The cover layer in close detail

An understanding of the cover layer is crucial to Blu-ray Disc manufacture, and dr. schwab provides inspection solutions to aid the process

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Now that commercial production of Blu-ray Disc is finally getting off the ground, BD line manufacturers and replicators alike face the core problem of producing discs as efficiently as possible while maintaining the specified standard. The past year has seen significant developments in production technology, with the majority of manufacturers in the US and Europe now using the spin cover process. Despite these advances, the BD cover layer remains the source of major challenges to production efficiency and makes exceptional demands of the inspection equipment employed in the quest for process optimisation.

Significance of the cover layer

To help understand why the cover layer is so challenging, it's worth taking a brief look at the evolution of the optical disc.

Each successive generation is characterised by key parameters such as track pitch, wavelength and numerical aperture of the pick-up head (Table 1). Another defining parameter is 'cover thickness': the depth of material through which the information layer is read. For CD, this corresponds to the substrate thickness of 1.2mm; for DVD, it is the 0.6mm half-disc.

From CD to BD, numerical aperture and wavelength change by a factor of two, whereas the cover thickness decreases from 1.2mm to 0.1mm – a factor of 12. Only the cover thickness has changed by more than an order of magnitude.

The BD cover layer aspect ratio of 1,200 (Table 1) puts it beyond the capabilities of moulding technology established for CD and DVD. Early BD production equipment used a bonded cover foil, but today the majority of line and disc manufacturers prefer the potentially cheaper and less complex spin coating process. The latest cover materials, incorporating scratch-resistant and anti-fingerprint constituents, further simplify production by removing the need to apply a final hard-coat layer.

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	CD	DVD	BD
Track Pitch (mu)	1.6	0.74	0.32
Numerical Aperture	0.45	0.6	0.85
Wavelength (nm)	780	650	405
Cover Thickness (mm)	1.2	0.6	0.1
Aspect Ratio*	100	200	1200

*Diameter divided by cover thickness

Table 1: Format evolution: key parameters

Layer thickness and uniformity

Spin coating is a well-established process for applying, for example, lacquer or bonding material in CD and DVD production. But the BD cover layer, though thin, is much thicker than any layer previously applied by this method. To compound the problem, the high numerical aperture of the BD pick-up head makes it susceptible to focus errors, so the surface of the finished disc must be highly uniform. The importance of cover/hard-coat layer uniformity is implied in the focus error limit: less than 45nm for BD compared with 200nm for DVD.

So, despite its apparent simplicity, spin coating such a thick layer with the requisite uniformity is an extremely exacting task. The thickness and uniformity of BD cover and space layers must be precisely controlled to ensure playability; however, BD's slim profile and tight tolerances make new demands of inspection technology, requiring high resolution measurement with excellent repeatability, plus the capability of measuring the gradient of the surface. It is also important to be able to measure beyond the specified limits: during the start-up phase, for example, discs may be wildly out of specification, but for effective process optimisation it is necessary to evaluate steep gradients and wide-ranging layer thicknesses.

Established methodology measures layer thickness by laser interferometer, using a focused beam with a large angle of incidence. With this method both spot size and measurement position are highly dependent on vertical deviation, making it impossible to measure with uniform sensitivity and accurate positioning.

dr.schwab's IQPC inline scanner takes a different approach. It measures BD cover and space layer using a spectrometer with a parallel beam, perpendicular >

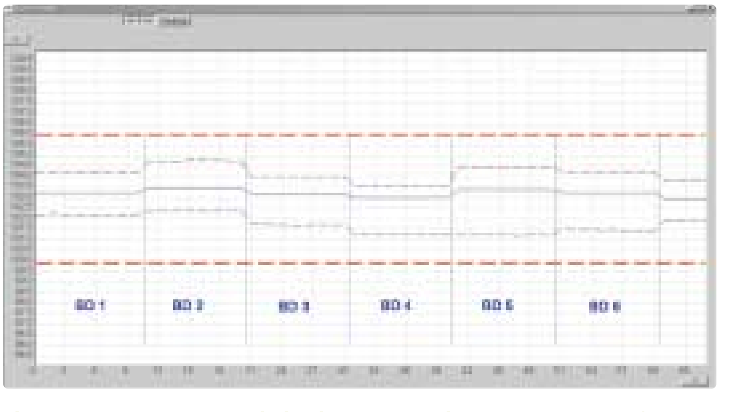

Figure 1: IQPC: process optimisation - successive measurements of cover layer thickness on 6 BD samples

> incidence, and effective spot size of 100µm. Spot size and measurement position are therefore independent of tilt and vertical deviation.

The optimum resolution of the laser

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interferometer is in the millimetre range. Because BD's very thin cover and space layer are at the lower limit of its measurement range, it has poor resolution, high noise and low repeatability, and cannot provide the accuracy required for reliable evaluation of small surface non-uniformities.

By contrast, the wavelength range of IQPC's spectrometer enables it to be optimised for BD layers, giving a resolution and repeatability of a few hundredths of a micron. Layer thicknesses are measured precisely, and even the smallest surface unevenness is calculated accurately. With this level of performance, IQPC is equipped for effective process optimisation within the process window.

For example, Figure 1 shows the results of 10 successive cover layer thickness measurements for each of six BDs, with the process window denoted by red lines. The variation between discs – process variation – is clearly visible, but there is no variation in the measurements for each disc. Fine-tuning within the process window is possible only with this level of repeatability.

IQPC offers a 10-radius measurement as standard, with an optional new 20-radius evaluation using a high-resolution, high-speed spectrometer. This option supports an enhanced 'top view' disc mapping and even a 3D representation of cover and space layer thickness that reveals all non-uniformities with outstanding accuracy and repeatability (Figures 2 and 5c).

Offline inspection system argus XE

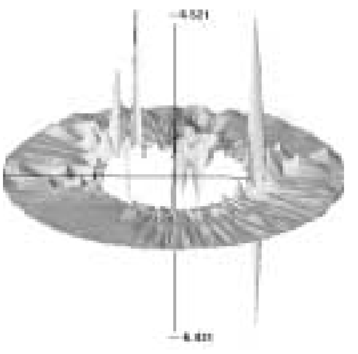

Figure 2: IQPC: 3D visualisation of surface non-uniformities

includes a spectrometer and interferometer; these two instruments can be used simultaneously, offering the broad measurement range – and combination of robustness and accuracy – necessary for efficient optimisation of the spin cover process (Figure 3). This combination also enables accurate determination of the refractive indices of the cover and space layers, a requirement for the new cover materials that incorporate hard-coat and anti-fingerprint constituents.

Surface defects

Surface defect detection and classification is another aspect of BD production optimisation that is profoundly affected by the nature of the cover layer.

Larger defects can be accepted on the surface of the disc than in the information layer, so it is essential for the inline scanner to identify surface defects and accurately measure their real size; failure to do so may lead to good discs being rejected, with a disastrous effect on yield.

Surface defects are characterised by a dual (defect and 'echo') image, the separation of which is dependent on angle of incidence and cover thickness: approximately 1mm for CD, 0.5mm for DVD, but just 60µm for BD. So, the two images from a large – but acceptable – BD surface defect of 80µm would overlap, appearing as a single 140µm defect. The inspection system must be capable of identifying

Figure 3: argusXE: (a) top view reveals SLT bump; (b) BD cover layer contour mapping

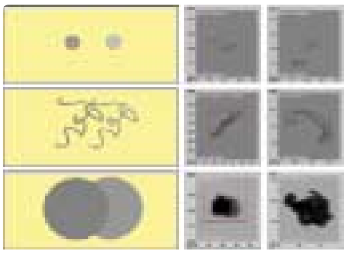

Figure 4: IQPC: accurate classification and real-size measurement of surface defects, irrespective of shape and contrast

it as a surface defect, and assessing its real size, or the disc would be falsely rejected.

The traditional approach is to use two cameras: one camera at zero angle of incidence – where defect and echo coincide – determines the size of the defect; correlation with a second camera at a different angle of incidence reveals whether it is a surface defect.

For BD, the minimal separation of the defect and echo images means that the correlation between the cameras must be performed with micron accuracy. But the limited pixel resolution and vertical deviation can result in a discrepancy of up to 100µm in the defect position from the two cameras; while this was not an issue for CD and DVD, it is less than ideal for BD. Further, during the correlation procedure, important information in the area of interest can be lost, giving rise either to a high false defect classification rate (reducing yield) or incomplete defect detection rate (reducing quality).

IQPC enhances the contrast, making it possible to clearly identify the defect and its echo with a single camera (Figure 4), irrespective of how irregular the defect may be. The advantages over the two-camera method are significant: there is no need for complex correlation; and the requisite micron accuracy of the real defect size is guaranteed without compromise.

One example of IQPC image analysis is the height classification of surface protuberances, an important defect, given BD's thin cover layer and high numeric aperture pick-up head (Figure 5). Tests show excellent correlation between this parameter and playability errors, and with thickness measurement results.

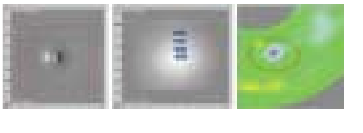

Figure 5: IQPC: surface protuberances (a) grey-scale image; (b) contour mapping; (c) top view