technology

The Blu-ray Disc was announced in February 2002. In 2005 the Blu-ray Disc Association (BDA) was formed and is now a voluntary membership group open to any organisation “with an interest in creating, upholding and promoting the BD formats”. The aim of the BDA is to develop Blu-ray Disc specifications; ensure BD products are manufactured by licensees; promote the wide adoption of BD formats and provide useful information to those interested in supporting BD formats.

Blu-ray Disc formats
Recordable versions of Blu-ray Discs also exist for use as a backup medium for computer data, as well as other applications. There is therefore a range of different formats based on Blu-ray, just as there are with DVD.
- BD-ROM: a read-only disc format that would normally contain movies in HD content.
- BD-R: a recordable format for archiving large amounts of data or video.
- BD-RE: a rewritable disc format for recording video or data.
All BD formats can be made in single-layer (25GB) and dual-layer (50GB) versions.

Blu-ray Disc characteristics
The developers of the Blu-ray Disc claim that it has the following characteristics:
- Broadest industry support from manufacturers and content providers.
- Lifespan of at least 10 to 15 years due to its high storage capacity.
- The strongest, renewable content protection, which includes strict licensing procedures.
- Cost of manufacture should be within 10% of the cost of DVD manufacture.
- Highest capacity for full-length movies in the highest quality HD video on a single disc.
- Use of a hard coating, which offers stronger resistance to scratches and fingerprints.

Blu-ray versus DVD
Some of the key differences between Blu-ray and DVD are listed in the table below:

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DVD-ROM</th>
<th>BD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layers</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number of sides</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Capacity (GB)</td>
<td>4.7</td>
<td>25</td>
</tr>
<tr>
<td>Substrate thickness (mm)</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Cover layer thickness (mm)</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Laser wavelength (nm)</td>
<td>650 (red)</td>
<td>405 (blue)</td>
</tr>
<tr>
<td>Numerical aperture</td>
<td>0.6</td>
<td>0.85</td>
</tr>
<tr>
<td>Track pitch (microns)</td>
<td>0.74</td>
<td>0.52</td>
</tr>
<tr>
<td>Minimum pit size</td>
<td>0.40mm</td>
<td>0.32mm</td>
</tr>
<tr>
<td>Hard coat needed</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Modulation</td>
<td>8 to 16</td>
<td>8 to 12</td>
</tr>
</tbody>
</table>

So do you want to make Blu-ray Discs?

There are a number of areas of expertise required to make Blu-ray Discs, as Graham Sharpless explains:

What is Blu-ray?
The Blu-ray Disc was developed to succeed DVD, which was seen to be threatened by the launch of high-definition television (HDTV) services, which would make standard-definition (SD) video appear inferior in comparison. HDTV offers increased picture resolution and a native widescreen format, with image sizes up to 1080 lines of 1920 pixels. The BD developers, including consumer electronic companies such as Sony, Philips and Panasonic, believed that a disc capacity of over 20GB was needed to store a full-length movie in HD video using MPEG-2. Blu-ray Discs can store 25GB per layer and dual-layer versions are also now available.
BDAV

BDAV is a read-only disc format for HD movies and is the BD equivalent of DVD-Video. Unlike DVD-Video, BDAV supports HD video using a choice of three video compression codecs (MPEG-2, MPEG-4 AVC/H.264 and VC1), and provides advanced graphical and interactive features that are far superior to DVD-Video. Like DVD-Video, BDAV includes region coding, but there are only three regions.

There are two HD video formats, 1920 x 1080 and 1920 x 720. Both of these are in 16:9 widescreen format and use progressive scan video; at 50 or 60Hz, instead of the interlaced video at 25 or 30Hz used in DVD and broadcast PAL and NTSC TV.

Even 720 lines of video is a significant improvement on the 480 lines of interlaced video, which is one reason why HDTV has taken off in the US. However, there is not much of an improvement compared with the 576 lines used in Europe. At average viewing distances of 2.7m, a large-screen display is needed to benefit fully from HD video and 1080 lines is probably overkill in most homes, without very large screen sizes.

Even where the full benefit of 1080 lines cannot be fully appreciated, the other features of HD video, widescreen and progressive scan, plus enhanced graphics and advanced interactivity, make BDAV more desirable than plain DVD-Video.

What about HD DVD? Until February 2008, Blu-ray had a competitor – HD DVD – which was developed by Toshiba and NEC, with support from other companies, including Microsoft. Both formats were developed primarily to distribute movies in HD video with advanced graphics and interactive features. HD DVD differed from BD in that it was an evolutionary development of DVD, being DVDs with smaller pits and with an increased capacity of 15GB per layer. Manufacturing HD DVDs with cover layers and tighter tolerances present significant challenges for the disc replicator starting out manufacturing these discs.

BD mastering

As with DVD mastering, BD mastering can be divided into data formatting, laser beam recording and Stamper production. But the similarities end there as an almost totally new approach is needed to meet the critical requirements of BD – especially for the first two of these processes.

The BD format/encoder is responsible for the AACS content protection (including key handing), error protection, 8 to 1 modulation and the ROM-Mark. Its output is used to modulate the laser in the laser beam recorder.

Suppliers of BD-ROM mastering formatters include DCA, whose Titan can format all formats including BD-ROM, and Eclipse Data’s ESP 7000 Encoder, which can also format all discs.

The very small pit sizes needed for Blu-ray Discs require very short wavelength lasers – if conventional laser beam recording is used – and increased numerical aperture. Possible solutions include the use of a Deep UV (DUV), typically 266nm laser, electron beam recording and dye polymer technologies.

But perhaps the most successful technology is Phase Transition Mastering (PTM), developed by Sony and also used by Siguliris Mastering. PTM uses a 405nm laser (as currently used for CD and DVD glass mastering) together with an inorganic substance that responds to the narrow peak of the laser beam to achieve the very small pit size of 15nm. Heat is used to record the information and changes the phase of the sensitive layer from amorphous to crystalline. After developing, a mother can be produced directly from the master, so reducing the number of stages in creating stampers.

Other mastering systems that can master BD-ROM discs include ODC Nimbus’s High Density Mastering System and M2 Measurement’s SGM CD/DVD/Blue-ray glass mastering system.

A group of companies including Sony, Siguliris Mastering, Sibert and technonovis have created a de facto standard for BD stampers, to ensure that the properties of all stampers are well defined.

BD replication

Replicating a BD has some similarities with CD replication, as both require moulding pits in a substrate 1.1 or 1.2mm thick. But the pits are much smaller for a BD and the discs need a very thin cover layer. Replication of a single layer BD-ROM disc comprises several stages (see Figure 4 on next page):

- Injection moulding of the 1.1mm substrate using the stamper to produce pits, similar to CD and DVD.

The substrate does not need to be optically transparent but must be flat. Polycarbonate is the

Figure 1: Pit geometry comparison

**CD**

- 830 nm aperture
- 1.6μm pit size

**DVD**

- 400 nm aperture
- 0.74μm pit size
- 0.32μm recorded layer thickness

**BD**

- 150 nm aperture
- 0.07mm pit size
- 0.03mm recorded layer thickness

BDAV

BDAV is a read-only disc format for HD movies and is the BD equivalent of DVD-Video. Unlike DVD-Video, BDAV supports HD video using a choice of three video compression codecs (MPEG-2, MPEG-4 AVC/H.264 and VC1), and provides advanced graphical and interactive features that are far superior to DVD-Video. Like DVD-Video, BDAV includes region coding, but there are only three regions.

There are two HD video formats, 1920 x 1080 and 1920 x 720. Both of these are in 16:9 widescreen format and use progressive scan video; at 50 or 60Hz, instead of the interlaced video at 25 or 30Hz used in DVD and broadcast PAL and NTSC TV.

Even 720 lines of video is a significant improvement on the 480 lines of interlaced video, which is one reason why HDTV has taken off in the US. However, there is not much of an improvement compared with the 576 lines used in Europe. At average viewing distances of 2.7m, a large-screen display is needed to benefit fully from HD video and 1080 lines is probably overkill in most homes, without very large screen sizes.

Even where the full benefit of 1080 lines cannot be fully appreciated, the other features of HD video, widescreen and progressive scan, plus enhanced graphics and advanced interactivity, make BDAV more desirable than plain DVD-Video.

What about HD DVD? Until February 2008, Blu-ray had a competitor – HD DVD – which was developed by Toshiba and NEC, with support from other companies, including Microsoft. Both formats were developed primarily to distribute movies in HD video with advanced graphics and interactive features. HD DVD differed from BD in that it was an evolutionary development of DVD, being DVDs with smaller pits and with an increased capacity of 15GB per layer. Manufacturing HD DVDs with cover layers and tighter tolerances present significant challenges for the disc replicator starting out manufacturing these discs.

BD mastering

As with DVD mastering, BD mastering can be divided into data formatting, laser beam recording and Stamper production. But the similarities end there as an almost totally new approach is needed to meet the critical requirements of BD – especially for the first two of these processes.

The BD format/encoder is responsible for the AACS content protection (including key handing), error protection, 8 to 1 modulation and the ROM-Mark. Its output is used to modulate the laser in the laser beam recorder.

Suppliers of BD-ROM mastering formatters include DCA, whose Titan can format all formats including BD-ROM, and Eclipse Data’s ESP 7000 Encoder, which can also format all discs.

The very small pit sizes needed for Blu-ray Discs require very short wavelength lasers – if conventional laser beam recording is used – and increased numerical aperture. Possible solutions include the use of a Deep UV (DUV), typically 266nm laser, electron beam recording and dye polymer technologies.

But perhaps the most successful technology is Phase Transition Mastering (PTM), developed by Sony and also used by Siguliris Mastering. PTM uses a 405nm laser (as currently used for CD and DVD glass mastering) together with an inorganic substance that responds to the narrow peak of the laser beam to achieve the very small pit size of 15nm. Heat is used to record the information and changes the phase of the sensitive layer from amorphous to crystalline. After developing, a mother can be produced directly from the master, so reducing the number of stages in creating stampers.

Other mastering systems that can master BD-ROM discs include ODC Nimbus’s High Density Mastering System and M2 Measurement’s SGM CD/DVD/Blue-ray glass mastering system.

A group of companies including Sony, Siguliris Mastering, Sibert and technonovis have created a de facto standard for BD stampers, to ensure that the properties of all stampers are well defined.

BD replication

Replicating a BD has some similarities with CD replication, as both require moulding pits in a substrate 1.1 or 1.2mm thick. But the pits are much smaller for a BD and the discs need a very thin cover layer. Replication of a single layer BD-ROM disc comprises several stages (see Figure 4 on next page):

- Injection moulding of the 1.1mmsubstrate using the stamper to produce pits, similar to CD and DVD.

The substrate does not need to be optically transparent but must be flat. Polycarbonate is the
material used, but Sony has experimented with alternative materials. The substrates are then cooled before the next stage.

- Layer 0: metallisation with aluminium or a silver alloy, approximately 35nm thick. This should not be too thick to avoid affecting the geometry of the pits. This is similar to layer 1 of a DVD-9, but with much smaller pits the problem is increased.
- Lacquer coating of the 0mm cover layer (which may involve two stages) to ensure that the cover layer is flat and within the tight tolerance of ±3 microns thickness variation. Other techniques have been tried, including the application of a thin film, but this was found to be too expensive.
- A hard coat is added to protect the disc surface from fingerprints and scratches. Without the hard coat it is likely that a caddy would be needed to protect the disc.
- Finally another extra layer is added to the label side to protect it from moisture, which would cause disc tilt. The disc is then ready for printing.

Dual layer BD-ROM discs with 50GB capacity require an extra stage to add layer 1, using a nickel stamper and suitable UV cured lacquer, as illustrated in Figure 5. The space layer is added next, 25 microns thick, followed by metallising with a semi-reflective coating plus a 75 micron cover layer and the hard coat.

Burst Cutting Area

The Burst Cutting Area (BCA) was introduced as an optional extra for BD-9 discs. For Blu-ray the BCA is mandatory and is used to add a unique serial number to each BD-ROM disc, following the addition of the hard coat and prior to label printing. The BCA code is written using a high-power laser diode, which is a lower cost solution than the use of a YAG (yttrium aluminium garnet or solid state) laser.

Figure 3: Hybrid BD and DVD

BD ROM replication equipment

New equipment is needed for replicating both single- and dual-layer discs because existing DVD replication lines are not suitable. A BD-ROM line comprises one moulding machine plus an integrated line for all stages from metallising to application of the moisture barrier and inspection. Manufacturers, for example, have had a line for production of both single- and dual-layer discs. In addition, Manufab Disc Systems sells integrated single- and dual-layer BD-ROM replication lines, manufactured by Origin Electric, using spin-coating processes developed in conjunction with Panasonic. Other companies have been, or are, working on Blu-ray and other equipment may be available.

BDA code writers are also new, but label printing can be carried out using existing printers. One supplier of BDA writers is Efolec Europe.

Raw materials

The main raw material is polycarbonate for the substrate, but there are new materials needed for the cover layer, hard coat and so on.

- The same polycarbonate as used for DVDs is suitable, although it does not need to be optically transparent and birefringence is not an issue. However, good pit replication and flatness are essential.
- Special UV cured lacquers are needed for the cover layer and, for dual layer discs, the space layer. A special hard coat is also required to protect the cover layer.
- A moisture barrier layer is needed to protect the label side of the polycarbonate from moisture, however, other materials, including printing inks, are unchanged.

Quality assurance

Quality assurance and the need to measure disc parameters is essential for BD. Parameters such as pit geometry, disc tilt and space layer thickness and reflectivity across the disc must be measured and kept within tight tolerances.

Blu-ray Discs present an even greater challenge, particularly in respect to pit geometry, tilt and cover layer thickness for dual-layer discs the space layer thickness must also be kept within tight tolerances.

Another lesson learnt by DVD replicators is the need to carry out age testing. As a result it was found that parameters such as disc tilt needed to be kept within even tighter tolerances to ensure that they remained within specification over the expected life of the disc.

Age testing will continue to be important for Blu-ray as well. As a result, yields will initially be low until replicators and their suppliers can fine-tune the processes, as has happened with DVD.

Suitable test and measurement equipment is available from a number of suppliers, including dr.schwab, AudioDev, DaTARIUS and Dr Schenk.

 Licensing

Disc replicators need to be licensed for the disc formats that they are manufacturing. There are two types of licences required: format and logo licensing, which also involves verification of discs manufactured by the replicator. Sample discs are tested by official verification laboratories to verify that the discs meet the specifications and that the replicator has the necessary test equipment and processes to ensure that all discs replicated meet the specifications. Once verified the replicator is permitted to add the appropriate format logo to the disc label and to associated printed parts. The replicator must also pay a fee and sign the licence agreement.

DVD replicators have to be licensed by the DVD Format/Logo Licensing Corp and by two groups acting for the DVD patent holders. There are also licence fees to be paid to MPEG LA for the MPEG-2 video on each disc.

Blu-ray replicators need to sign the Format and Logo Licence Agreement (FLA), which is for the development, manufacturing, use or sales of products, and for use of the BD logo. Licence terms are usually five years and there is a one-off payment of $5,000, which is non-refundable.

BD logo licensing differs from DVD, where only the replicator is licensed to add the BD logo and associated printed parts. Content owners and others who need to use the BD logo sign a Logo Licence Agreement.

Patent licensing, where the replicator signs an agreement to pay a fee per disc to the patent holders or agent that operates on the patent holders’ behalf. DVD patent licensing was administered by two groups, operating on behalf of the BD patent holders, plus individual companies. In addition there is a one-off payment on behalf of the MPEG-2 patent holders in licensing the use of MPEG-2 video on DVD discs.

For Blu-ray, MPEG LA handles patent licensing for the three video compression formats specified for use on Blu-ray Discs. These are MPEG-2, MPEG-4 AVC/H.264 and VC-1. MPEG LA will also licence the BD technology patents, but this licensing programme is still in development while patents are being submitted to MPEG LA.

AAACS content protection is licensed by the AAACS Licensing Administrator, which is also responsible for providing the keys and revoking licences for compromised hardware.

Competition and markets

They main application for Blu-ray is HD video and therefore a Blu-ray replicator’s customers are Hollywood studios and publishers of video in HD format. When DVD was launched there was a wide range of suitable content from movies to TV series, all available in SD video. But there is less content available in HD video outside the movie industry. This is changing rapidly as major broadcasters record more of their productions in HD rather than SD.

Blu-ray started with the major studios supplying almost 100% of content. But in 2008 the independents increased their share to 15% or more. This will benefit the smaller replicators, who may have difficulty getting work from the major studios.

The demand for Blu-ray will depend on how the market develops in the face of the current worldwide economic problems. The prices for Blu-ray players have fallen dramatically in the past year or so and this should stimulate more sales of players and therefore of discs.

- www.aaca.com
- www.blu-raydisc.com
- www.blu-raydisc.info
- www.dcainc.com
- www.dvdflicc.jp
- www.ecipesdata.com
- www.eofus.co.uk
- www.m2.se
- www.mansenbidisc.com
- www.mpegla.org
- www.optical-disc.com
- www.singulus.nl
## Blu-ray Glossary

**AACS** – Advanced Access Content System, a mandatory content management system designed for ‘next-generation’ pre-recorded and recordable optical media for consumer use. AACS has been adopted for Blu-ray in conjunction with SPCD.

**AACS LA** – The AACS Licensing Administrator, which licenses AACS, distributes keys to licensees and, if necessary, revokes compromised hardware.

**BCA** – Burst Cutting Area, an area inside the lead-in of a Blu-ray (or DVD) Disc where a unique serial number can be written by a high-power laser after manufacture.

**BD** – Blu-ray Disc, the latest consumer optical disc format with capacities of up to 50GB and available in read-only, write-once and rewritable versions.

**BD-ROM** – Content protection for Blu-ray Discs that adds a version of SPCD developed by Cryptography Research Inc. to AACS allowing the protection to be renewed if and when hacked. BD+ is implemented using a virtual machine embedded in licensed BD players. If any playback device has been hacked, the manufacturer can release new BD+ firmware that will still protect new content releases.

**BCA** – Blu-ray Disc Association, which develops BD specifications, ensures BD products are manufactured by licensees, promotes BD and provides useful information (see www.blu-raydisc.com).

**BD+** – A read-only disc format for HD movies that is the BD equivalent of DVD-Video. BD+ supports HD video using a choice of three video compression codes (H.264, MPEG-4 AVC/H.264 and VC1), and provides advanced graphical and interactive features.

**BD-Live** – Also known as Profile 2.0, BD-Live allows suitable players to access additional content from the internet. Profile 2.0 players must include an internet connection and local storage. Downloadable content can include additional video, audio, text and still images. In the future BD-Live features may include ringtones, live virtual events and games.

**COVER LAYER** – The read-only version of Blu-ray, mainly for movies in HD video.

**BD-ROM** – The transparent layer between the read laser and pits on an optical disc. For single layer Blu-ray the cover layer is only 0.1mm thick and for dual layer Blu-ray only 0.07mm thick.

**DUV** – Deep UV, describing the use of UV lasers at, typically, 266nm for glass mastering Blu-ray Discs. H.264 – Another name for MPEG-4 AVC video compression.

**Hard coat** – A thin layer added to the play side of a Blu-ray Disc to protect the surface from scratches and fingerprints.

**HDTV** – High Definition TV, comprising image sizes of 1920 x 1080 or 1280 x 720, a 16:9 widescreen format and progressive scan at 50Hz in Europe and 60Hz in the US and Japan.

**Hybrid disc** – A combination of a single-layer BD and single-layer DVD on a combined dual-layer disc. Such a disc can hold the same video content in both SD and HD video to be playable on a DVD player and a Blu-ray player.

**Modulation** – The conversion of the raw data, after error correction, into data from which the pits are created during mastering. For Blu-ray an 8 to 12 modulation is used, whereby every 8-bit byte is stored on disc as 12 bits.

**MPEG** – Moving Picture Expert Group

**MPEG-2** – The MPEG video compression system used for DVD, Blu-ray and most HDTV broadcasts.

**MPEG-4 AVC** – The MPEG video compression system used for Blu-ray and some HDTV broadcasts. It offers a compression rate approximately twice that for MPEG-2.

**MPEG LA** – The MPEG Licensing Administrator, which licenses the patents for MPEG-2 and other technologies including Blu-ray.

**NA** – Numerical Aperture, defining the angle of the incident laser beam as it hits the surface of a disc. The higher the NA the smaller the minimum spot size that can be achieved for a given wavelength laser.

**Progressive scan** – Video display comprising lines of pixels being displayed in sequence, unlike interlace scan, which is used for PAL and NTSC video.

**PTM** – Phase Transition Mastering, developed by Sony, and using a 405nm laser together with an inorganic substrate that responds to the narrower peak of the laser beam to achieve the small pit size of 150nm. Heat is used to record the information and changes the phase of the sensitive layer from amorphous to crystalline.

**ROM-Mark** – Part of the content protection for Blu-ray, whereby a unique identifier is embedded in the disc surface during mastering to prevent discs being copied.

**SPDC** – Self-Protecting Disc Content, an addition to AACS, which allows the protection algorithms to be renewed to combat attacks at hacking the content protection.

---

**PACK FOR SUCCESS**

**NICKERT.**

**Impressing alive ...**

**Simply singulary!**

**NICKERT.**

**Exclusive custom-made Mediabooks® and Systempackagings**

Mediabooks ® · High-End Laminatings · Calender Prints · Flash Memory & USB · Nature Book · Archiv-Bookboxes · Double- & Triple-Push Trays · Disc Lids & Flying Disks · CD & DVD Bookboxes · Systempackagings · Hardcoverboxes & Slipcases · Digital Printing & many more.

J. Nickert GmbH · Boettgerstr. 7 · D - 89231 Neu-Ulm · Fon + 49 (0) 731 / 970 10 - 0 · Fax - 30 · info@nickert.de · www.nickert.de

---

wwwOTOonline.com