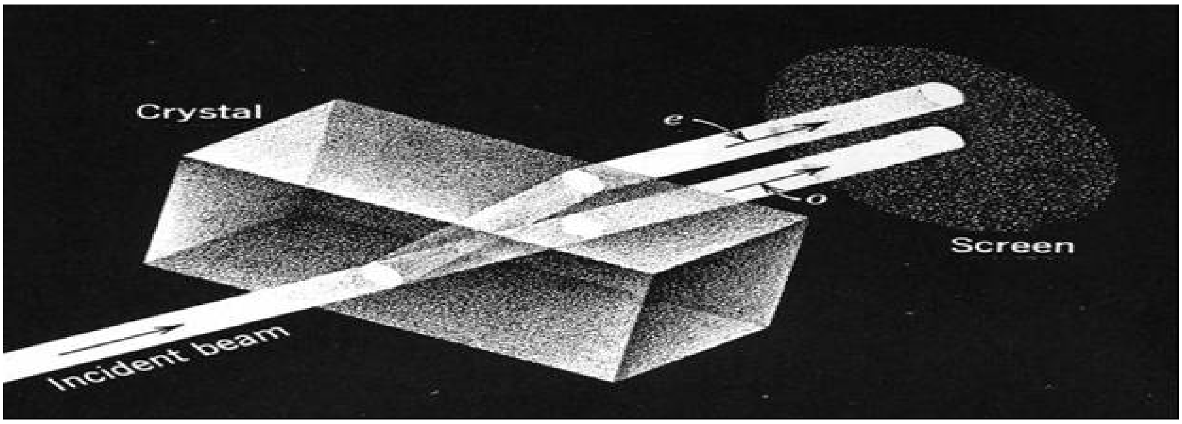


Fig 35 Birefringence phenomenon

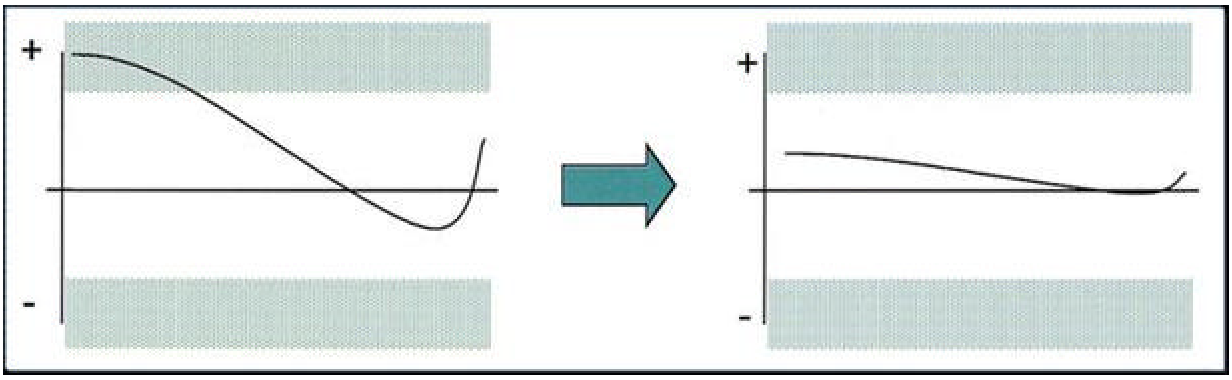


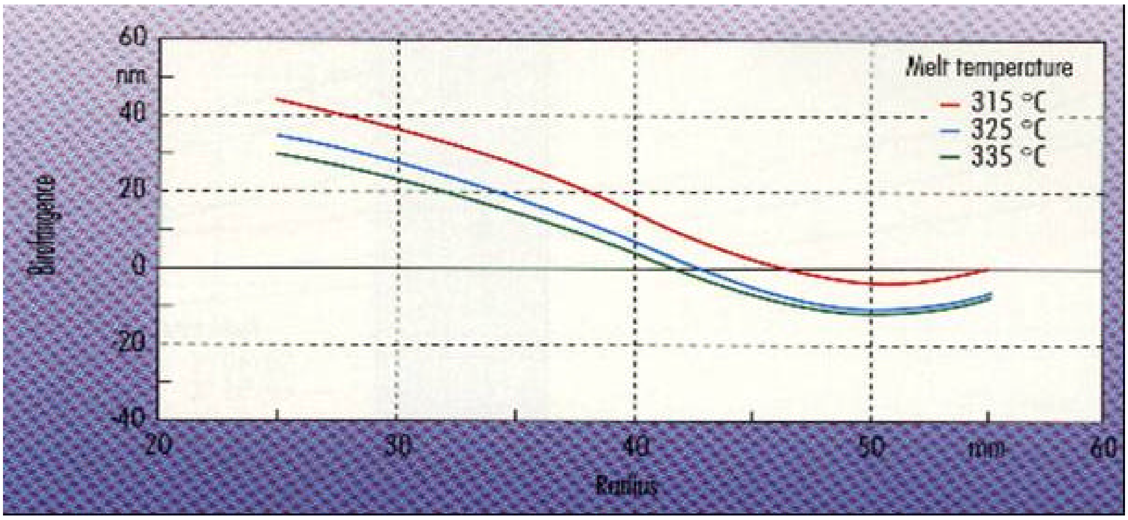
Fig 36 Birefringence phenomenon w.r.t. blank substrate

Table 13 Root causes of tangential tilt and their probable corrective actions

ROOT CAUSE	CORRECTIVE ACTION
❖ Substrate is kept in cavity for too long after the solidification of the melt: shrinkage is constrained. ❖ Cavity filling speeds are too low, melt begins to vitrify while still flowing causing high "molded in stress"	❖ Shortening the cooling time. ❖ Raise mold temperatures. ❖ Increase filling speeds.

FACTOR AFFECTING BIREFRINGENCE

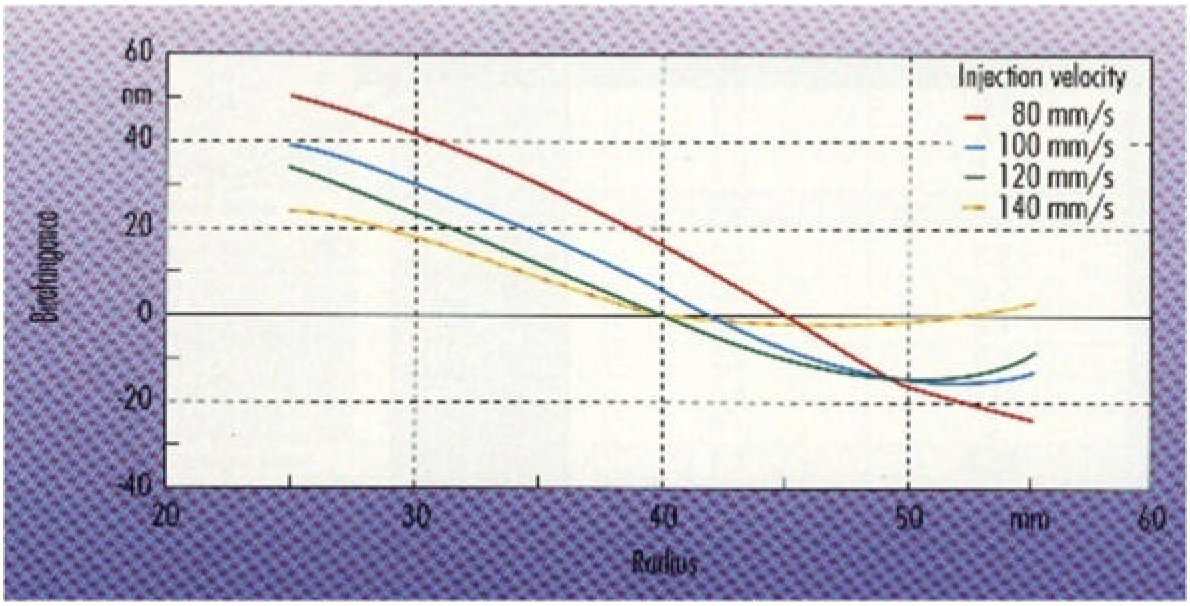
❖ **Effects of ‘melt temperature’ on ‘birefringence’**



Graph 6 Effect of ‘melt temp’ on the ‘birefringence’ across the blank substrate

Above graph indicates the effect of melt temperature on the birefringence. As the melt temperature increases, the birefringence decreases througho ut the disk radius.

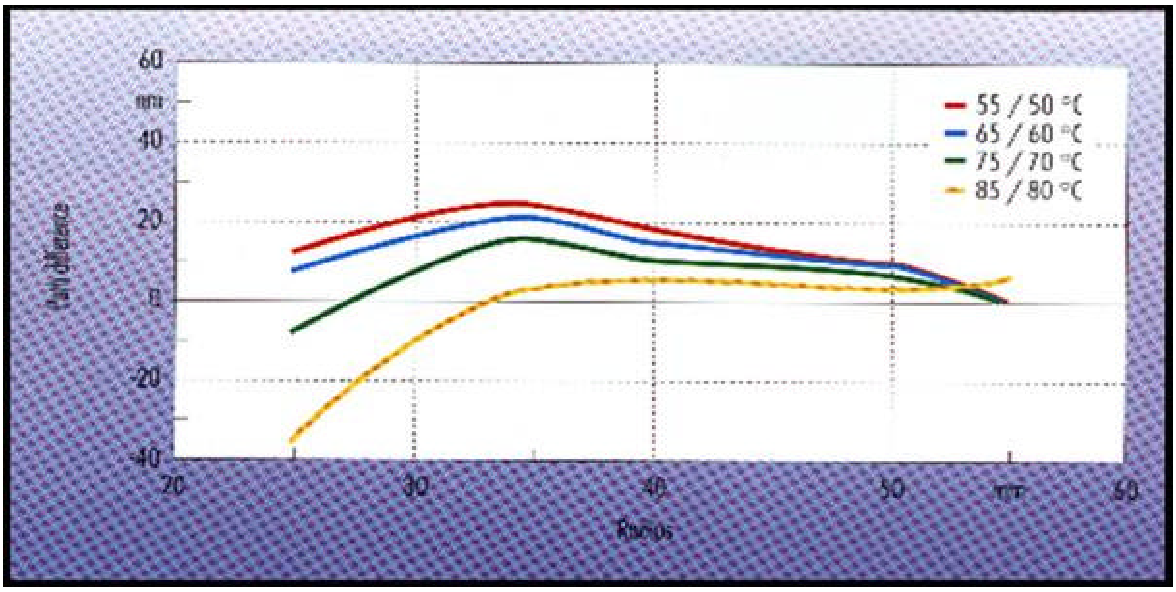
❖ **Effects of injection speed on birefringence**



Graph 7 Effect of ‘injection speed’ on the birefringence across the blank substrate

Above graph indicates the effect of injection speed on the birefringence. Higher the injection velocity, lower the birefringence.

- ❖ **Effects of 'mould temperature' on 'birefringence'**



Graph 8 Effect of 'mould temperature' on the birefringence across the blank substrate

The above graph indicates that optimum mould temperature is required to control the birefringence.

SURFACE REPLICATION & ELECTRICAL SIGNAL

Surface replication forms the grove geometry and the shape of pits. The formation of good pits through electrical signal depends upon intensity of that signal.

The intensity of that signal depends upon the type of surface replication occurred during the replication.

ELECTRICAL SIGNAL → **SURFACE REPLICATION**

SURFACE REPLICATION → **GOOD PITS**

HF Signals are the Analog signals containing High Frequency data information in contrast to low frequency servo information.

Table 14 Root causes for the improper grooves geometry and their corrective actions

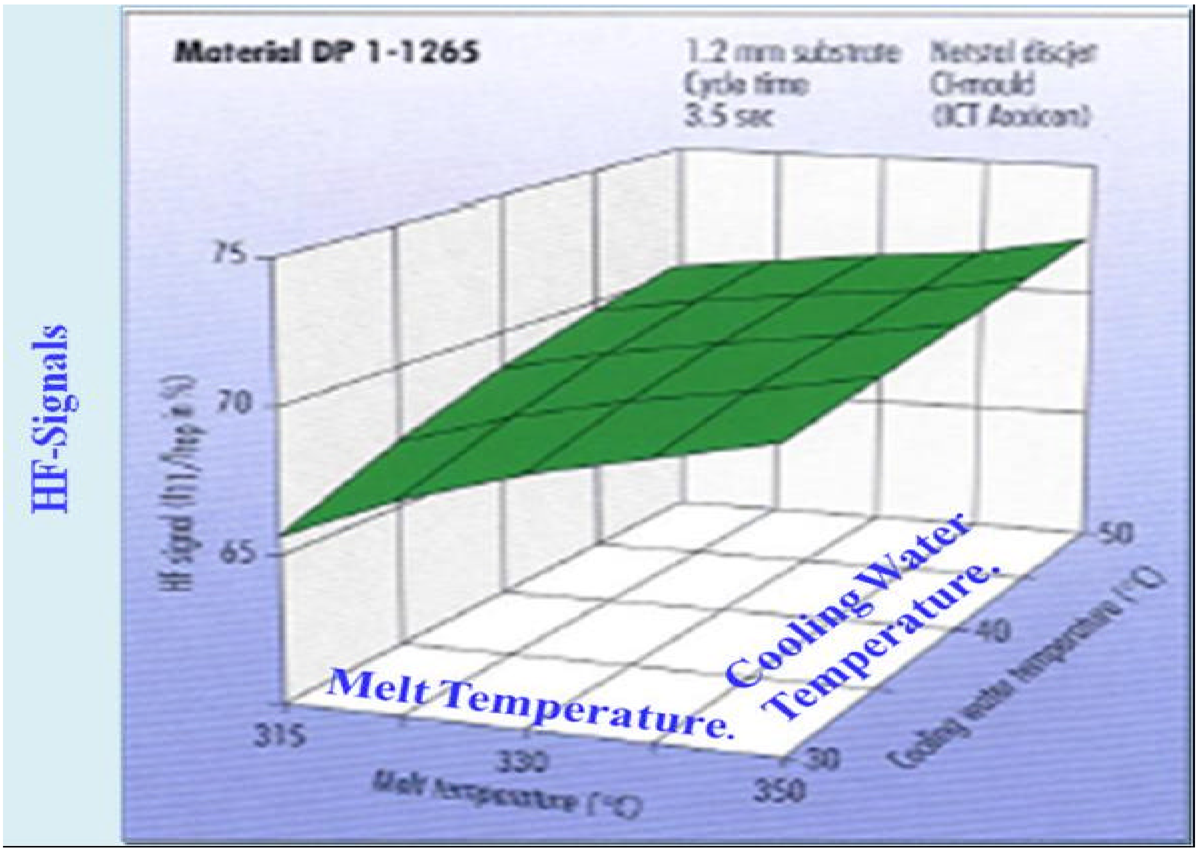
ROUTE CAUSE	CORRECTIVE ACTION
Melt with viscosity does not replicate the micro pits or grooves.	• Raise mold temperature • Raise barrel temperature • Increase filling speeds
Outer edge of information area not fully replicated insufficient pressure/packing	• Decrease transfer position • Clean vent ring to ensure proper venting
Part of melt flows back into plastication cylinder after cavity filled	• Increase mold clamping force • Increases hold pressure • Shorten cut punch delay time

HF SIGNALS DEPEND ON

- Good geometry of the pits (originating from mastering process)
  - Pit depth
  - Pit length
  - Pit wall angle
- Good reflectivity
- Good replication or formation of grove depth (G.D.) during the molding process

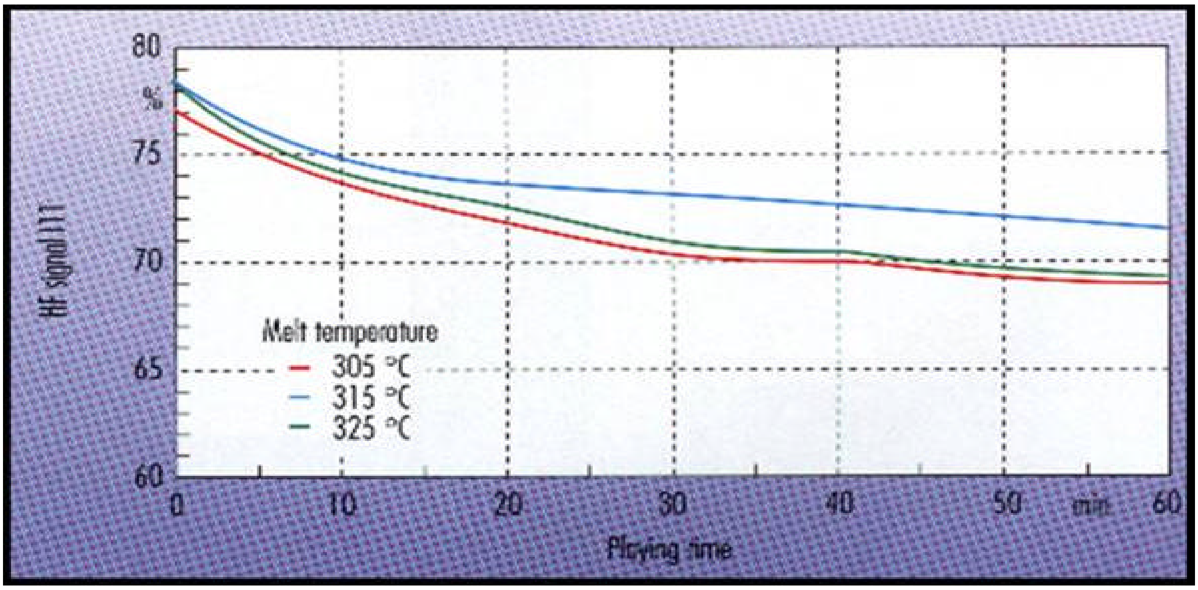
A change on one process parameter changes different quality characteristics at the same time with different intensity. There are some examples of how the molding process can influence the HF- signals.

EXAMPLE-1



Graph 9 Effect of 'melt and cooling water temperature' on HF signals

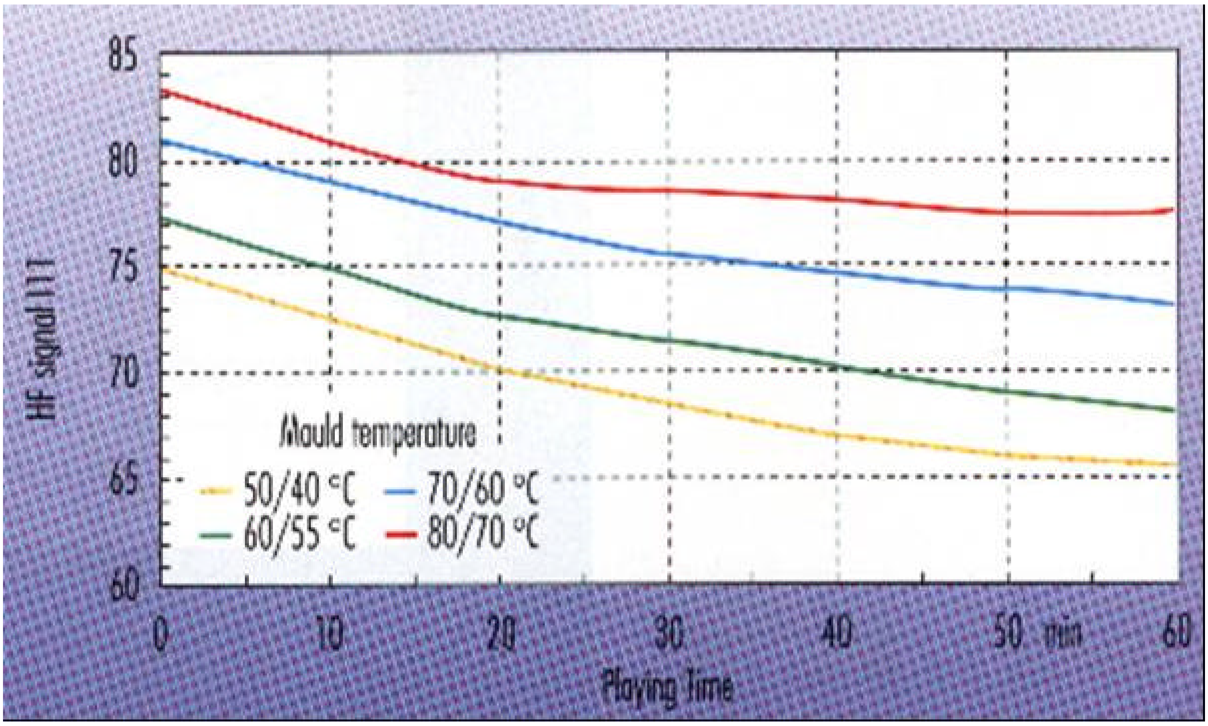
EXAMPLE-2



Graph10 Effect of 'melt temperature' on HF signal

Above graph explains that for better HF Signal melt temperature should keep on higher side.

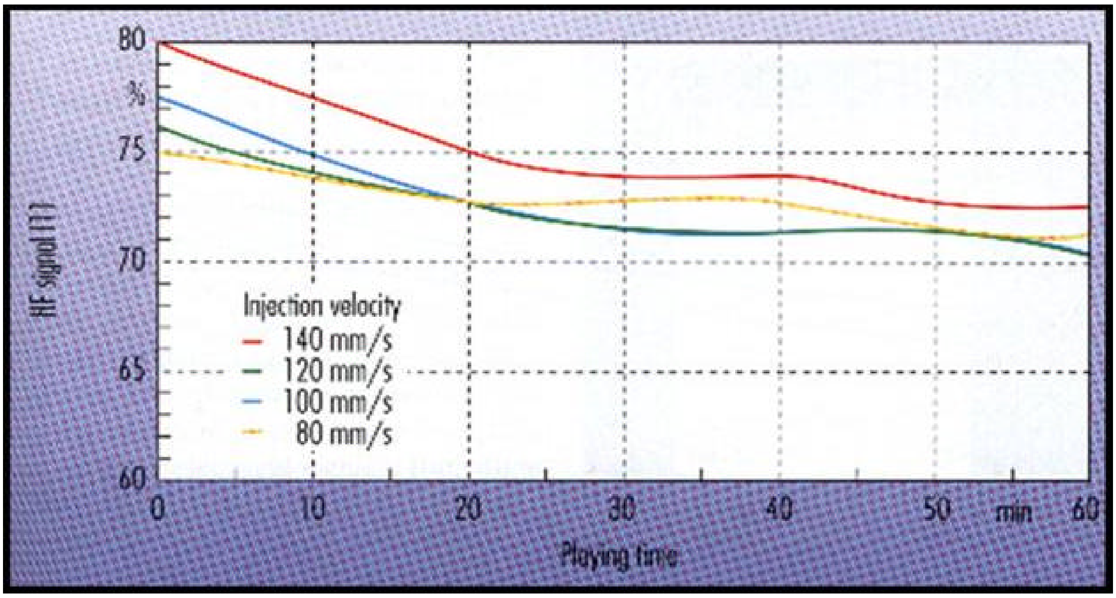
EXAMPLE-3



Graph 11 Effect of 'mould temperature' on HF signal

Above graph explains that for better HF Signal mould temperature should keep on higher side.

EXAMPLE-4



Graph 12 Effect of 'Injection Velocity' on HF signal

Above graph explains that the effect of injection velocity on HF signal higher the injection velocity, or better HF signal.

DYE PROCESS MEDIA (AZO BASED DYE)

Dye coating the heart of any DVDR replication line; this system offers good reproducibility by applying dye in a climate controlled environment with up to six cups depending on the line throughput speed and the process. The automated dye dosing system, one for each cup, uses a production proven "pressure – time" tank system. Automated stock tanks maintain dye levels and can be refilled without having to interrupt production. Emphasis has been placed on simple, reliable operation. The environment provides absolutely consistent temperature and humidity levels thanks to controlled airflow.

DYE PROCESS CONSISTS OF FOLLOWING SEQUENCE OF PROCESS:

- Dye solution preparation
- Dye dispensing system (Dye circuit)
- Dye spinning profile to get the required dye density in the grove
- Dye edge wiping profile
- Conditioning

DYE PROCESSING CONDITIONING

For maintaining the required optical density it is must to maintain following conditions.

- Temp -25^{0}C
- Relative Humidity 35-45% varying format to format
- Air Flow = 2 m/sec
- Exhaust = 2 m/sec
- Dust count (0.5 micron)
    - Inside dye processing area is Zero.
    - Outside environment less than 1000 count

DYE SOLUTION PREPARATION

- Dye Solution = Dye powder dissolved in a solvent TFP/OFP with the required concentration of 1.2 gm/ltr
- Optical Density set and validate through the UV spectra as well as HPLC

COMPOSITION OF THE DYE SOLUTION

Dye powder =154.0 gm (azo based dye)

DMH (Dye Methyl Heptanes) =128 gm

DBE (Dye butyl ethylene) = 118 gm

The all above ingredients poured in to a dark bottle and placed in the electronics starrier and starrier up to 40 min

Then this concentration dissolves with the suitable solvent as per the specified by the OEM'S.

Table15 Different OEM's dye and their solvents

DIFFERENT TYES OF DYE AND SOLVENTS	
DYES	**SOLVENTS**
SONY	TFP
TDK	TFP
MKM	TFP
FUJI	TFP
RICOH	TFP
M CC	TFP
MBI	TFP / OFP
TFP is used with 16X Speed and OFP is used in 8X Speed	

DYE CIRCUIT

The schematic view of dye dispensing circuit is explained in Fig 37

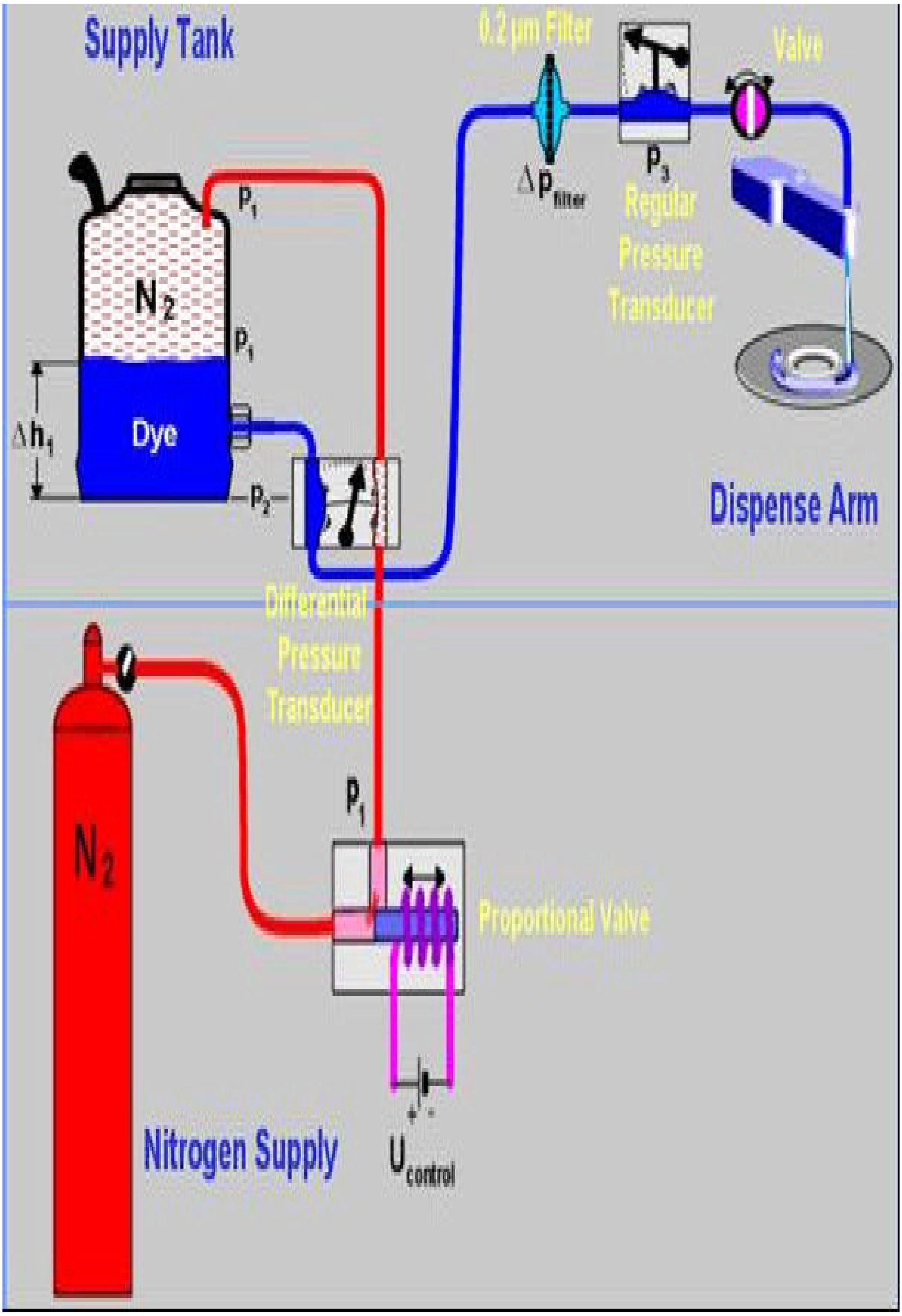


Fig 37 Complete dye dispensing circuit for the DVD-Dye coating process

GENERAL PARAMETERS REQUIRES TO DYE COATING PROCESS

Before processing of the dye it is mandatory that outside dye coating area all the parameters listed in table below should be maintained through Weiss (climate control) unit.

Table 16 Parameters which are must maintain outside area before the dye coating.

S.N.	PARAMETERS	SPECIFICATION
1.	Dye Volume	0.7 +/- 0.02gm
2.	Dye Cup Exhaust setting	0.35 to 0.65 m/sec.
3.	Needle Height	3.0+/-0.6 mm
4.	Dye Pressure	110 mbar
5.	Humidity	40-45 +/- 1%
6.	Temp.	25 +/- 0.25 ^{0}C
7.	Ionization pressure	1.2~2.0 bar
8.	Waiting time ideal dispense	600S
9.	Pulsed ideal dispense valve open	2
10.	Pressure Tolerance	+/- 5 bar
11.	Needle angle	90 ^{0}
12.	Needle diameter	0.8 mm
13.	Ionization flow continue	Yes

DYE COATING PROCESS

Dye coating process in which dye dispensing in to the blank active substrate ,but for optimum filling of grove by dye solution that's decide the optical density of the disc.

PHENOMENON OF OPTICAL DENSITY

Optical Density, D, is computed as the logarithm of the reciprocal of transmittance. That is,

$D=\log_{10} (1/T)$ Where T=Transmittance. Or absorption factor of dye, mathematically

$OD= -\log T$ where $T=T_t/T_i$

T_t= transmitted light through the medium (dye) T_i= Incident light on the medium.

DYE DISPENSING AND SPINNING PROFILE

So the proper filling and for obtaining the desired optical density process engineer design such a profile for the dye dispensing and spinning which ensure the proper amount of dye fill in the grove, also known as D-AB's or dye absolute.

Table 17 Parameters which required to 1maintain inside the dye coating.

PARAMETERS	VALUE	TOLERANCE
Dye Volume	0.4-0.5 G	± 0.025
Needle Size	Teflon Coated 21	NA
Humidity	40 ~ 45 % RH	± 1 %
Ionization Pressure	0.25bar	NA
Needle Height	1.8mm	+/-0.6mm
Chamber Temperature	25 deg C	±0.25
Dryer Temperature	85 deg c	±1
Dryer Time	1080 s	NIL
Cooler Temperature	25 deg C	±0.25
Sub tank Pressure	0.010 mpa	±0.004
Dye Stock Tank	0.06 mpa	NIL
Exhaust Air Flow	0.2—0.3 m/s^2	NIL

DYE MAIN STOCK TANK WEIGHT (Kg) LIMIT

This is necessary to ensure the continuous production.

Table 18 Dye main stock tank weight (kg) limit

	HH	H	L	LL
Dye Stock Tank	25.0	23.0	12.5	11.0
Dye Pressure Tank	7	6.5	6.3	0.0

Table 19 Designing of dye dispensing profile to get the required dye density in the grove

Step	NZ U/D	Wait time(sec)	Pos(mm)	V(mm/sec)
1	UP	0.1	45	150
2	DOWN	0.1	N	22
3	DOWN	0.3	N+4 upto 8	35
4	UP	1	HOME	150
5	END			

Range of N – 12 to 26 mm

Table 20 Designing of spinning profile to get the required dye density in the grove

Step No	RPM	Acceleration	Const Time.
1	250 ~300	0.10	10
2	250 ~300	0.10	2.0~ 2.5
3	1000	1	A
4	2000	B	0.10
5	6500	C	0.10
6	7500	0.1	1
7	0	0.8	0
8	END		

Note: Cycle Time of time of dye process should be less than 13S, A, B, C, Variable parameter and can be changed to control O.D.

A:—0.2 ~ 0.75

B: ---2.5 ~ 3.6

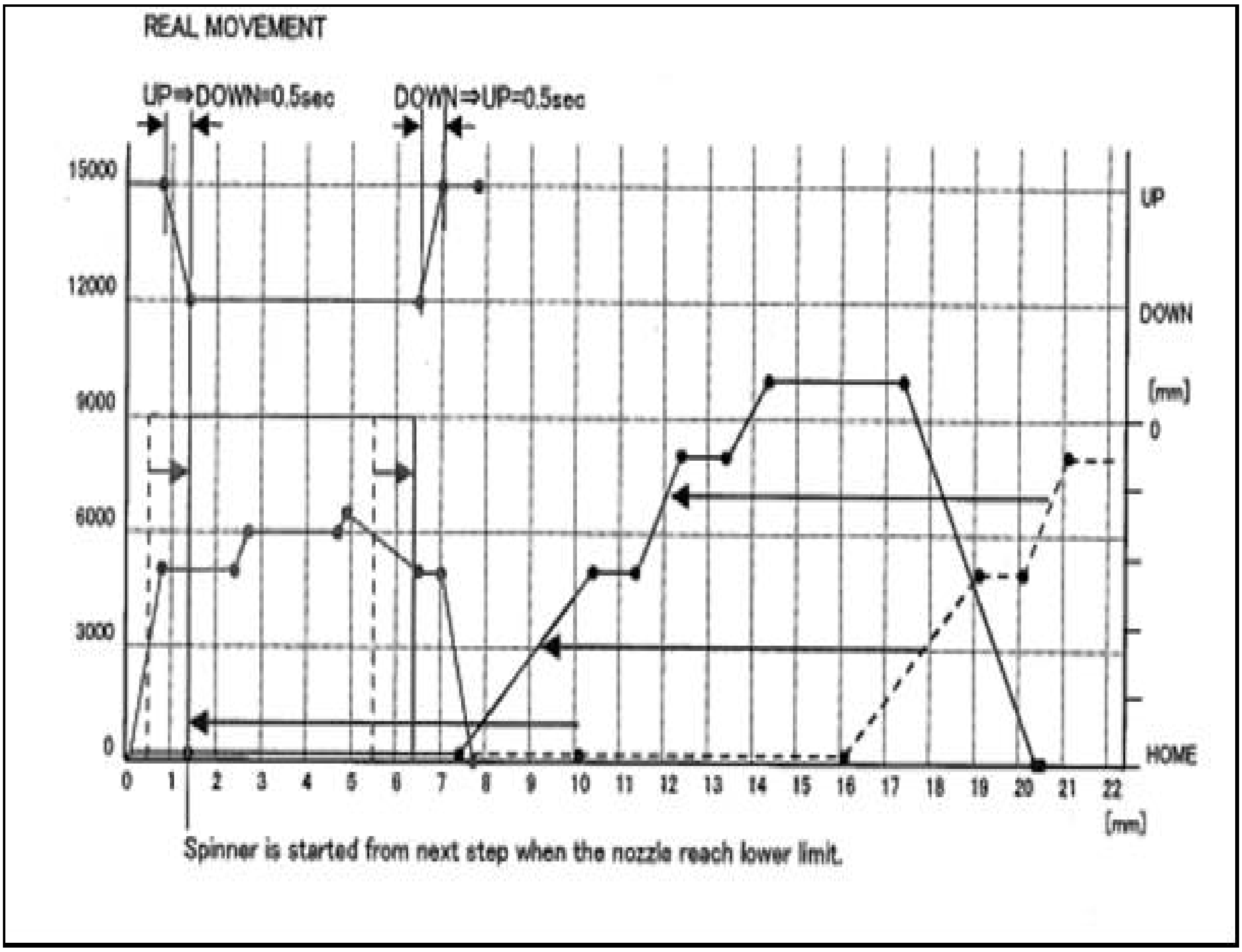
C: ---1.0~ 2.0

DYE DISPENSE TIME

This is the time dye when valve open for that particular time and dispense dye continuously till to the set time.

Table 21 Dye dispense time profile for the DVD dye coating process

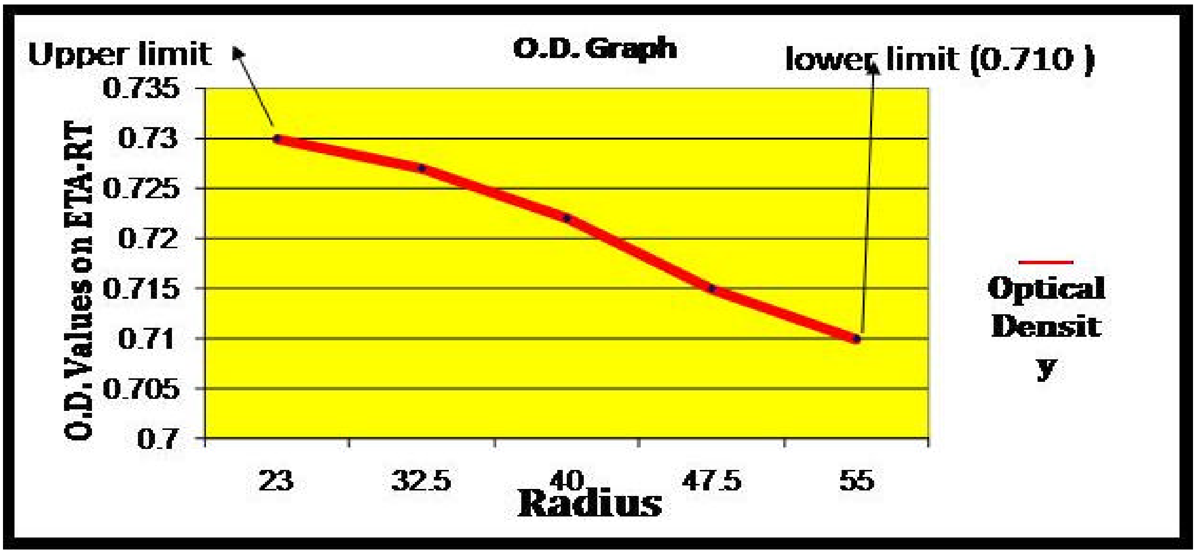
STEP	ON(S)
1	**2.0**
2	



Graph 13 Graphical view of dye profile

OPTICAL DENSITY OPTIMISATION

According to the various formats OD should optimize through Eta-RT as per specified value or format.



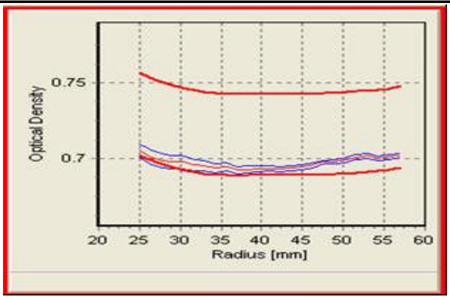
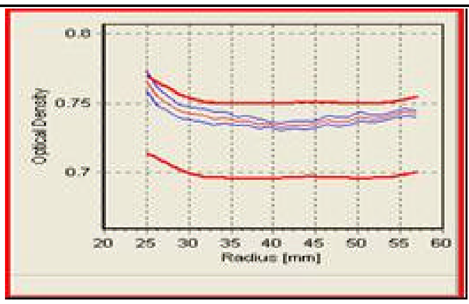
Graph 14 Optical density optimization graph

Although all the above parameters are constant during the dye processing but still there is lot of dye density rejection or variation during the production due to inherent causes these such type of rejection eliminate by adjusting the A,B,C, parameters mentioned in the dye spinning profile. By referring the above mentioned graph set the OD, which can detects in the QC-1 scanner.

EFFECT OF OPTICAL DENSITY

The detailed effects and their remedy of dye density on disc's electrical properties are explained in Table 22.

Table 22 Effects of dye density on electrical properties if it deviates from set value.

OPTICAL DENSITY	If OD- LOW FROM SET (SPECIFICATION)	If OD- High FROM SET (SPECIFICATION)
EXAMPLE 16-X + R		
EFFECTS	Recording failure (insufficient dye for burn)	Low reflectivity (R14H) High PISUM8, POF, PIF Low TCS High Consumption dye
CAUSES	Insufficient dye or low dye volume Grove Depth (GD) less than the specification	Dye volume high or excess dye dispenses
PRECAUTION	GD should be within the specification as per the format. Optimize dye volume Dye crystallization should be prevented by maintaining the temp, and air flow. Required Dye concentration and homogeneity of dye solution should be maintained.	

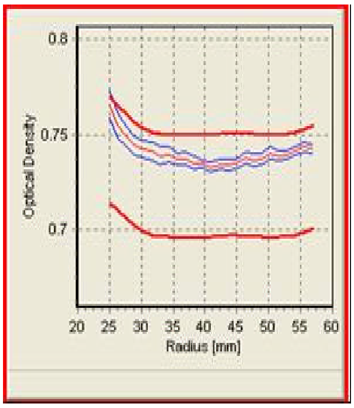
TYPE OF REJECTION DURING DYE PROCESSING

- ❖ DYE DENSITY REJECTION
- ❖ DYE COMET
- ❖ DYE VOID

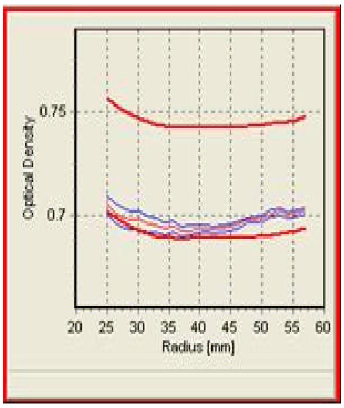
The variation in optical density mainly depends upon the various factors.

- ❖ Dye concentration
- ❖ Temp and Humidity
- ❖ Other factors
    - Either dust, black spot or fiber
    - V-Cut or Dye spot problem
    - Splash either at the inner or outer radius of the disc
    - Problem from Scanner

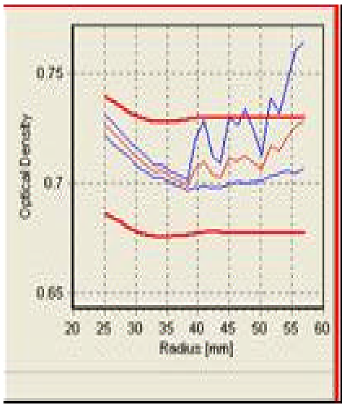
The rejection pattern has been shown in the following graph such as high, low OD rejection and splitting of OD graph respectively in QC-1 scanner due to the variation in temp or humidity.



Graph 15 High OD rejection



Graph 16 Low OD rejection



Graph 17 splitting OD rejection

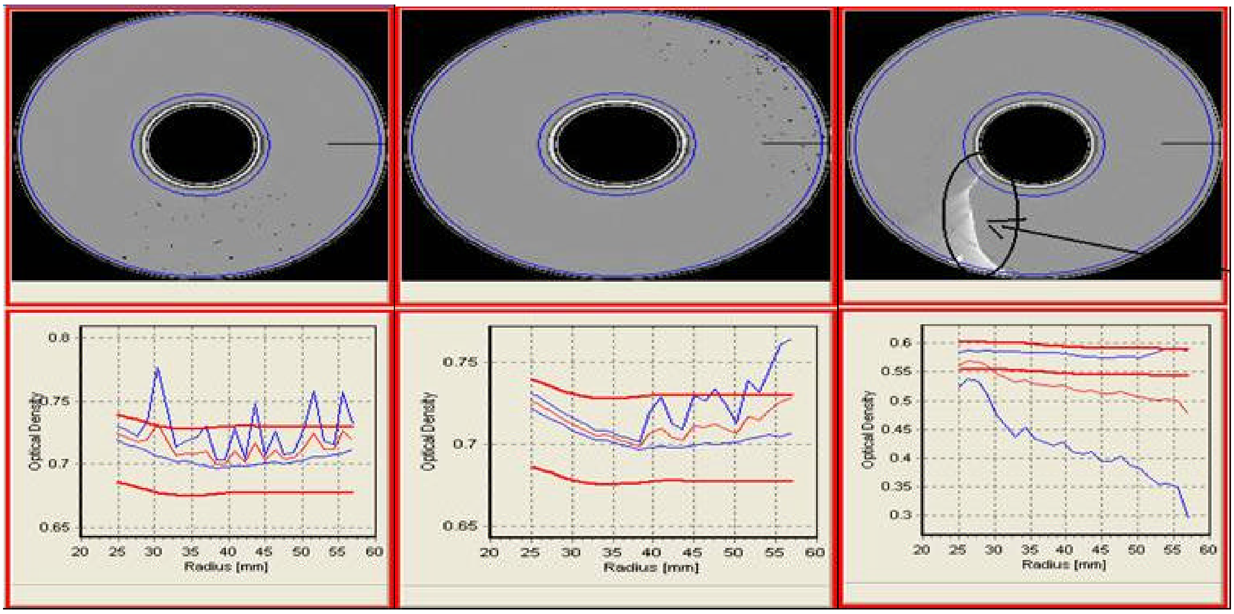
CORRECTIVE ACTIONS

- ❖ Check whether the problem is cup specific or in all cups.
- ❖ If it is cup specific, correct it by increasing or decreasing the Changeable parameters.
- ❖ If problem is in all cups, check the WEISS UNIT Temp and Humidity.

OTHER FACTORS

DUST, BLACK SPOT OR FIBER

FACTOR 1



Graph 18 OD rejection due to dust Graph 19 OD rejection due black spot Graph 20 OD rejection due fiber

CORRECTIVE ACTIONS

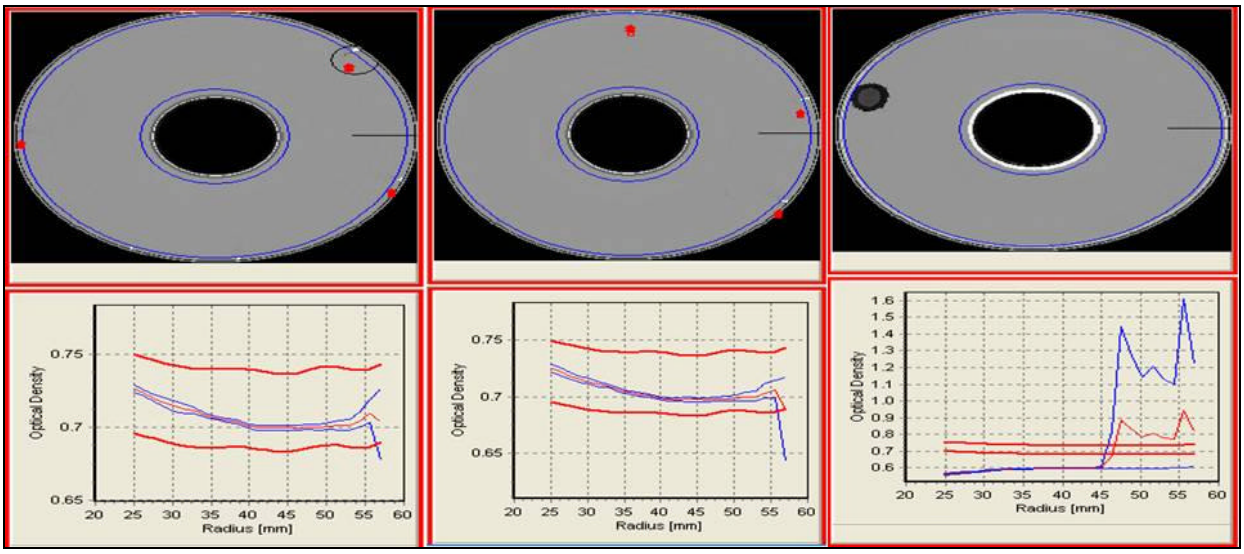
- Check molding parameters for black spot and sprue tail or fiber because fibre generation occurred due to overheating and also responsible for black spot. So lowered down the back pressure of barrel and temp of nozzle.

- If the dust problem is coming in all six cups so check the polymer in the hopper if find the dust in that then inform to the pivon to stooped material supply and change the fresh material.

- If is it cup specific that was due to dye crystallization on to the tip of needle or in the dye cup. Does purging for dust if it appears to be from specific cup. Can also change the Dye cups.

V-CUT OR DYE SPOT PROBLEM

FACTOR 2



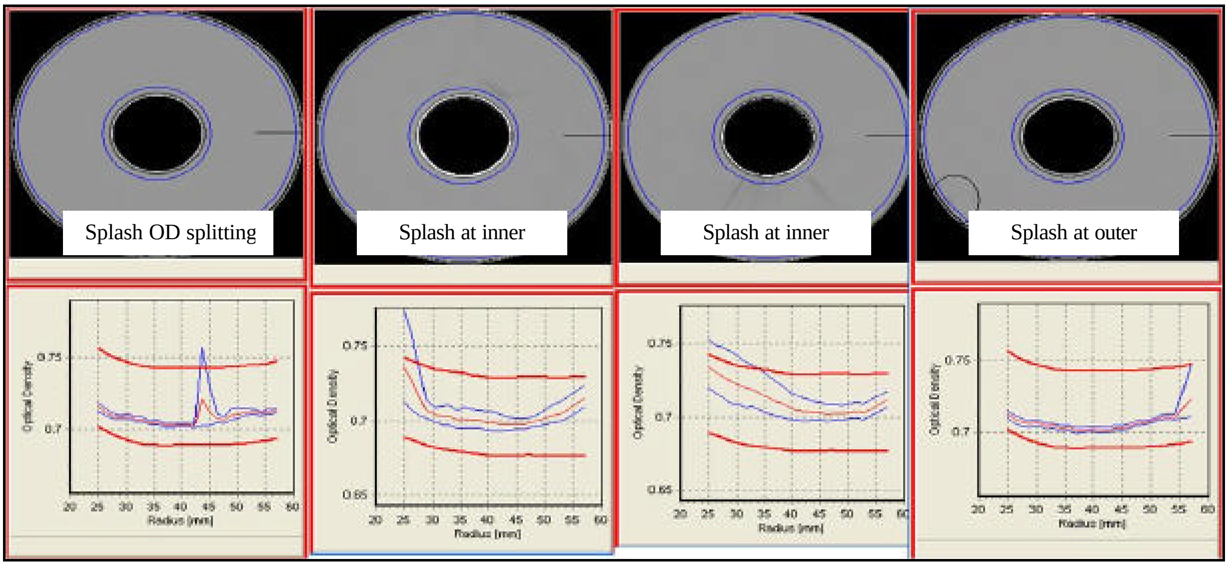
Graph 21 and 22 Dye rejection due to dye spot Graph 23 Dye rejection due to v-cut

CORRECTIVE ACTIONS

- ❖ Check whether the problem is cup specific or in all cups.
- ❖ For V-cut problem, check dye needle (It might get chocked)
- ❖ Does purging or change the needle.

SPLASH EITHER AT THE INNER OR OUTER RADIUS OF THE DISC

FACTOR 3



Graph.24 OD Split Graph.25 Inner Splash Graph.26 Inner splash Graph.27 Outer splash

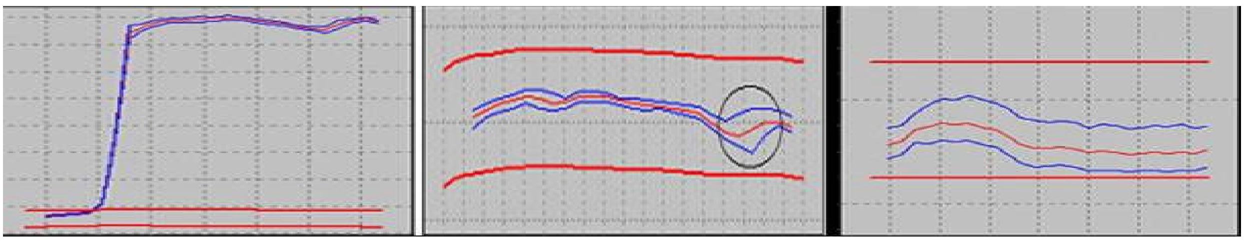
CORRECTIVE ACTIONS

- Check whether the problem is cup specific or in all cups.
- If it is cup specific, do the purging or change the needle if it looks chocked.
- If problem is in all cups then check the air flow in dye section and also the cooler air flow

PROBLEM FROM SCANNER

The all three rejection showing below are due to scanner malfunction of scanner.

FACTOR 4



Graph.28 Rejection type 1 Graph.29 Rejection type 2 Graph.30 Rejection type 3

CORRECTIVE ACTIONS

- Check whether the scanned disc was dye coated or not.
- If it looks ok, then go to service mode and does the top and bottom camera referencing.
- Scanner calibration for optical density with respect to Eta-RT by adjusting off-set.
- If it still doesn't get ok, ask main to check the scanner or replace the scanner.

DYE COMET

Dye comet is the defects which arise due to obstacle present on the disc surface that coming on the way of dye at the time of dispensing, that obstacle creates comet type structure, known as dye comet.

The obstacles are various types such as

- Dye particle / dust particle / cut-punch dust
- Fiber / dust particle big in size / grease
- Scratch / rubbing marks

DYE PARTICLE / DUST PARTICLE / CUT-PUNCH DUST

Following are the dye comet defects arise due to dye crystal, dust particle and cut punch.

FACTOR 5

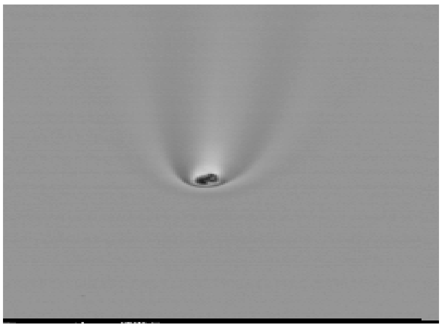


Fig 38 Dye crystal

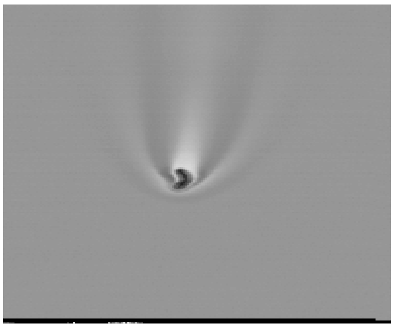


Fig 39 Dust particle

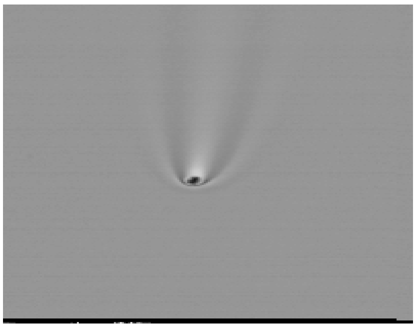


Fig 40 Cut punch

CORRECTIVE ACTIONS

- ❖ Check whether the problem is cup specific or in all cups?
- ❖ For cup specific problem, do purging and venting, also change the needle & dye cups if found dirty.
- ❖ If problem is in all cups, check the airflow and exhaust for dye crystallization

FIBER / BIG DUST PARTICLE / GREASE

Following are the dye comet defects arises fiber, big dust particle and grease.

FACTOR 6

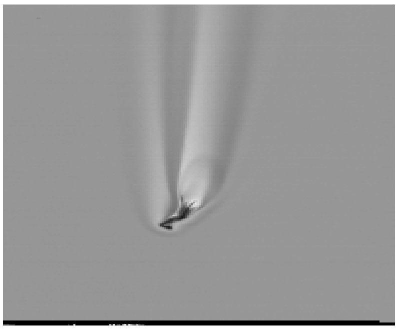


Fig 41 Fiber

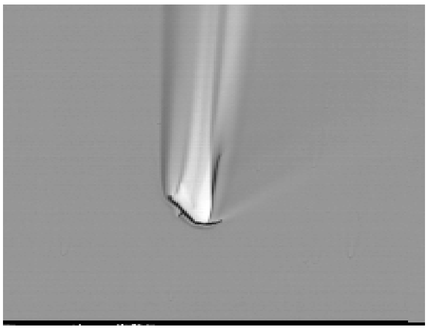


Fig 42 Big Dust particle

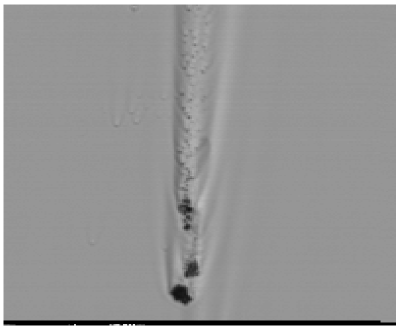


Fig 43 Grease

DYE VOID

Dye void arises due to edge washing solvent (methyl lactate) coming in the form of droplet on the surface of the disc.

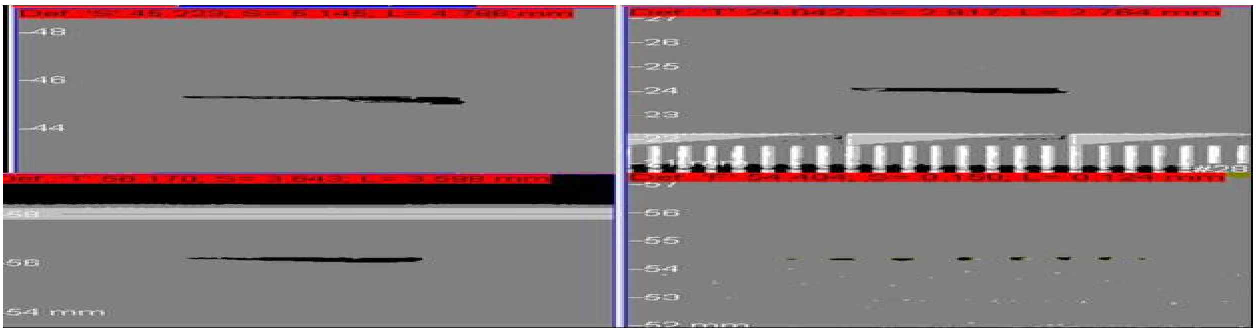


Fig 44 Various types of dye void occurred during the edge washing process

Table 23 Factor which arise the dye void and actions

Sr. No.	Factors	Action Plan
1	Damper Setting /Airflow of Edge Wash Cup	Damper setting adjust to Fully Closed for edge wash Cups.
		Exhaust inverters of Edge Wash Cup switch to 'OFF' Condition
2	Edge wash cup condition	Change the cleaning freqency of Edge wash cup on Weekly Basis.
3	Angle of edge wash nozzle	Angle set at 40-45 degree by changing Nozzle arm height from 6.0 - 9.5 mm.
4	Volume Regulator (Only Main Hall)	Set to fully open and adjust ML Volume to 0.2 ~ 0.3 gm
5	Edge wash profile	Edge Washing parameter adjust as per following Process Window.
6	Needle height (Z Axis)	Height(0.6-1.2mm) adjusted at the time of Angle adjustment
7	Dye volume (V-Cut Prob.)	Dye volume adjust from 0.4~0.5 gm as per Process Window.

DYE DISPENSING PROCESS AND EDGE WASHING PROCESS

The dispensing and edge washing (dye coating) process is happening simultaneously. The whole process occurred automatically controlled through PLC. This PLC work as per the designed profile. Photographic views of this process refer A**nnexure-7.**

EDGE WASHING PROCESS

The dye edge wiping process is mainly required due to two important factors.

- Poor visual appearance ---Aesthetics direct customer aspects.
- To prevent the dye to expose from the edges this leads the moisture absorption.
- Moisture absorption affects the life of the discs. --- Disc Life or durability.

So it is required that, the dye dispensing and edge washing process designed in such a way that the inner dye border should not exceeds from set limits.

i.e. ODB=59 mm +/- 1 mm and IDB=19 mm +/- 1mm

Inner dye border (IDB) = Dye should not crossed inner part of the disc.

Outer dye border (ODB) = Dye should not crossed outer periphery of the disc.
The various types of IDB and ODB defects has been shown in Fig 45

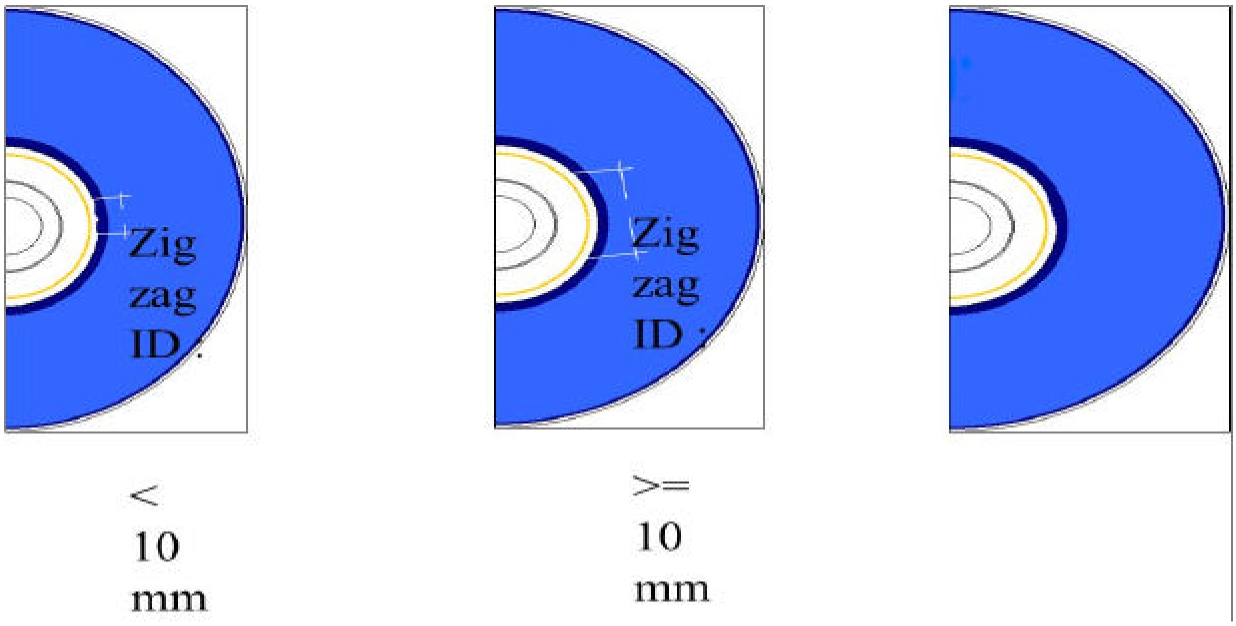


Fig 45 Improper inner and outer edge in the form of excess dye dispensed

These defects arise due to following reasons…

- ❖ High dye volume—Adjust the dye volume
- ❖ Dye dispensing needle co-centric --- adjust the vertical and horigental position of dispensing arm
- ❖ In Fig 46 has been shows the proper inner edge formation for DVD-R.
- ❖ In fig. 46, blue line represents the inner edge or (IDB) while red lines are the limits (upper and lower) for the inner edge and same system is applicable for the outer edge.

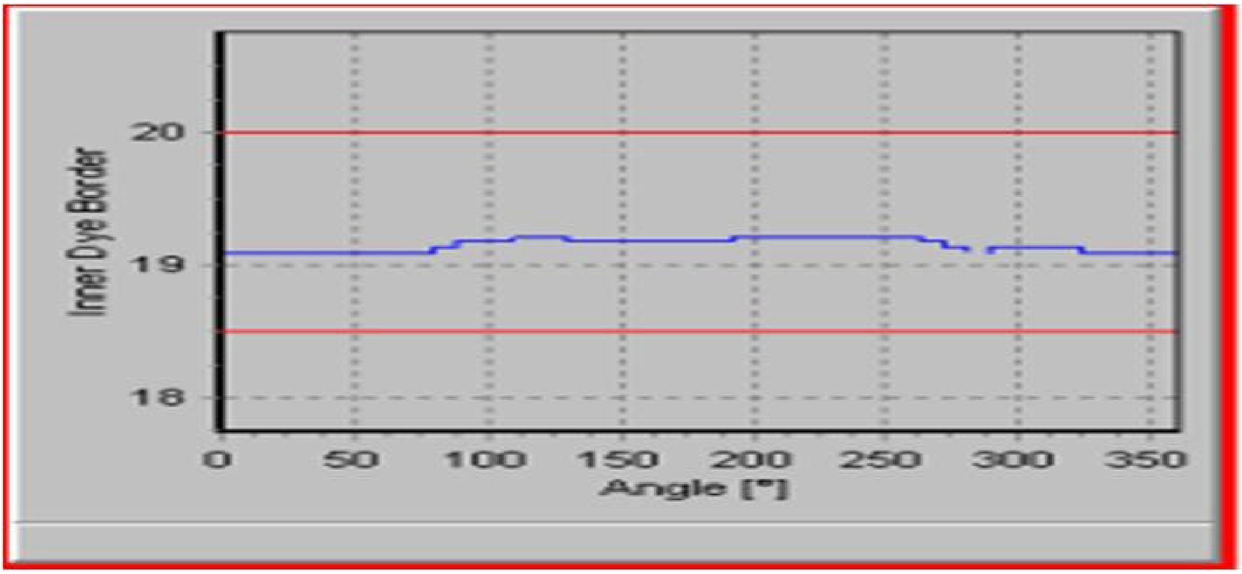


Fig 46 Proper inner edge

DESIGNING OF DYE EDGE WASHING PROFILE

- ❖ Inner or outer edge wiping run through a designed program and efficiency of that program depends how you design it.
- ❖ We have to design such profile that IDB and ODB fall under set limits.
- ❖ Designed detailed profile is given in Table 24.

Table 24 Rinse or edge washing profile

Rinse nozzle height	Exhaust velocity	Nozzle position (N)
0.6 TO1.2 mm	0.2 ~ 0.9 m / sec	50 to 70 mm

SPINNER

Step No	Rpm	Acceleration	Cont
1	700 ~ 1200	0.1	4 TO 5
2	700 ~ 1200	0.1	4 TO 5
3	2000 ~ 3000	1	4 TO 5
4	0	0.3	0
5	END		

NOZZLE

Step	NZ U/D	Wait time (sec)	Pos (mm)	V (mm/sec)
1	UP	0.1	N +2	150
2	DOWN	0.1	N	1.8 ~3.0
3	DOWN	0.3 to 0.6	N+2	1.8 ~ 3.0
4	DOWN	0.1	N + 2 ~5	3.0
5	UP	0.1	Home	150
DISPENSE				

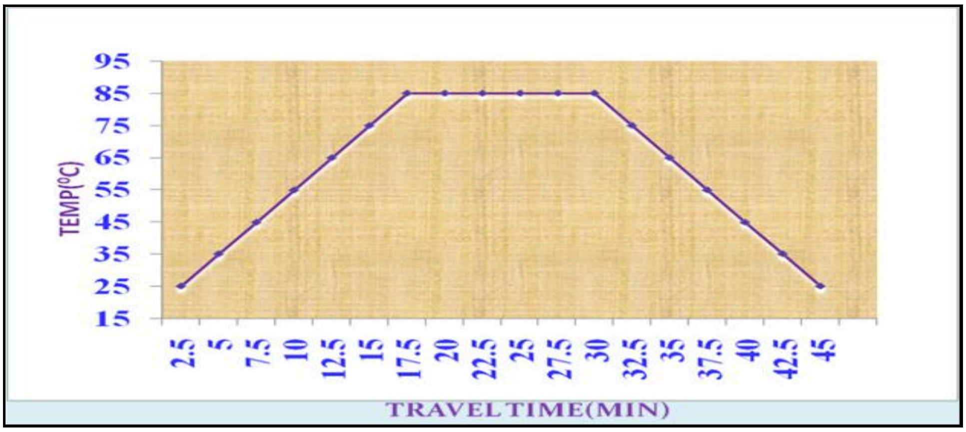
Step	On time(Sec)	Dispense pressure (Mpa)
1	3.0	0.035 ± 0.002

ANNEALING PROCESS

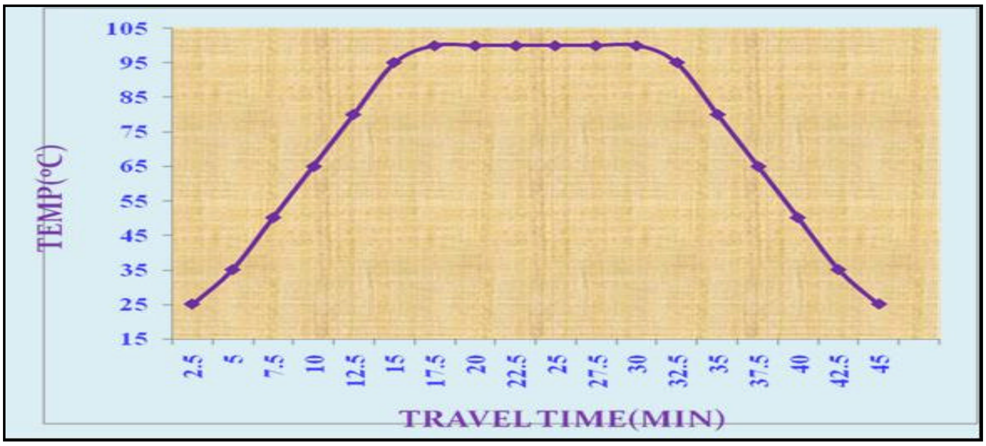
Annealing process is required to remove the all the residual stress and complete removal of solvent from the surface of the disc.

The dye coated disc after dye coating process then move to the annealing chamber where disc annealed through a gradual increasing of temp from 25-85 or 100°C and then gradually lowered 100 or 85-25°C temp.

The high-capacity oven with pre-heating, heating and cooling areas – evaporates all remaining solvents in the dye coating. The oven temperature range up to 110° C – corresponds to all current and emerging dye processes (OFP, TFP and all others currently available). Active and dummy discs are dried at the same time, and rotated to insure homogeneous temperature distribution and drying. The design of the oven allows edge cleaning after the subsequent metallization stage without contamination of the transport mechanism.



Graph 30 Annealing chamber temp profile (for +R format)



Graph 31 Annealing chamber temp profile (for -r format)

SPUTTERING PROCESS

PRINCIPLE OF METALLIZATION

Metallization is the application of a thin metal material onto a substrate surface, usually done within a vacuum chamber. This can be by E-beam evaporative coating or by a different process called sputtering. Electron beam hits target, melts the target material, vaporized atoms land on substrate to form thin film made of the same material as the target source.

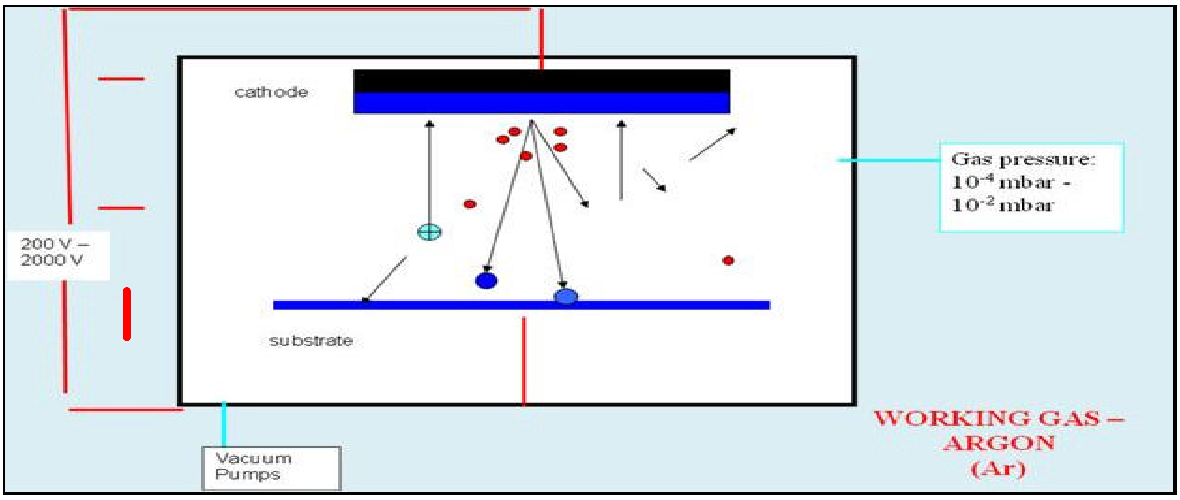


Fig 47 Striking of argon gas to the surface of the target which release electron

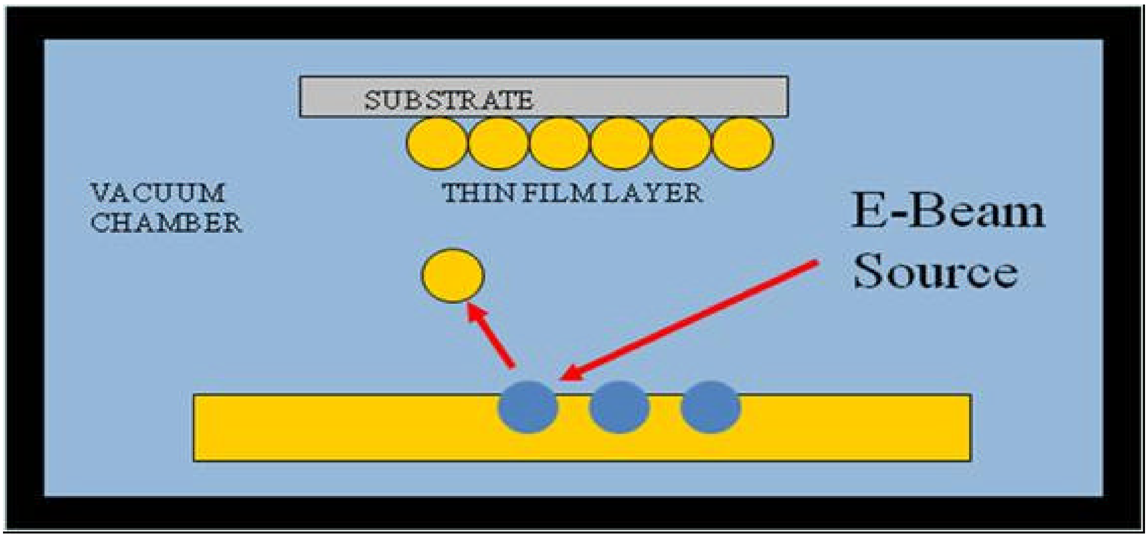


Fig 48 Deposition of freed particle in to the substrate

FORMATION AND STABILIZATION OF PLASMA

Plasma is an ionized gas, generated by exposing a gas being under low pressure to a static electric field or high frequency electrical field. For Maintaining Plasma under the influence of several hundreds of volts, the working gas requires pressure of about10^{-4} to 10^{-1} mbar. If the pressure is too large, the parts will collide before reaching the required ionizing energy. If the pressure is too low, the part density will also be low, which reduces the probability of collision.

Fig 49 Formation and stabilization of plasma

WORKING GAS

Argon (Ar) is used as working gas, which is stimulated to ionize by a static electric field. Due to commonly present ionizing radiation (cosmic radiation and natural nuclear radiation) each gas contains a certain rate of gas ions. Due to this several atoms within the working gas are split into positive Argon ions (Ar+) and negative electrons.

$$Ar \longrightarrow Ar^{+} + e^{-}$$

The electrical field accelerates the Argon ions towards the cathode and the negative electrons towards the anode. The accelerated parts collide with other atoms and ionize those by their kinetic energy.

MATERIAL TRANSPORTATION

After plasma has been ignited, lots of positive Ar ions impacts on the target. Due to their large mass they transmit a large impulse to the target, so the single atoms as well as atoms clusters become knocked out of the target, and moves towards the substrate results into the uniform deposition. This effect also heats up the target so target is to be water cooled regularly.

HOW DEPOSITION IS CONTROLLED

Since the target is slowly becomes used up by the metallizing process, the geometry between the target and substrate slowly changes during the target lifetime. As a result the metallizing rate slowly decreases in spite of constant metallizing power. Increasing the metallizing power compensates this aging of target. For this compensation charts are provided, the machine control reads the current target lifetime from the metallizer control and calculates the metallizing power with the help of compensation charts. This value is transmitted to the power supply for the metallizer and shown as compensated metallizing power.

CATHODE

In the metallizing process Target works as cathode. This target is screwed into a water-cooled heat sink with a central fixing screw and centered via a inner ring of the heat sink. The sink is made of the copper. For improving the heat transport function, a graphite thin foil is laid between the target and heat sink.

MASKING

Masking is the set up which protect to cover the areas where the sputtering not required inner mask protect the inner part of the disc till the lead in area and outer mask cover the till the lead out area start.

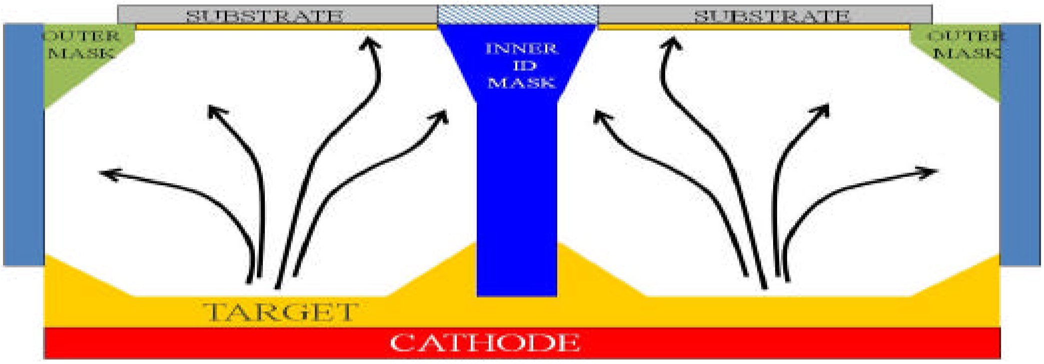


Fig 50 Masking (protecting of plasma deposition where it is not required)

UNI-JET METALIZER (Planer Magnetron Type)

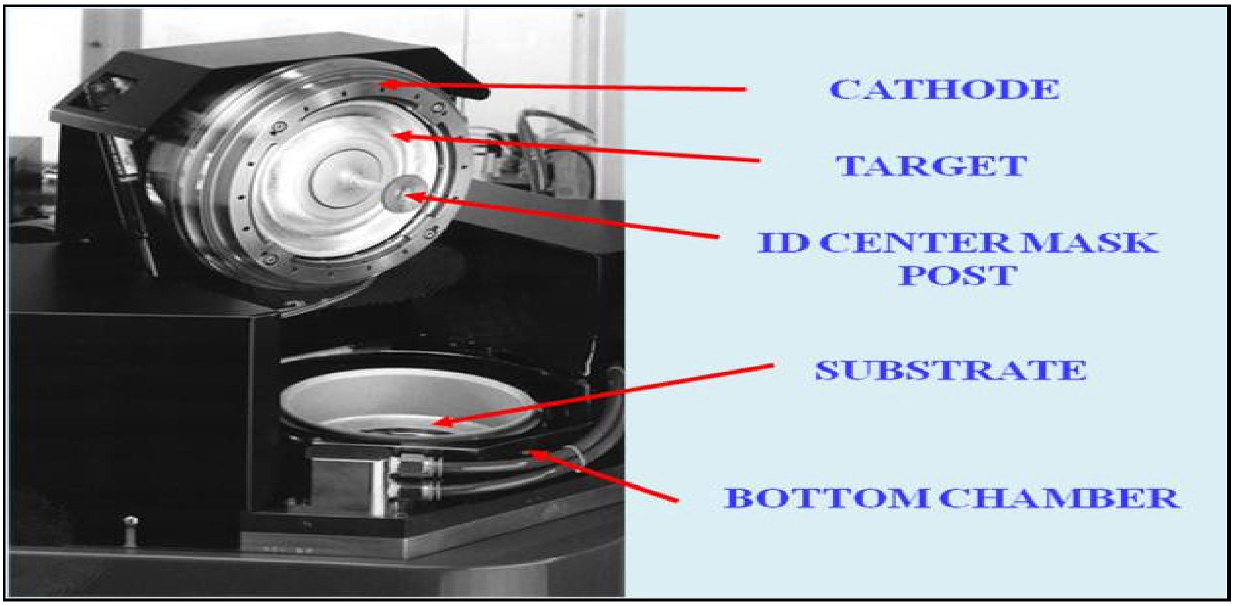


Fig 51 Uni-jet metallizer showing the sputter chamber

PRINCIPLE OF PLANER MAGNETRON

In Planer magnetron technology the metalizer is equipped with magnetron system, which is mounted behind the target. This system consists of two magnet placed with same poles facing each other. The electrical field created by magnetron forces the free electrons to move with circular motion, so that a helical motion results. Thus the travel path of the electron is enlarged. Due to this a larger degree of dissociation and better homogeneity results for the Plasma. For substrate a higher degree of deposition and thus a shorter metallizing time results.

WORKING OF METALIZER

Loading/Unloading of Metalizer

The handler arms pick clear disc with the vacuum suction plate, turn for 180° and puts it on the load lock chamber plate. The prep ump generates the vacuum in the load lock chamber. As soon as the pressure difference between the load lock chamber and main chamber is small enough, the lift cylinder lowers the disc deposit plate. The internal handling steps the clear disc through the main chamber into metallizing chamber at the same time the metalized disc is stepped back to load lock chamber.

The lift cylinder again lifts the disc plates, thus the load lock chamber as well as metallizing chamber are closed from below. The load lock chamber becomes vented; the handler suction plate picks the metalized disc and swivels back.

INTERNAL HANDLING OF METALLIZER

Inside the metallizer the disc is stepped via 2 & 3 position in the counterclockwise wise direction. The disc deposits also serve for the sealing of the metallizer chamber/load lock chamber against chamber.

Internal handling System has to perform following

The disc is taken out of the evacuated load lock chamber.

(2) The disc stays in the main position (3 rd).

(3) The disc becomes metallized in the metallizer chamber.

(4) The disc is handed over to loading /unloading plate.

This system is driven by an indexing unit, whose lift turn motion is governed by the control. When being in the position under load lock chamber & metallizing chamber, the disc deposits plates are lifted and lowered by lift cylinders, which are attached below the position. The lift cylinder is shielded by a metal below to provide sealing towards chamber vacuum.

COMPONENTS OF VACUUM SYSTEM OF METALLIZER

Pre-Vacuum Pump-1 Produces the Pre-vacuum for load –lock and sputter chamber (Process Chamber)

Pre-Vacuum Pump-2 Produces the pre-vacuum for turbo pump. (10-2)

Turbo-molecular Pump Produces the High vacuum in Main Chamber and Sputter Chamber (10-4)

Gauge-1 Measure the pressure in the pre-vacuum pressure in the load lock chamber and Process Chamber. (Pirani gauge)

Gauge-2 Measure the Pressure in the Main Chamber.

STANDBY MODE

Whenever the metallizer is not used for the short time it is recommended to operate it in standby mode, in order to maintain the chamber vacuum. If the metallizer is not used for long time periods, the vacuum becomes vented and air penetrates the system.

MEDIA SUPPLY OF THE METALLIZER

- ❖ Cooling water ---------------------- 11 – 14 L/min at 5 to 6 bar at 18 deg.

  (This water is softened, particle free and neutral.)

- ❖ Argon gas---------------- 1- 2 bar
- ❖ Compressed air (CDA) -----4- 6 bar, oil & moisture free.

DIFFERENT REFLECTIVE MATERIALS

Table 25 Different reflective materials the DVD-R

ALUMINUM	GOLD	SILICON	SILVER ALLOY
Lowest in cost Easy to sputter But low reflectivity Hard to control thickness for very thin layers	High cost, but very little used for the L0 layer Easy to sputter High reflectivity Thin uniform layers can be consistently achieved	Low cost (need high purity therefore cost is more than aluminum) Hard to sputter (semi-conductor vs conductor) Fragile target and sputtered layer Impurities contribute to lower yields	Medium to low cost Easy to sputter Alloy uniformity and composition becomes important

DEVELOPMENT OF DVD-R PROCESS WINDOW FOR THE SPUTTERING PROCESS

Table 26 Different reflective materials the DVD-R

S .No.	Parameters	Specification (Cathode)
1	Layer Thickness	120 nm
1	Layer Thickness (16X ±R MKM & MBI)	140 nm
2	Ramp Time	0 sec
3	Sputtering Time	1.4 sec
4	Venting Time	0.1 sec
5	Roughing Time	0.55 sec
6	Argon pressure set value	9.00 sccm
7	Water Flow Rate	20.0 l/min.

BONDING PROCESS

The DVD-R 3503 system operates with two injection molding machines running simultaneously to provide half disc pairs. The half discs receive a dye and metal coating and then are bonded together with UV-curable resin. Finished discs are then inspected for quality and sorted onto spindles.

The two injection molding machines run at similar cycle times: one produces active disc substrates and the other produces dummy disc substrates. Each disc has a groove on one side near the disc inner diameter (ID) that is referred to as the moat. The moat is formed by the stamper holder and acts as a reservoir to contain the bond resin. The active disc has a stacking ring and the dummy disc is featureless on the mirror side.

The active and dummy discs are placed on a bonding chuck and bowed so that a needle can extend between them to dispense bond resin. After dispense, the disc pair is slowly unbowed, allowing the bond resin to spread between the discs. The disc pair is then transported to a capillary table and indexed to the spin bowls, which spin the discs to remove excess resin and create a uniform bond.

BOND RESIN DELIVERY SYSTEM

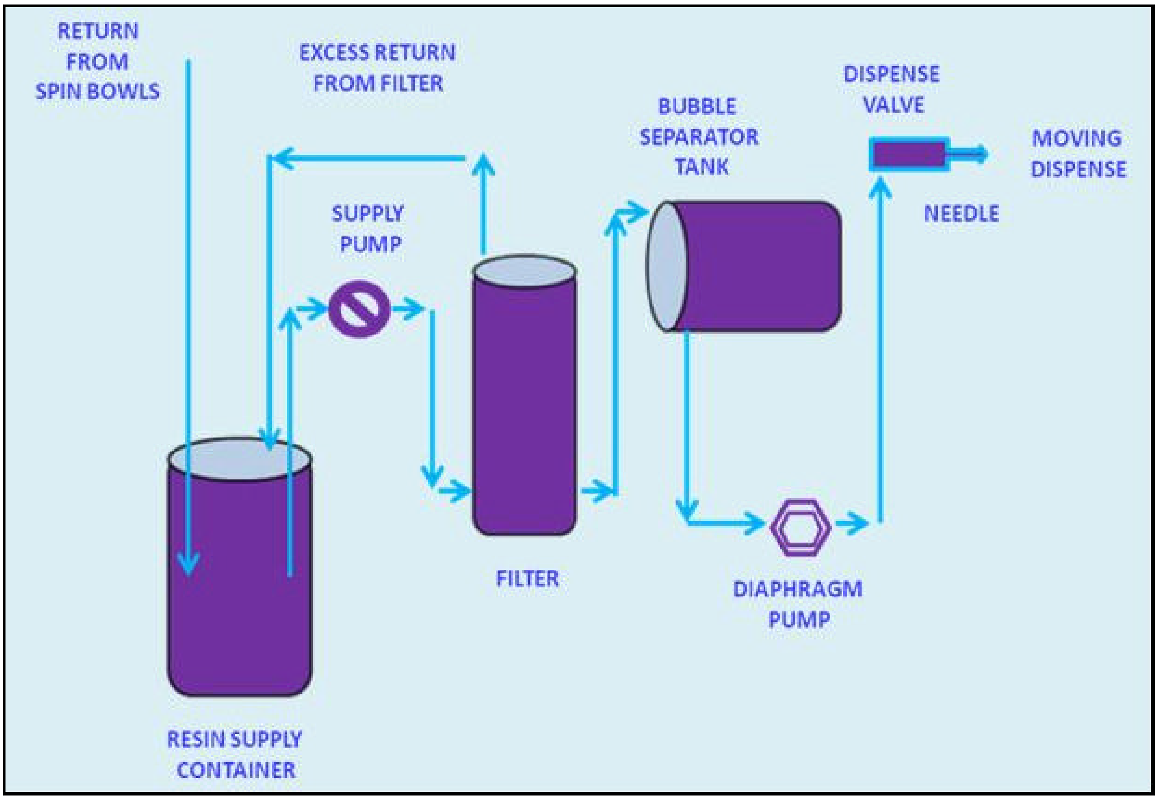


Fig 52 Bonding resin dispensing circuit

BONDING RESINS

The typical constituent's of U.V cure bond resin are as follows.

Oligomers 1 (High molecular weight acrylate)	30-50%
Oligomers 2 (High molecular weight acrylate)	5-20%
Acrylate Monomer	<25%
NN-Di methyl Acryl amide Monomer	<25%
Photo-initiator (2 types)	1-5%
Adhesion Promoter	<1%

Due to trade secrets it is impossible to know what type of acrylate used.

COMPONENTS OF UV FORMULATIONS

- Oligomers
- Monomers

OLIGOMERS

An oligomer is polymer molecule consisting of only a few monomer units.

Oligomers tend to be higher in molecular weight and more viscous than the other monomers in the formulation. The overall properties of the resin are determined by the Oligomers used in the formulation (flexibility, toughness, adhesion, etc.).

They are moderately low molecular weight polymers, most of which are based on the acrylation of different structures (hence acrylates).

The acrylation imparts the unsaturation of the "C=C" group to the ends of the Oligomers.

MONOMERS

Monomer tends to be lower molecular weight materials. Monomers are primarily used as diluents to adjust the viscosity of the uncured resin to facilitate application or processing.

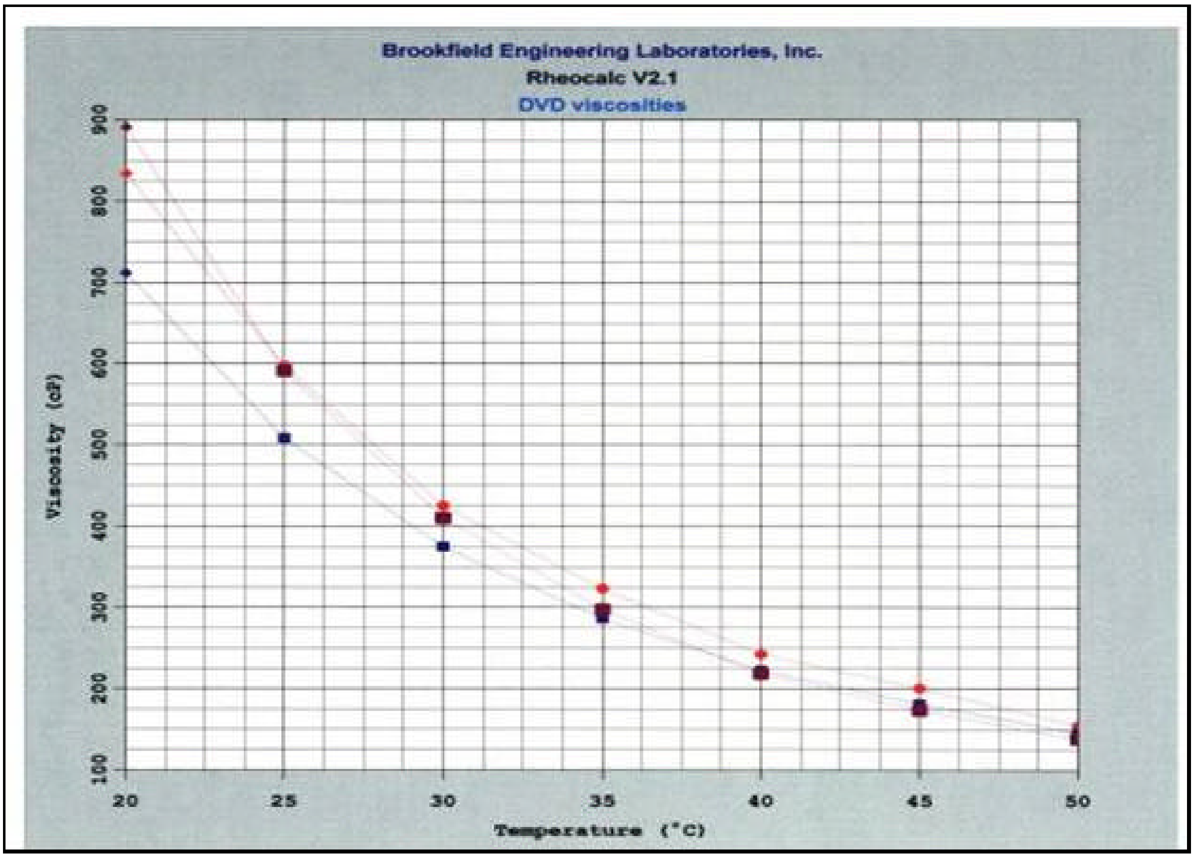
They can be mono functional, containing only one reactive group or unsaturation site, or multifunctional.

This unsaturation allows them to react and become incorporated into the cured resin, rather than volatizing into the atmosphere as is common with solvent based formulations.

Multifunctional monomers, because they contain two or more reactive sites, form links between oligomers molecules and other monomers in the formulation.

DVD BOND RESIN VISCOSITIES

At room temperature a 5.0^0c change in temp will cause the viscosity to change by almost 50% so the quality of bonding is also depends upon the bonding viscosity. The bonding temperature controlled through a chiller unit which maintain bonding area temp 25+/- 0.1^0c



Graph 32 Effects of temp on the glue viscosity

High viscosity caused cross moat and low viscosity caused the improper bonding glue dispersion.

BONDING PROCESS

Flow dig of bonding process, mainly consists of three processes.

Dispensing ⟹ Bonding ⟹ Spinning

❖ **<u>Dispensing</u>**

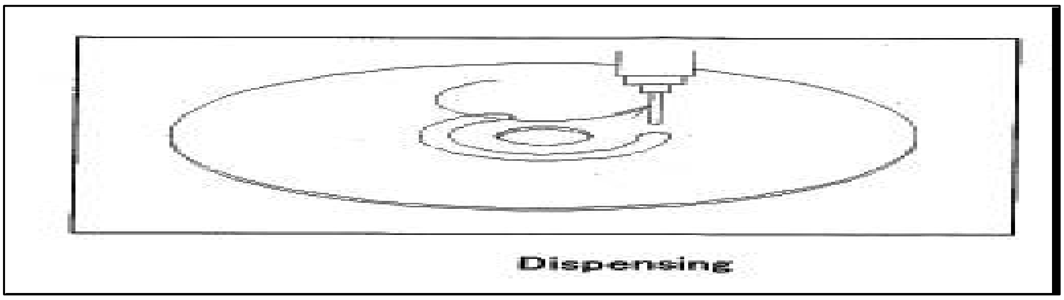


Fig 53 Glue dispensing on the top of sputtered disc under EF

❖ **<u>Bonding</u>**

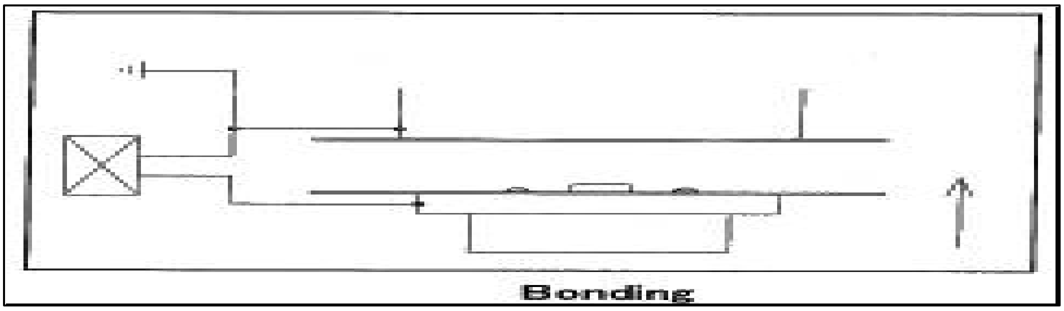


Fig 54 bonding (dummy disc sits on the dispensed glue under EF)

❖ **Spinning**

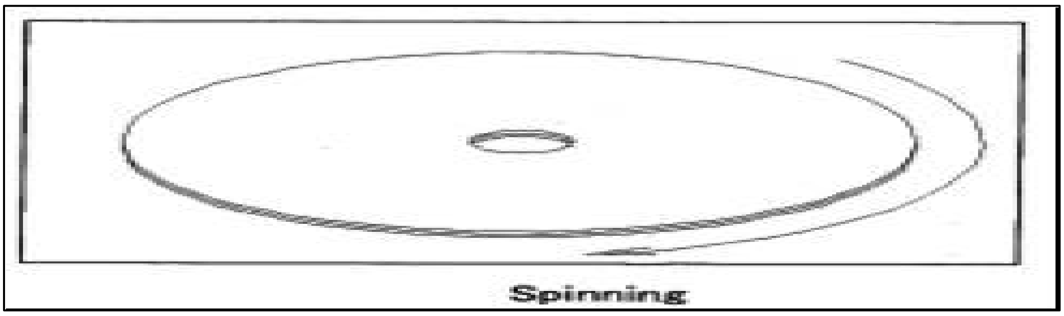


Fig 55 Spinning of bonded disc for removal of excessive glue

DISPENSING PROCESS

Dispense the bonding resin on to the sputtered side of recorded discs by applying a turning nozzle. Appling an EF process system for dispensing but …

- ❖ The quantity of the dispensed bonding resin on disc: 1gm.
- ❖ Aligning the center of the ring of the dispensed bonding resin uniform width of the ring.

BONDING

Putting a dummy disc on a recorded disc and dappling an EF process system for bonding but this process apart from EF process depends upon the two important factors.

- ❖ Release point-settings.
- ❖ To avoid scratching the disc-suction plates of the bonding arms and the bonding stage at the maintenance.

SPINNING

For the bonding two discs, required glue layer should be very thin. Excessive bonding glue or resin should be removed that's done thru the spinning of both the bonded discs. But the quality of bonding and the visual appearance of the disc depend upon the…

- Spin setting and Inner suction setting.
- Formation of centric glue ring during dispenses.
- Bonding stage and Bonding Profile.

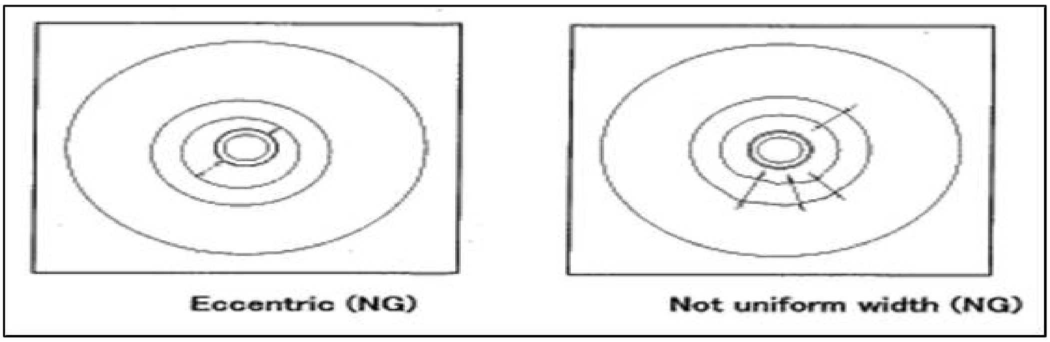


Fig 56 Eccentric and uneven width of dispended bonding glue ring

FUNCTION OF AN EF PROCESS SYSTEM FOR BONDING

The bonding resin contacts the surface of the disc at a small point in electric field. Elimination of micro bubble in the ring of dispensed bonding resin. The electric field developed surrounding of the needle tip which decrees the resin surface tension.

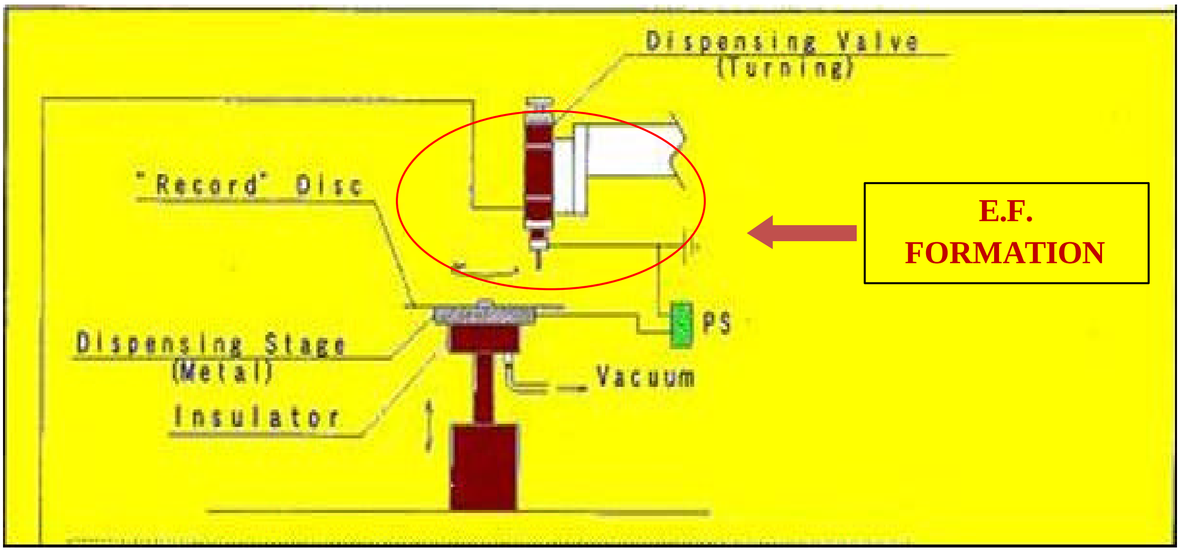


Fig 57 Formation of electric field surrounding of the needle tip during bonding process

EF PROCESS DURING DISPENSING

The pinpoint contact in the electric field between the dispensed bonding resin and the surface of the disc eliminates air in its boundary and it eliminates bubbles from the bonded bonding resin layer.

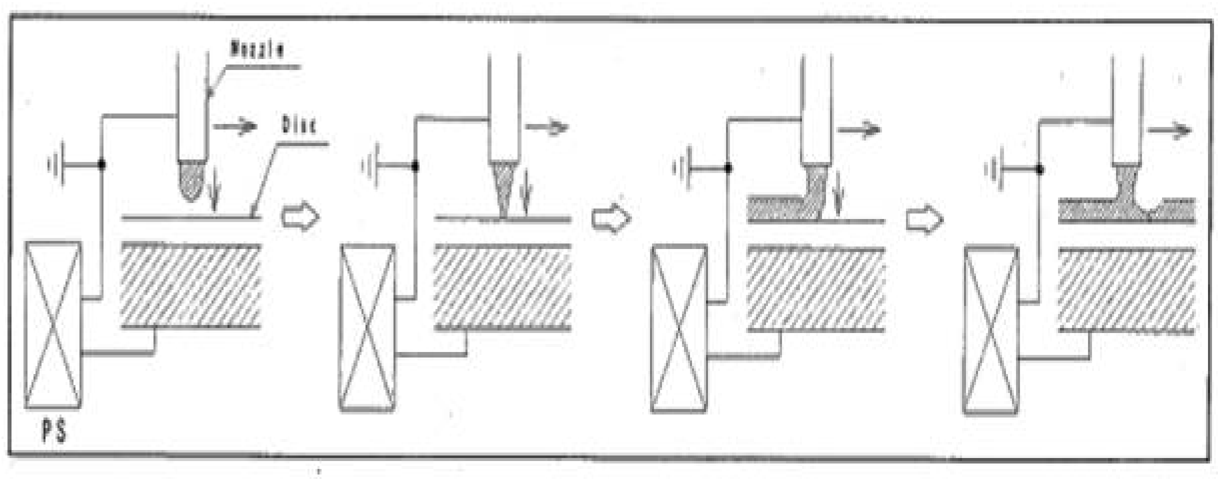


Fig 58 Dispensing process with EF

EF PROCESS DURING BONDING

The pin point contact in the electric field the dispensed bonding resin and the surface of the disc eliminates air in its boundary and it eliminates bubbles from the bonded bonding resin layer.

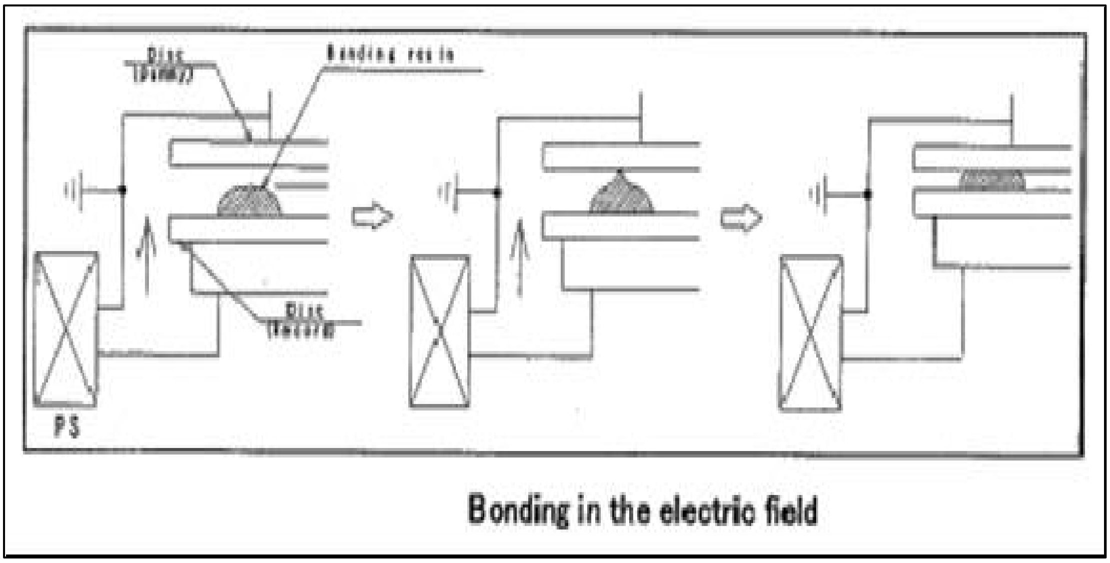


Fig 59 Bonding process with EF

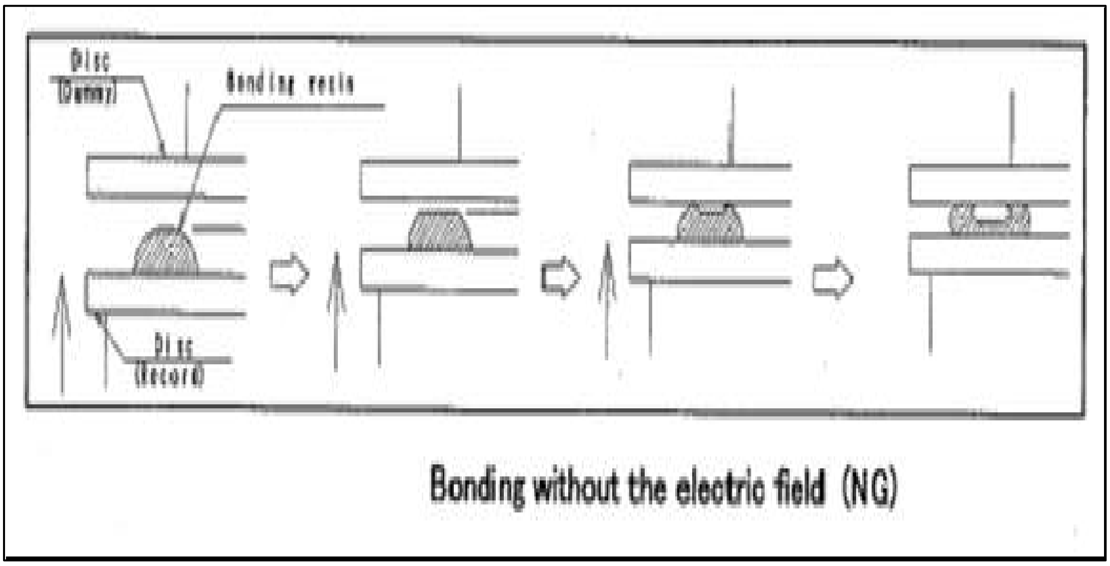


Fig 60 Bonding process without EF

DESIGNING OF DVD-R BONDING PROFILE

Bonding profile consists following parameters.

- ❖ Bonding process setting
- ❖ Inner suction setting
- ❖ Inner suction setting profile

DEVELOPMENT OF DVD-R BONDING PROCESS SETTING

Table 27 Bonding process parameters

S.NO.	PROCESS PARAMETERS	VALUE	STATUS
1	Dispense Time	1.15	Fixed
2	Dispense Revolution	45~55	Changeable
3	Dispense Purge Time	1	Fixed
4	Dispense Purge Cycle	900	Fixed
5	Bonding Time Out 1(Nozzle~Tb Out)	8	Fixed
6	Bonding Time Out 2(Spin~UV Out)	17	Fixed
7	Cycle Time Set	2.75	Fixed
8	Bonding Stage Release Point	0.70~0.85	Changeable
9	Accept Table 2 Spindle	150	Fixed
10	Dispense Radius From Centre Hole	18	Fixed
11	Capillary Time	5~605	Changeable
12	Dispense Volume(gm)	0.98~1.05	Changeable
13	Dispense Pressure(mpa)	0.14~0.20	Changeable

SPINNER PROFILE

Table 28 Bonding spinner profile

PROCESS PARAMETERS	VALUE	STATUS
Step 1	0.00~0.15	Changeable
Step 2	0.6	Fixed
Step 3	1000	Fixed
Step 4	0.65	Fixed
Step 5	0.7	Fixed
Step 6	3000	Fixed
Step 7	0.75	Fixed
Step 8	0.5	Fixed
Step 9	6200	Fixed
Step 10	1.8	Fixed
Step 11	0.3	Changeable
Step 12	0.3	Fixed

INNER SUCTION SETTING PROFILE

Table 29 Bonding suction profile

Process Parameters	Value	Status
P1	0.01-0.04 mpa	Changeable
P2	0.05-0.25 mpa	Changeable
P3	0.05-0.25 mpa	Changeable
T1	0.4 sec	Fixed
T2	1.2 sec	Fixed

THE WAY BONDING PROCESS WORKS

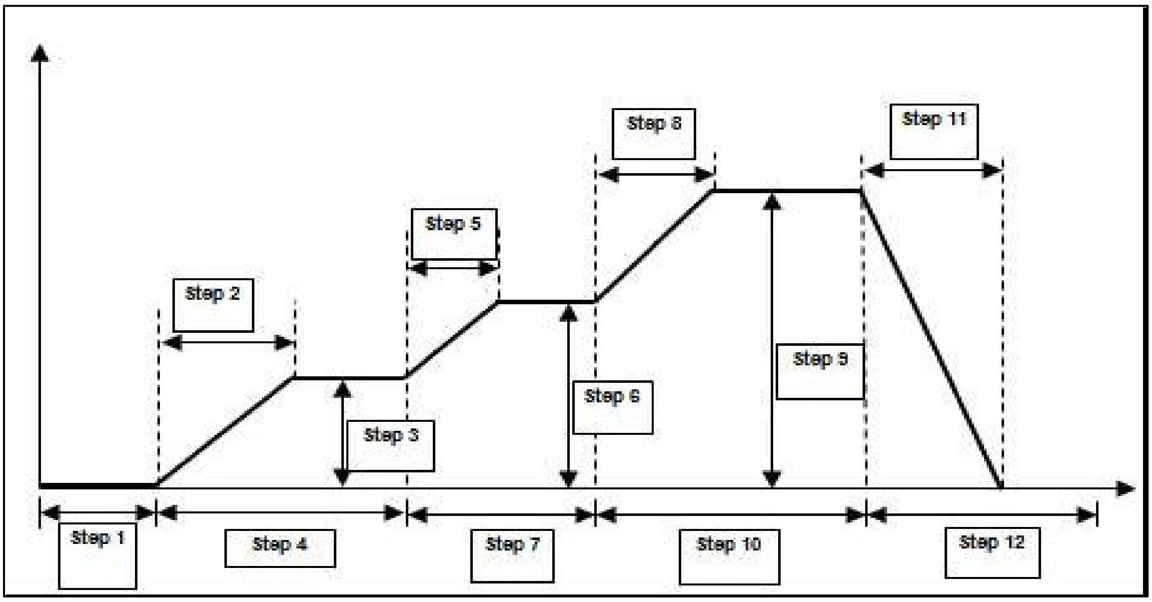


Fig 61 Spinner setting

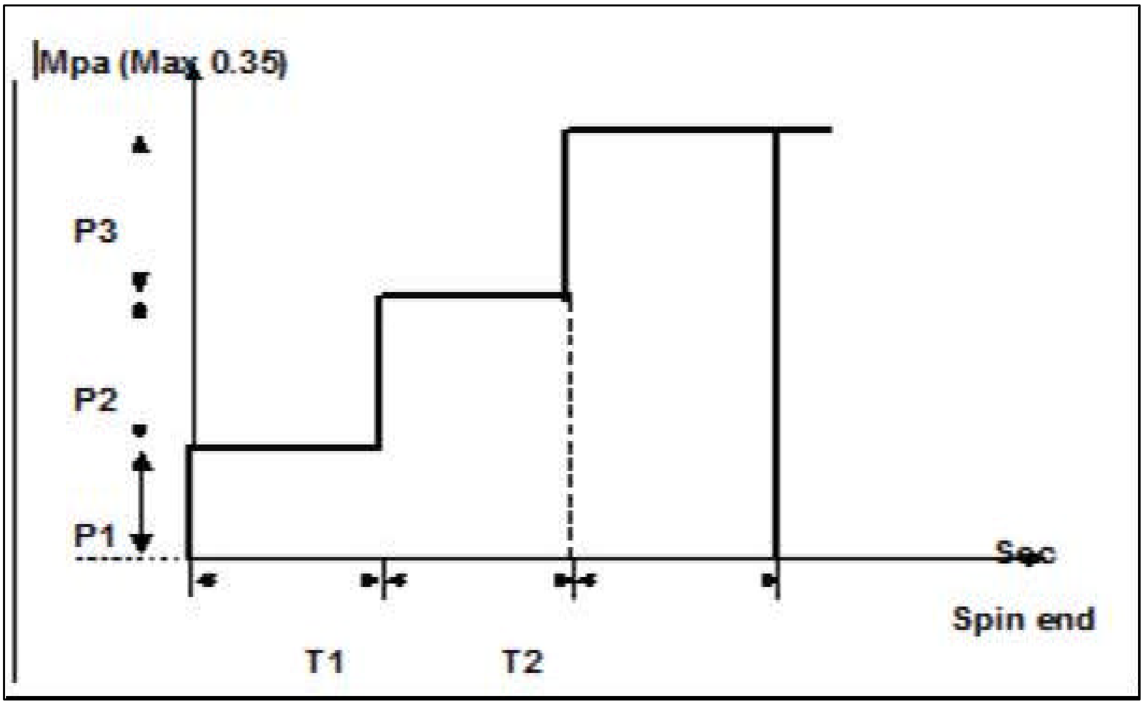


Fig 62 Inner suction setting

BONDING PROBLEMS AND THERE REMEDY

BUBBLES RADIAL AT OD

When bubbles are radial at the outer diameter (OD,) unbow rate exceeds the wetting ability of the bond resin.

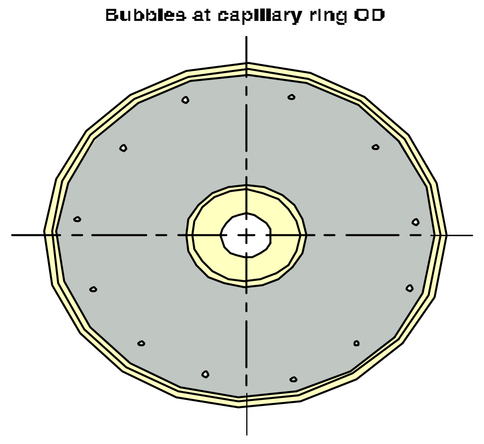


Fig 63 Bubbles radial

Since the wetting ability of the bond resin is dependent on substrate temperature, resin temperature, and resin viscosity, quantifying the proper unbow rate is difficult. However, observing the dispense allows the operator to identify the proper unbow rate control the bow / unbow rate using the Process page of the user interface. The discs should come together slowly, almost at the same time (the top disc unbows slightly before the bottom disc). The gap dispense process can be accelerated if the bond resin is dispensed at a higher rate. The limitation to the gap dispense speed is the flow limitations imposed by the dispense needle. The needle should deliver the desired volume of bond material with fluid velocity high enough to prevent needle contamination and to place the resin at the disc junction. Excessive fluid velocity can cause bubbles within the capillary ring.

BUBBLES RADIAL AT MIDPOINT

When bubbles are radial at the midpoint, there may be more than one cause. If insufficient bond resin is being applied, the dispense needle may be too far away from the ID or the dispense speed may be set too fast.

If the dispense system is ejecting bubbles (you can observe this at the bonder station during dispense), the needle flow sputters. Identify and correct the source of inconsistent flow. It could be excess pump pressure, a damaged pump diaphragm, leaky fittings, or a damaged needle.

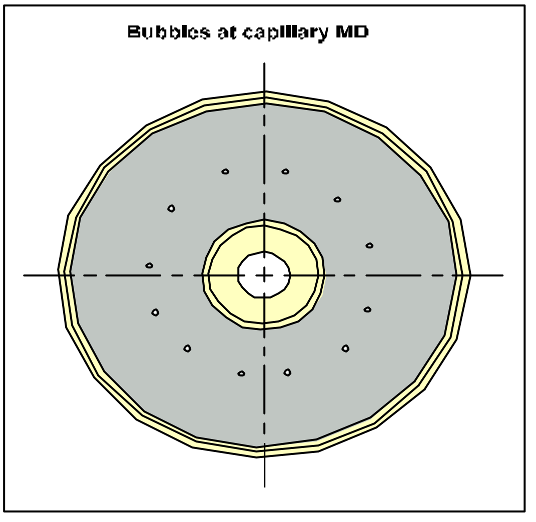
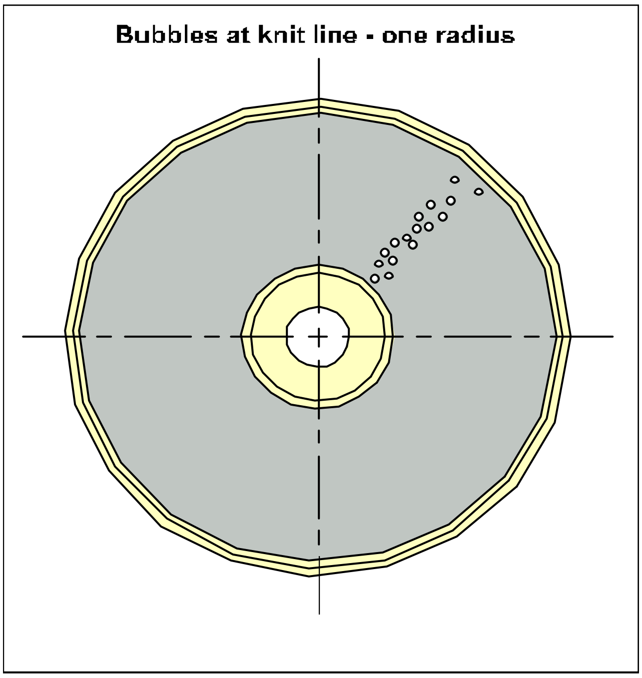


Fig 64 Bubble radial at midpoint

BUBBLES AT ONE RADIUS (AT KNIT LINE)

If bubbles appear at one radius on the disc, the dispense rotation may be incorrect. Observe the capillary ring immediately after dispense: the ends of the capillary ring should be 1-3mm apart or closed after the unbow, before being picked by the robot.



Bubbles at one radius can also be caused by insufficient or excess dispense rotation. The dispense rotation should allow the ends of the capillary bridge ring to flow together after the unbow sequence. Overlapping the ends of the capillary bridge ring generate small bubbles at the overlap. A small gap (approximately 1-3mm in between the start and end of the bead) is preferred.

Fig 65 Bubble at one radius

FLOWERING

Flowering is a disturbance in the spacer layer from the moat outward. This defect mainly occurs during the cure cycle when the bottom disc separates from the top disc during the vacuum pull down. If the cure chuck ID posts are contaminated by cured resin, the top disc scratches on the cured resin and separates from the bottom disc. Several conditions aggravate this defect: placement form the Unload Handler onto the cure chucks. Clean the UV-pins.

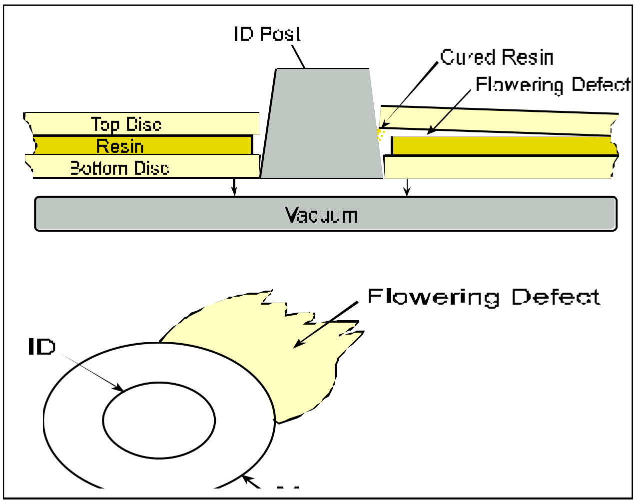


Fig 66 Flowering

BUBBLES DISPERSED THROUGHOUT CAPILLARY RING

Bubbles dispersed throughout the capillary ring indicate that there is an incomplete capillary bridge ring. Observe the dispense process to determine the cause. The dispense speed may be too fast, the needle may be too far from the disc interface, there may be insufficient pump pressure, or the bow geometry may not be uniform

RESIN PULL OUT DURING SPIN

Resin pull out occurs during the high-speed spin process. The resin pulls out from the ID of the disc, leaving small to large voids. The cause of this is due to improperly formed moat areas on the substrates. This substrate abnormality can best be seen as the discs come down the in feed conveyor or by observing the moat area as the discs spin. If the abnormality is large, then replace or rehang the stamper.

Decreasing the amount of vacuum that holds the disc in place during the spin can help reduce the resin pull out.

SCRATCHES OR MARKS

The bonder OD suction rings can cause scratches or marks near the outer edges of the disc on the mirror sides of the disc (sides without data). The rings are either damaged, dirty, old, or have resin on them. Clean OD suction rings with soap and water; do not use isopropyl alcohol or solvents. If the problem persists, replace the rings with new ones.

- ❖ The o-rings in the UV chuckscould create marks
- ❖ Check the rotational speed from the cure chucks and reduce it if necessary.
- ❖ Clean the o-rings or replace them but be careful and observe the tangential deviation.

UV CURING PROCESS

The bonded disc is placed on the cure table where the due to UV light photo initiators activate and initiate the curing reacting, resin cured, and post cooled. Curing occurred when complete UV table with disc exposed under ultraviolet (UV) lamp. Cooling after cure creates a steady-state temperature in the discs, which helps bring the discs close to their final condition before inline inspection. In this station the bonded and cured DVD's move in a vertical direction.

The UV curing process depends upon the following factors…

- Homogenized UV radiation across the disc
- Adjustable UV power between 2 and 20 kW
- High exposure power only when disc is below UV radiators
- Use of cold light mirrors to reflect only UV light
- Shielding arrangement to avoid direct radiation towards the disc
- Nature and activity of photo initiators…

Which all are controlled through UV lamp set up and curing profile.

To cure the lacquer the photo initiator needs to be cracked into it's active form. This is done by applying a radiation of high energy, the so-called UV-C radiation. A high pressure mercury vapour lamp produces an UV-C radiation in the range of 100-280nm.

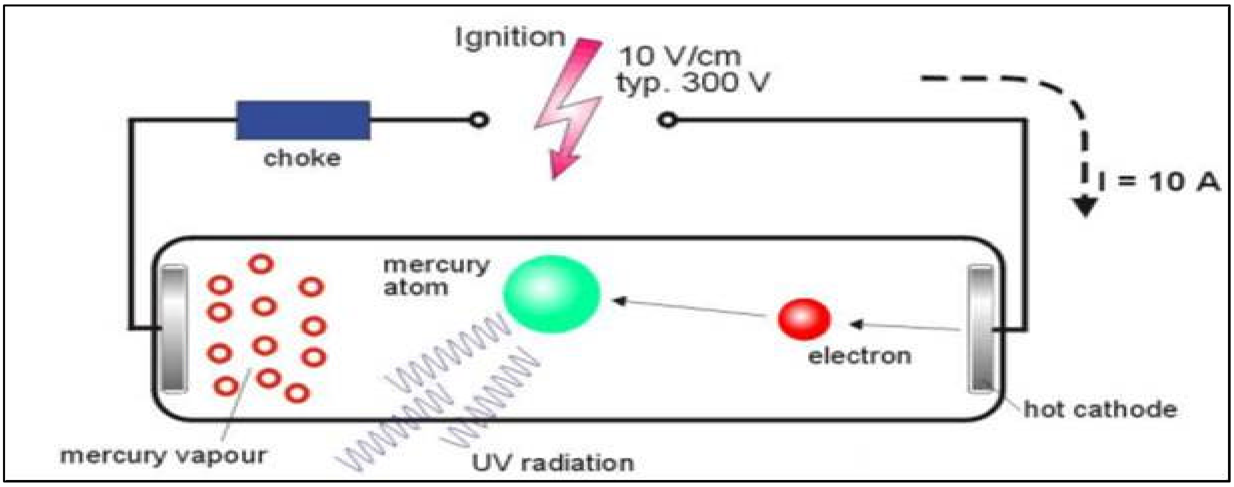


Fig 67 UV lamp

PHOTO-INITIATORS

This ingredient absorbs light and is responsible for the production of free radicals. It is the critical component of the UV curing process. It is the additive that initiates the polymerization process to quickly reach the final cross linked product.

As UV light energy is emitted, it is absorbed by the photo initiator in the “mobile” coating, causing it to fragment into reactive species (either free radical or cationic).

Free radicals are high energy species that induce cross linking between the un saturation sites of monomers, Oligomers and polymers. Some formulations use more than one photo initiator.

CATEGORIZATION

A Photo-initiator can be categorized In Different Ways.

ACCORDING TO ITS MECHANISM	**ACCORDING TO ITS ABSORPTION**
❖ Free radical ❖ Cationic	❖ UV light ❖ Visible light
ACCORDING TO ITS FORM	**ACCORDING TO ITS APPLICATION**
❖ Liquid ❖ Solid	❖ Clear ❖ Pigmented

ROLE OF PHOTO INITIATORS The roles of photo initiators are as follows.

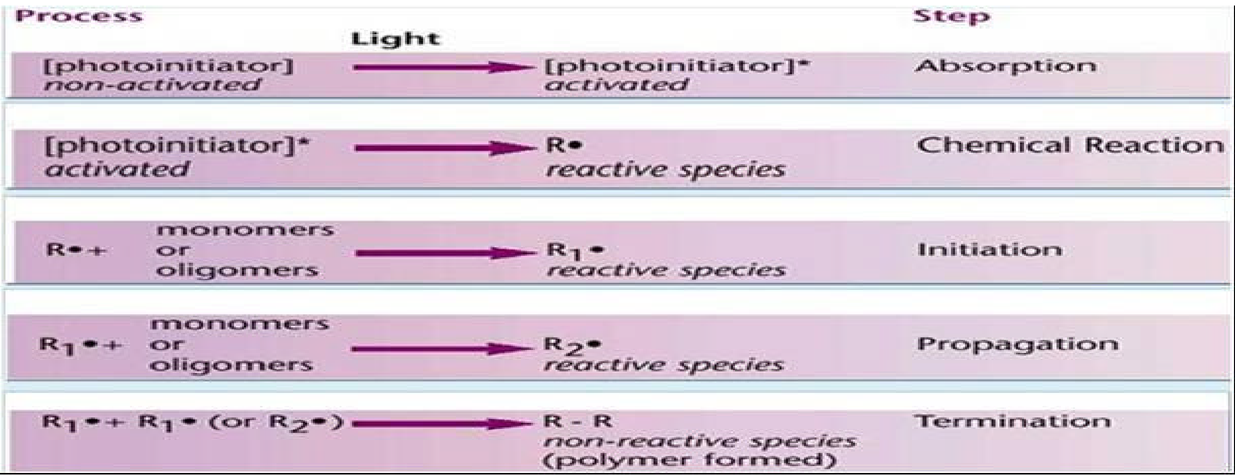


Fig 68 Role of photo initiator

PHOTO-INITIATORS (EXTINCTION COEFFICIENTS)

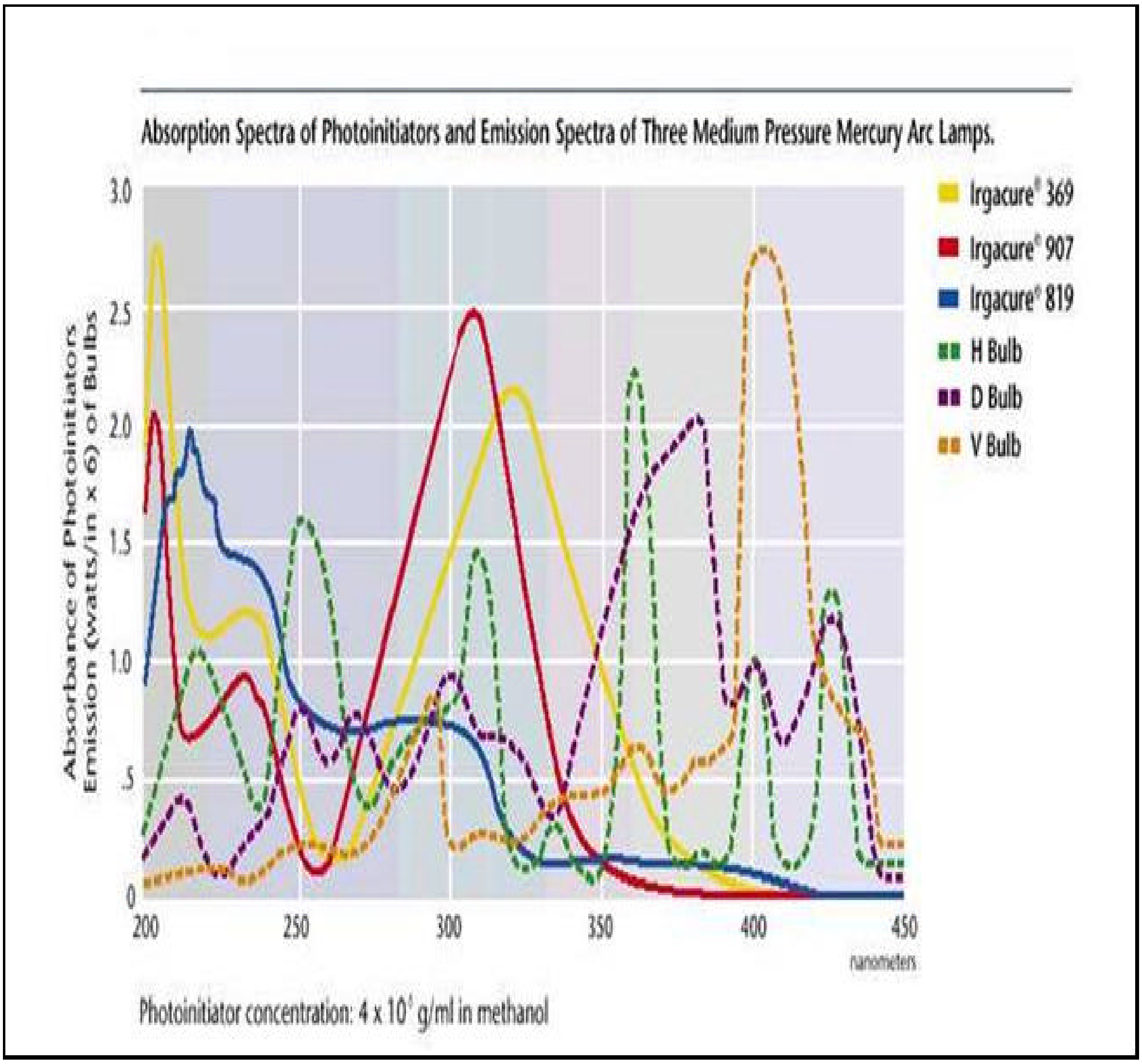
Extinction Coefficients=Absorption coefficient/concentration of substance in solution

Various types of extinction coefficient at different wave length for methyl alcohol are given in Table 30.

Table 30 Extinction coefficients at different wavelength relative to mercury vapor lamps, ml/grams cm^2 in MeOH solution at room temperature

Photoinitiator	254 nm	302 nm	313 nm	365 nm	405 nm	435 nm
Irgacure 184	3.317×10^4	5.801×10^2	4.349×10^2	8.864×10^1		
Irgacure 369	7.470×10^3	3.587×10^4	4.854×10^4	7.858×10^3	2.800×10^2	
Irgacure 500	6.230×10^4	1.155×10^3	5.657×10^2	1.756×10^2		
Irgacure 651	4.708×10^4	1.671×10^3	7.223×10^2	3.613×10^2		
Irgacure 784	7.488×10^3	1.940×10^4	1.424×10^4	2.612×10^3	1.197×10^3	1.124×10^3
Irgacure 819	1.953×10^4	1.823×10^4	1.509×10^4	2.309×10^3	8.990×10^2	3.000×10^1
Irgacure 907	3.936×10^3	6.063×10^4	5.641×10^4	4.665×10^2		
Irgacure 1300	3.850×10^4	1.240×10^4	1.560×10^4	2.750×10^3	9.300×10^1	9.000×10
Irgacure 1700	3.207×10^4	5.750×10^3	4.162×10^3	8.316×10^2	2.464×10^2	
Irgacure 1800	2.660×10^4	6.163×10^3	4.431×10^3	9.290×10^2	2.850×10^2	
Irgacure 1850	2.235×10^4	1.280×10^4	8.985×10^3	1.785×10^3	5.740×10^2	
Irgacure 2959	3.033×10^4	1.087×10^4	2.568×10^3	4.893×10^1		
Darocur 1173	4.064×10^4	8.219×10^2	5.639×10^2	7.388×10^1		
Darocur 4265	2.773×10^4	4.903×10^3	3.826×10^3	7.724×10^2	2.176×10^2	

Photo initiators are selected based upon their extinction coefficients (absorption strength) in response to the UV wavelength used in the curing lamp. Photo initiator must match the lamp spectra for getting proper UV curing it is mandatory that the:



Graph 33 Absorption spectra of photo initiators

UV CURING PROCESS PARAMETERS

Table 31 designing of UV Curing process parameter

ORIGIN LINE	
Voltage	1450 Volts
No of flashes	7 SHOTS
CHALLENGER LINE -I & IV	
Curing Time	1400 ms
Normal Power	2800 W
Base Power	700 W

The power of UV lamp calibrated by the energy meter which measure minimum UV energy required to cure the disc.

The last phase of DVD production is a quality inspection. Unlike standard CD-Rs, DVD-Rs are scanned for defects from the top and the bottom. The bottom of the disc is scanned for standard physical defects. The top of the disc is scanned for bubbles and other physical defects particular to the specific DVD format.

CHAPTER-4

CONCLUSION AND SCOPE OF WORK

CONCLUSION

In the field of optical storage media production, the raw material cost is increasing day by day because of the 70% (poly carbonate and bonding glue) of raw material came from petroleum and the final product cost goes down day by day. To cope up this manufacturer need to improve the productivity without affecting the quality of the disc. Productivity increases only by process optimization in low cycle time.

The above project work helps optical media manufacturers to stabilize their process in low cycle time and able to increase their productivity.

In principal for manufacturing of any optical media technology requires.

1) Injection Molding Technology

2) Dye Coating Technology

3) Sputtering Technology

4) Bonding Technology

5) UV curing

SCOPE OF WORK

So this works helps to develop the new age optical storage media devices in their process stabilization and further development such as DL-1P, DL-2P and BD-R third generation optical disc.

THIRD-GENERATION

Third-generation optical discs are in development, meant for distributing high-definition video and support greater data storage capacities, accomplished with short-wavelength visible-light lasers and greater numerical apertures. The Blue-Ray disc uses blue-violet lasers of greater aperture, for use with discs with smaller pits and lands, thereby greater data storage capacity per layer. In practice, the effective multimedia presentation capacity is improved with enhanced video.

DATA COMPRESSION

In computer science and information theory, **data compression** or **source coding** is the process of encoding information using fewer bits than a code representation would use through use of specific encoding schemes.... **VC-1** is the informal name of the SMPTE 421M video codec standard initially developed by Microsoft. It was released on April 3, 2006 by SMPTE. It is now a supported standard for HD DVDs, Blu-ray Discs, and Windows Media Video 9....

Currently shipping:

BLU-RAY DISC

Blu-ray Disc is an optical disc data storage device medium. Its main uses are high-definition video and data storage. The disc has the same physical dimensions as standard DVDs and CDs....

In development:

FORWARD VERSATILE DISC

FVD, or **Forward Versatile Disc**, is an off shoot of DVD developed in Taiwan jointly by the Advanced Optical Storage Research Alliance and the Industrial Technology Research Institute as a less expensive alternative for high-definition content....

DIGITAL MULTILAYER DISK (DMD)

Digital Multilayer Disk is an optical disc format developed by D-Data Inc. It is based on the 3D optical data storage technology developed for the Fluorescent Multilayer Disc by the defunct company Constellation 3D....or

FLUORESCENT MULTILAYER DISC

Fluorescent Multilayer Disc was an optical disc format developed by Constellation 3D that uses fluorescence, rather than reflection materials to store data....

Next generation

The following formats are ahead of current (third-generation) discs, having the potential more than one terabyte Tera byte

HOLOGRAPHIC VERSATILE DISC

The **Holographic Versatile Disc** is an optical disc technology that, in the future, may hold up to 3.9 terabytes of information, although the current maximum is 250GB....

LS-R

LS-R, or the **Layer-Selection-Type Recordable Optical Disk**, is the term coined by Hitachi, Ltd. in 2003 for a next-generation optical disc technology which allows much larger data storage densities than DVD, HD DVD or Blu-ray Disc, by allowing the use of a large number of data layers in a single disc....

PROTEIN-COATED disc

Protein-Coated Disc is a theoretical optical disc technology currently being developed

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ACRYNOMS

TB	A **terabyte** is a measurement term for computer storage. The value of a terabyte based upon a decimal radix is defined as one 1000000000000 bytes or 1000 gigabytes...) of data storage space.
BD-R	**Blue-Ray Disc** is an optical disc data storage device medium. Its main uses are high-definition video and data storage. The disc has the same physical dimensions as standard DVDs and CDs.... Or 120 mm optical disc achieving very high density through use of 405 nm blue-violet lasers, high numerical aperture optics, and, optionally, multiple information layers.
HD- DVD	**HD DVD** is a discontinued **high-density optical media optical disc** format for storing data and high-definition video.HD DVD was supported principally by Toshiba, and was envisaged to be the successor to the standard DVD format....but now abandon by DVD-Forum.
FVD	**FVD**, or **Forward Versatile Disc**, is an off shoot of DVD developed in Taiwan jointly by the Advanced Optical Storage Research Alliance and the Industrial Technology Research Institute as a less expensive alternative for high-definition content....
DMD	**Digital Multilayer Disk** is an optical disc format developed by D-Data Inc. It is based on the 3D optical data storage technology developed for the Fluorescent Multilayer Disc by the defunct company Constellation 3D....or
DL-1P	DVD-R dual technology with one layer.
DL-2P	DVD-R dual technology with two layers.
CD-Rs,	Compact Disc recordable
DVD-Rs	Digital Versatile Disc recordable
UV	Ultra violet
Bit stream	Formation of Pits and lands

Pits	Information area viewed as a depression from the label surface that can be sensed by an optical system.
Land	Empty region.
EFM	Electrical Field Modulation
EFM	Eight-to-Fourteen Modulation used to convert eight data bits to fourteen channel bits prior to recording.
Bit	One binary information element having the value ZERO or ONE.
DVD-RAM	Digital Versatile Disc- Read Access Memory.
CD-RAM	Compact Disc- Read Access Memory
DVD-R	Digital Versatile Disc-Recordable
DVD+/-R	Digital Versatile Disc-Recordable –Formats; DVD-R (Fuji) and DVD+R (Philips)
DVD-RW	Digital Versatile Disc-Rewritable.
RD/TD	Radial deviation/ Tangential Deviation
	Angle between the incident and reflected laser beam caused by disc or lens tilt, resulting in different off-axis focal points for rays from different radii of the focusing lens and asymmetrical distortion of the focused laser spot (coma).
HF signal.	Analog signals containing High Frequency data information in contrast to low frequency servo information.
Byte	Contiguous set of eight data bits, represented by an equal or greater number of channel or recorded bits.
VIDEO CD	Special CD-Bridge implementation for MPEG-1 digital videoþ specified in the

CD-R	D-Recordable, write once-read many disc specified by Orange Book Part II using a pre-stamped, wobbled groove to guide a write laser that irreversibly changes regions of a dye polymer layer to an optically absorbing state. A special drive is required for writing.
CD-ROM	CD-Read Only Memory, first specified in the Yellow Book, later in ISO/IEC 10149 (Second Edition 1995).
CD-RW	CD-Rewritable phase change media specified by Orange Book Part III that can be reversibly recorded, erased, or overwritten. Uses a pre-stamped groove to guide a write laser. Data is contained in an alloy layer that can be converted by a laser from a reflective crystalline state to a non-reflective amorphous state or erased back to the crystalline state, depending on laser power. A special drive is required for writing, but CD-RW recorded media can be read in modified CD-ROM drives capable of detecting the low light levels resulting from CD-RW reflectivity of 15-25%. (Formerly CD- Erasable or CD-E.)
CIRC	Cross Interleave Reed-Solomon Code is a method of error detection and correction employing Reed-Solomon parity bytes together with different interleaving, or delay, patterns that assists in error correction by distributing concentrated read errors over multiple frames that then form the input to a CIRC decoder. After the first deinter leave, CD discs correct small read errors at the C1 level, followed by a second deinterleave and correction of large read errors at the C2 level.
Clamping Area	Region between the center hole and information area where the disc is physically connected to the drive spindle.
Color	Response of the eye to different wavelengths of light. Ultraviolet < 400 nm, violet 400-424 nm, blue 424-491 nm, green 491-575 nm, yellow 575-585 nm, orange 585-647 nm, red 647-700 nm, infrared > 700 nm. Maximum visibility occurs at 556 nm.
Compression	Decreasing the size of stored information by reducing the representation of the information without significantly diminishing the information itself, usually by removing redundancies. Requires decompression upon retrieval. Lossless compression allows the original data to be recreated exactly. Lossy compression sacrifices some accuracy to achieve greater

compression. Fixed rate compression, such as MPEG-1, has been super ceded by variable bit rate compression methods, such as MPEG-2, that dynamically adjust the compression ration between fixed upper and lower bounds depending on the

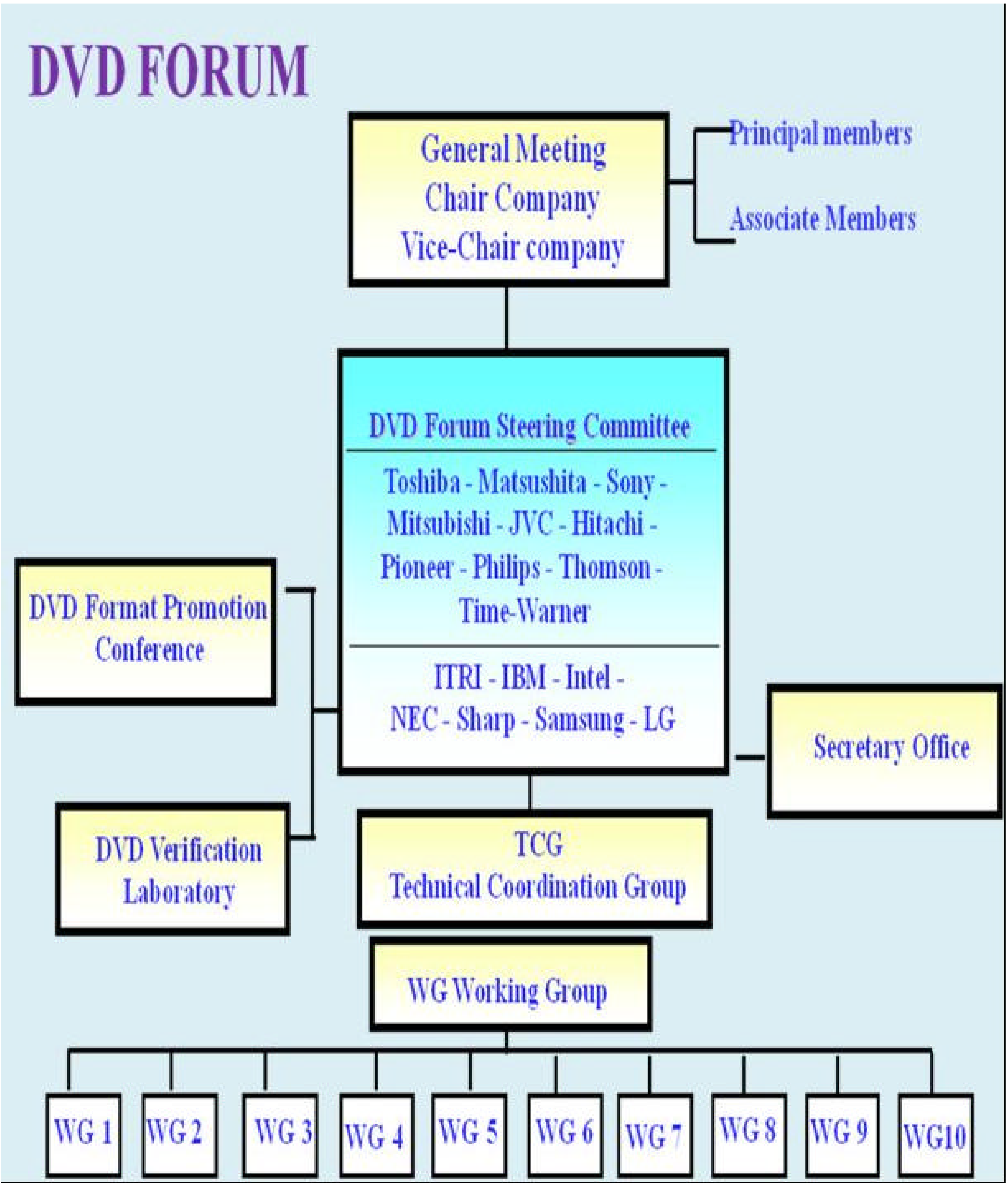
complexity of the original information. Compression ratios can reach 175:1 depending on the specific coder/decoder (codec).

(CRCC or CRC)	Cyclic Redundancy Check Code
Data Area	Logical sectors in a volume containing descriptors, path tables, and files.
Data Bit	Information received from the host for storage or transmitted to the host after retrieval.
Data Field	A fixed length field containing the user information in a sector.
DVD	120 mm optical disc achieving higher data density through use of 650/635 nm lasers, high numerical aperture optics, and, optionally, multiple information surfaces and/or layers.
Dye Polymer	Organic chemical that changes reflectivity when exposed to intense light of a particular wavelength.
Eccentricity	Variation in radius of an information track from the true axis of rotation of the disc.
ECC	Mathematically determined Error Correction Code specified in the standards that represents data and is recorded with that data to enable limited correction of read errors.
GB	Gigabyte, 1 GB equals 230 bytes or 1024 megabytes. Or, 1 GB may equal 109 bytes. GB may denote gigabits.
Groove	Continuous, spiraled trench-like radial guidance track of a recordable or rewritable disc offset towards the entrance surface that defines track centerline for recording purposes and contains CLV clocking, addressing, and other information.
HFS	Hierarchical File Structure defining the native Apple Macintosh format for mass storage.
High Sierra	Draft version of ISO 9660 (MS-DOS) standard for volume and file structure. Named for the Lake Tahoe, California hotel that hosted the conference resulting in the draft standard.

Holography	Recording of both amplitude and phase information of an object using interference between an object wave and a coherent reference wave, both incident on a photo sensitive medium. Coherent illumination of this medium, upon wave front reconstruction, results in an image having both amplitude and phase characteristics of the original, resulting in three dimensional and other special properties.
Hybrid	Disc containing both an ISO 9660 (MS-DOS) partition and an HFS partition. Or, a disc containing both ISO 9660 and UDF volume and file structures. Or, may indicate that the first session of a multi- session CD-R or CD-RW disc is a mastered session followed by recorded sessions.
Information Area	One area of a physical track consisting of one lead-in (with TOC), one program area, and one lead- out.
Information Layer	Physical layer of a CD or DVD disc that contains optically recoverable data after replication or recording.
Injection Molding	Replication involving injection under pressure of molten plastic into the cavity of a mold followed by cooling and removal of the solidified part that retains a replica of the mold.
Lacquer Splash	Dried protective coating material on the entrance surface or outer rim.
Land	Unrecorded optical surface area between pits, grooves, or marks, further away from the entrance surface than pits.
Laser	Light Amplification by Stimulated Emission of Radiation generates monochromatic, coherent light, usually from an excited gas or semiconductor.
Lead-In	Area at the beginning of a disc or session containing the Table of Contents (TOC) and other important information. Lead-in is followed by the Program Area.
Lead-Out	Buffer area following the Program Area used in case the player reads past the track.
MB	Megabyte, 1 MB equals 220 bytes or 1024 kB. Or, 1 MB may equal 106 bytes. Mb may denote megabits.
Micrometer (µm)	One millionth of one meter or 39.4 microinches.

Microsecond (µs)	One millionth of one second.
Millimeter (mm)	One thousandth of one meter or 0.0394 inches.
Millisecond (ms)	One thousandth of one second.
Numerical Aperture (NA)	Resolution or "spot" size of a lens. A small spot is produced by a lens having a high numerical aperture achieved using a large physical aperture and/or a short focal length. NA is equal to one-half of the reciprocal of the f-stop.
Substrate	Transparent physical layer providing mechanical support through which the laser can access an information layer.
Track	A physical track consists of one contiguous physical spiral area from inner diameter to outer diameter containing information (dual layer DVD discs have two physical tracks.) Or, the information contained within a single 360 ° rotation of the disc. Or, one contiguous logical element of information, such as a single CD audio track (a song) or computer data region (an information track.) One CD session contains from one up to 99 such logical tracks, each consisting of a pre-gap, user data, and a post-gap.
Track Pitch	Center-to-center distance between two radially adjacent information sequences.
w.r.t.	With respect to
R14H	Minimum % of laser reflectance which required for the Reading or writing (for DVD-R it should be 45-80%)
High PISUM8,	Sum of parity inner error from their 8 ecc blocks
POF	Parity Outer function
PIF	Periti inner function
CAV	Constant Angular Velocity (Laser movement during writing or reading)
CLV	Constant Linear Velocity (Laser movement during writing or reading)

ANNEXURE: 1 DVD FORUM



ANNEXURE: 2 THE DETAILED PROPERTIES OF THE DVD GRADE POLY CARBONATE

S. N.	Properties	Test Condition	Units	Test Methods	Makrolon	
					CD 2005	DP1 - 1265
1.	**Rheological Properties**					
a.	Melt Volume Flow Rate	300^0 C @ 1.2 Kg	Cm3/10 min	ISO 1133	60	71
b.	Melt Mass Flow Rate	300^0C @ 1.2 Kg	Cm3/10 min	ISO 1133	63	75
2.	**Mechanical Properties**					
a.	Tensile Modulus	1 mm/min	MPa	ISO 527	2300	2300
b.	Yield Stress	50 mm/min	MPa	ISO 527	60	60
c.	Tensile strain @ yield	50 mm/min	%	ISO 527	6	6
d.	Nominal Tensile strain @ Break	50 mm/min	%	ISO 527	>50	50
e.	Charpy Impact Strength	230 C	Kg/m2	ISO 179eU	NB	NB
f.	Charpy Impact Strength	-230 C	Kg/m2	ISO 179eU	NB	NB
g.	Izod Notchd Impact strength	230 C	Kg/m2	ISO 180 4A	45	45
3.	**Thermal Properties**					
a.	Glass Transition Temp	10K/min	0C	IEC 1006	145	143
b.	HDT	1.8 MPa	0C	ISO 75	122	122
c.	HDT	0.45 MPa	0C	ISO 75	137	136
d.	VSP	50 K/h	0C	ISO 306	143	142
e.	Coefficient of thermal Expansion	To 55 0C	10-4/k	ASTM E 831	0.7	0.7
f.	Melt Temp.		0C	ISO 294	280	280
4.	**Density**		Kg/m3	ISO 1183	1200	1200
5.	**Viscosity Number**		Cm3/gm	ISO 1628-1	40	38
6.	**Refractive Index**			ISO 498-A	1.58	1.583
7.	**Injection Velocity**		Mm/sec	ISO 294	200	200

ANNEXURE: 3 ROCESS WINDOW FOR THE DVD-R ACTIVE MOULDER

SUMITOMO 40 T- ACTIVE		CHANGEABLE PARAMETER ACTIVE		CYCLE TIME 2.7 SEC	
S.NO.	**PARAMETERS**	**STD.**	**LCL**	**UCL**	**RANGE**
A	**HOLDING**				
1	Hold pressure 1	300	300	300	FREEZE
2	Pressure 2	0	0	0	0.00
3	**Plasticizing position**	16.00	15.00	17.00	2.00
4	**Slow Down position**	15.00	14.00	16.00	2.00
4	**Back pressure 1**	20	0.00	40.00	40.00
5	**pressure 2**	20	0.00	40.00	40.00
5	**pressure 3**	5	0.00	10.00	10.00
7	**Plast. Revolution 1**	250	220	280	60.00
8	**Plast. Revolution 2**	230	200	260	60.00
9	**Plast. Revolution 3**	220	200	240	40.00
B	**CLAMP CONTROL**				0.00
9	Delay Time	0.15	0.10	0.20	0.10
10	Initial Platen Distance	0.50	0.30	0.60	0.30
C	**Clamp Force**				0.00
11	**2**	35	30.00	40.00	10.00
12	**3**	13	5.00	20.00	15.00
13	**4**	13	5.00	20.00	15.00
14	**5**	30	20.00	40.00	20.00
D	**CLAMP TIME**				0.00
15	**3**	0.70	0.15	1.20	1.05
E	**AIR BLOW FIX SIDE**				0.00
16	**Air Blow Mode**	DUR COOL	DUR COOL	DUR COOL	FREEZE
17	Delay	0.80	0.80	0.80	FREEZE
18	Acting	1.50	1.50	1.50	FREEZE
G	**FILLING**				0.00
19	Filling Velocity 1	130	100.00	160.00	60.00
20	Filling Velocity 2	130	100.00	160.00	60.00
21	Filling Position 1	13	12.00	13.00	1.00
H	**Barrel Temp**				
22	15A	280	260.00	300.00	40.00
23	15	305	280.00	330.00	50.00
24	4	370	360.00	380.00	20.00
25	3	370	360.00	380.00	20.00
26	2	350	350.00	350.00	FREEZE
27	1	280	280.00	280.00	FREEZE
I	**CUT PUNCH**				
28	**Delay**	0.04	0.00	0.08	0.08
29	**Eject Release Pos.**	0.75	0.70	0.80	0.10
30	**Velocity**	2.50	1.00	4.00	3.00
31	**Time**	1.25	1.00	1.50	0.50
32	**Pressure 1**	23.00	15.00	30.00	15.00
33	**Pressure2**	23.00	15.00	30.00	15.00
J	**MOULD TEMPERATURE**				0.00
34	Fixed Side	122	118.00	125.00	7.00
35	Moving Side	90	80.00	90.00	10.00
36	Sprue Temp	23	15.00	30.00	15.00
37	COOLING TIME	1.6	1.55	1.70	0.15

ANNEXURE 4 PROCESS WINDOWS FOR THE DVD-R DUMMY-MOULDER

SUMITOMO 40 T DUMMY		CHANGEABLE PARAMETER OF DUMMY		CYCLE TIME 2.7 SEC	
S.NO.	PARAMETERS	STD.	LCL	UCL	RANGE
A	HOLDING				
1	Hold pressure 1	250	200	300	100.00
2	Pressure 2	250	200	300	100.00
3	**Plasticizing position**	17.00	14.00	20.00	6.00
4	**Slow Down position**	15.00	14.00	16.00	2.00
4	**Back pressure 1**	20	0.00	40.00	40.00
5	**pressure 2**	20	0.00	40.00	40.00
5	**pressure 3**	5	0.00	10.00	10.00
7	**Plast. Revolution 1**	270	240	300	60.00
8	**Plast. Revolution 2**	250	220	280	60.00
9	**Plast. Revolution 3**	220	200	240	40.00
B	CLAMP CONTROL				0.00
9	Delay Time	0.15	0.10	0.20	0.10
10	Initial Platen Distance	0.30	0.20	0.40	0.20
C	Clamp Force				0.00
11	**2**	35	30.00	40.00	10.00
12	**3**	13	5.00	20.00	15.00
13	**4**	13	5.00	20.00	15.00
14	**5**	30	20.00	40.00	20.00
D	CLAMP TIME				0.00
15	**3**	0.70	0.15	1.20	1.05
E	AIR BLOW FIX SIDE				
16	**Air Blow Mode**	DUR COOL	DUR COOL	DUR COOL	Freeze
17	Delay	0.80	0.80	0.80	Freeze
18	Acting	1.30	1.30	1.30	Freeze
G	FILLING				
19	Filling Velocity 1	90	70.00	110.00	40.00
20	Filling Velocity 2	100	100.00	130.00	30.00
21	Filling Position 1	13	12.00	13.00	1.00
H	Barrel Temp				
22	15A	280	290.00	330.00	40.00
23	15	305	300.00	340.00	40.00
24	4	370	350.00	370.00	20.00
25	3	370	350.00	370.00	20.00
26	2	350	350.00	350.00	0.00
27	1	280	280.00	280.00	0.00
I	CUT PUNCH				
28	**Delay**	0.04	0.00	0.08	0.08
29	**Eject Release Pos.**	0.75	0.70	0.80	0.10
30	**Velocity**	2.50	1.00	4.00	3.00
31	**Time**	1.25	1.00	1.50	0.50
32	**Pressure 1**	23.00	15.00	30.00	15.00
33	**Pressure2**	23.00	15.00	30.00	15.00
J	MOULD TEMPERATURE				
34	Fixed Side	100	90.00	110.00	20.00
35	Moving Side	90	80.00	100.00	20.00
36	Sprue Temp	23	15.00	30.00	15.00
37	COOLING TIME	1.6	1.55	1.70	0.15

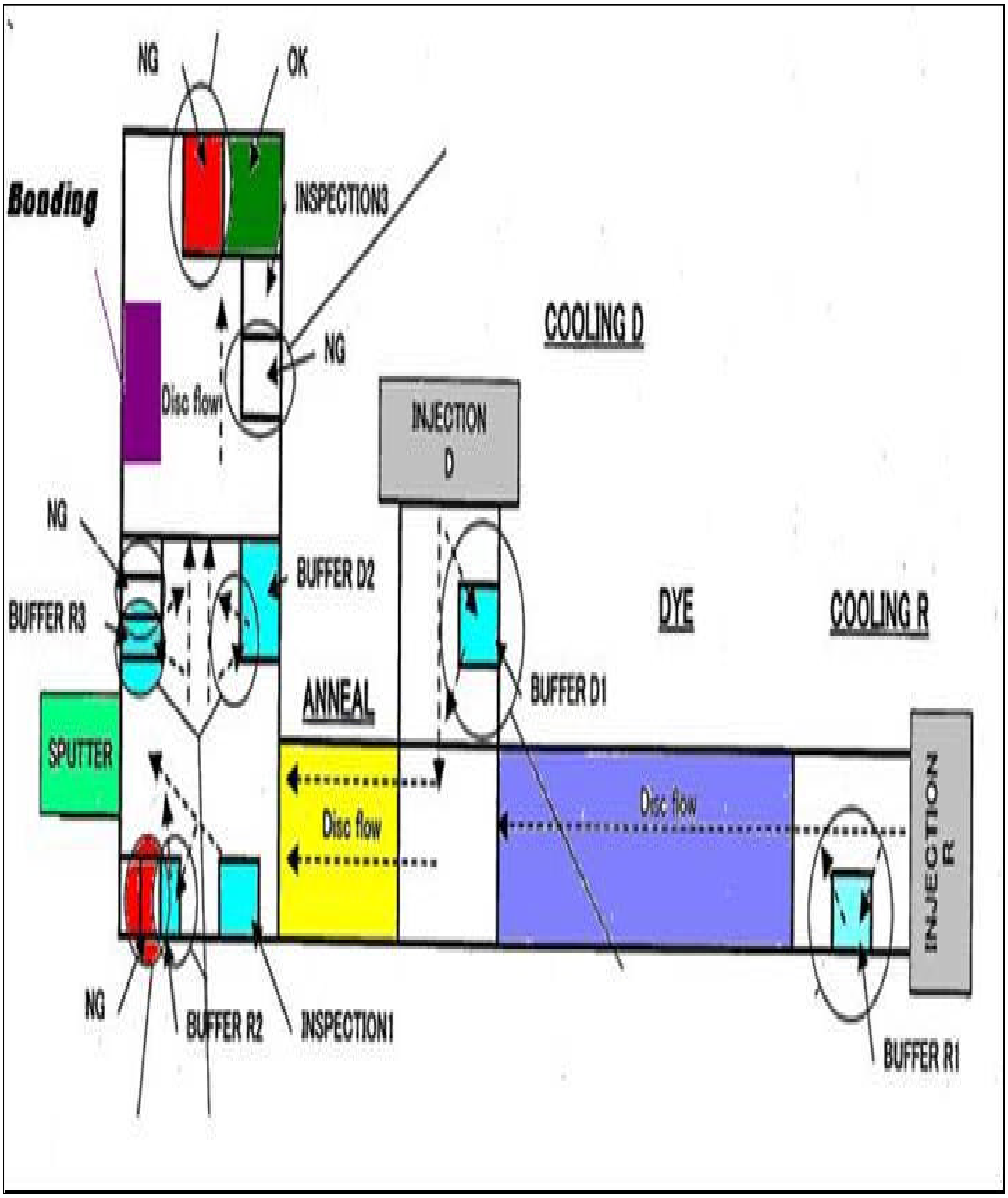
ANNEXURE 5 STAMPER AND MACHINE WISE GD SPECIFICATION

STAMPER AND MACHINE WISE GD SPECIFICATION DATA						
MACHINE	STAMPER	SPEED	G.D. (nm) Average			
			23mm	40mm	55mm	57mm
SUMITTOMO	MCC-R	8X	145-151	159-163	159-163	159-163
	MCC+R		147-151	156-160	156-160	156-160
	MBI-R		114-120	114-120	112-118	112-118
	MBI+R		147-153	154-160	155-163	153-161
	MBI+R M&G		142-148	141-147	140-146	140-146
	MBI-R(KURARE)		114-120	112-118	112-118	112-118
	MCC-R	16X	148-153	156-161	156-161	156-161
	MCC+R		147-151	154-158	154-158	152-156
	TDK-R		115-121	121-127	132-138	134-140
	TDK+R		108-114	112-118	119-125	122-126
	MBI+R		139-145	147-153	149-155	149-155
NETSTAL	MBI-R M&G	8X				
	MBI+R M&G		143-145	142-144	138-140	135-140
	MBI-R(KURARE)		112-118	113-119	110-116	112-118
	MCC+R(MBI-Code)	16X	140-145	144-150	143-149	142-148

ANNEXURE 6 STAMPER WISE OD SPECIFICATION DATA

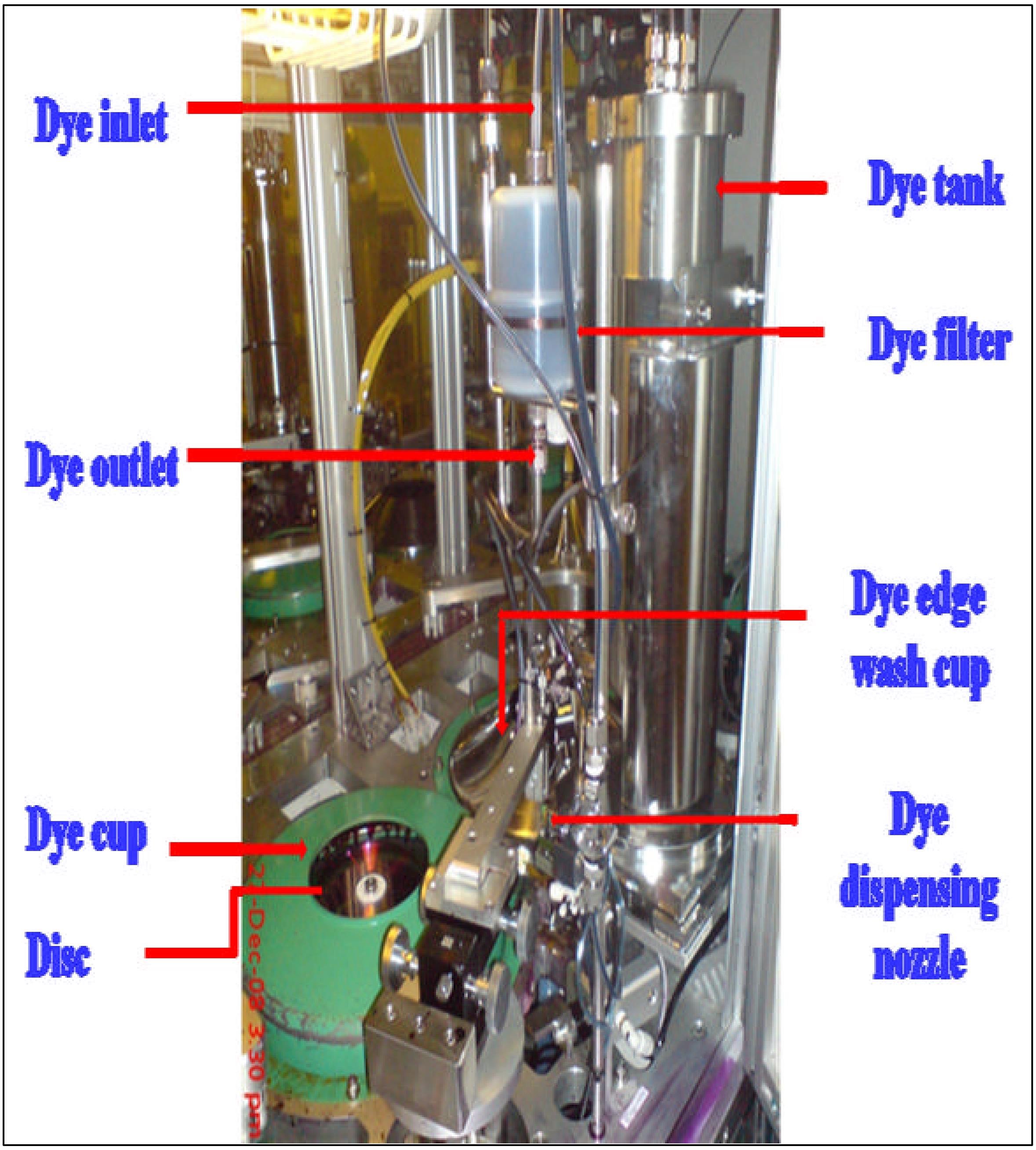
FORMAT	OD SPECIFICATION	WAVELENGTH
RICOH 16X + R	0.605 ~ 0.595	608 nm
SONY 16X - R	0.530 ~ 0.510	606 nm
SONY 16X + R	0.530 ~ 0.510	606 nm
TDK 16X + R	0.580 ~ 0.570	600 nm
TDK 16X - R	0.570 ~ 0.550	600 nm
FUJI 16X - R	0.800 - 0.790	580 nm
MBI 16X + R	0.710 ~ 0.690	595 nm
MBI 16X - R	0.750 ~ 0.730	595 nm
MBI 8X + R	0.800 ~ 0.790	580 nm
MBI 8X - R	0.705 ~ 0.685	580 nm
MKM 16X - R	0.775 ~ 0.755	595 nm
MKM 16X + R	0.730 ~ 0.710	595 nm

ANNEXURE 7 BLOCK DIG. OF DVD MANUFACTURING PROCESS



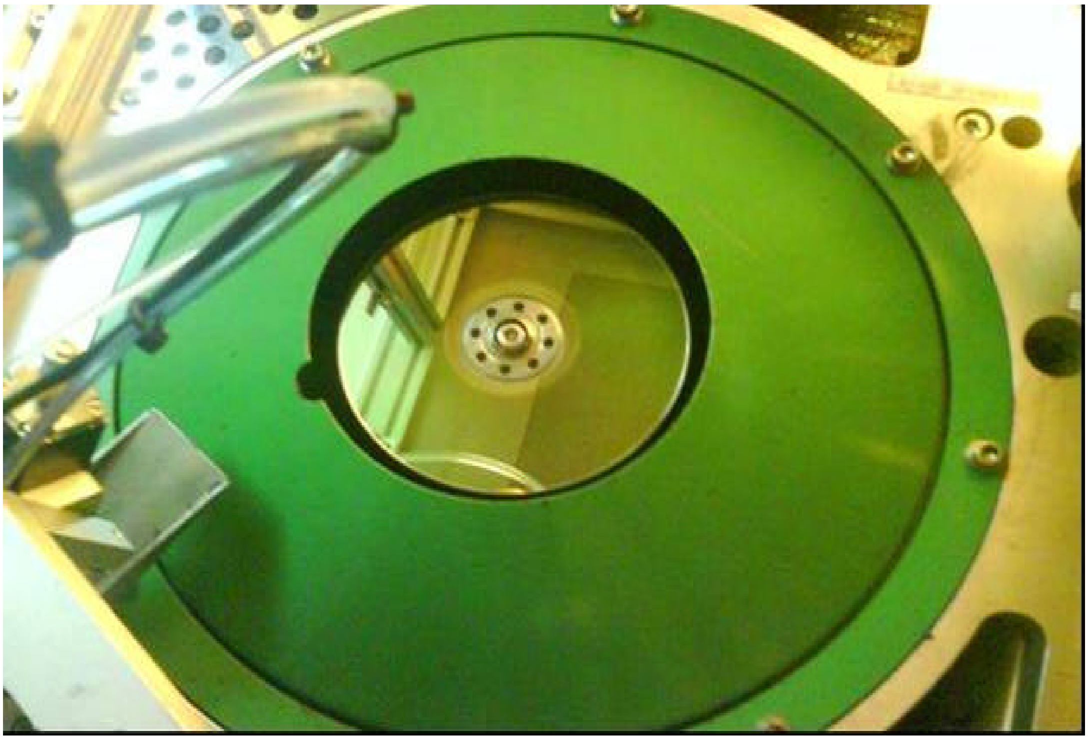
ANNEXURE 8 PHOTOGRAPHIC VIEW OF DYE COATING PROCESS

DYE CIRCUIT



DYE DISPENSING AND EDGE WASHING PROCESS

DYE PROCESS COMPLETED



ANNEXURE 09 BONDING PROCESS VIEW FOR DVD-R