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A Better Measure.

TRANSPARENT FILM THICKNESS BY 3D NON CONTACT PROFILOMETRY

Prepared by
Duanjie Li, PhD

6 Morgan, Ste156, Irvine CA 92618 · P: 949.461.9292 · F: 949.461.9232 · nanovea.com

INTRODUCTION

Transparent thin films and overcoats are extensively applied in industries such as optics, semiconductor, and solar cells to achieve specific functions. Effective and precise measurement of the thickness, metrology and quality of the transparent films becomes vital to ensure proper function and performance of the coated device. Traditional stylus-based profilometers determine the surface morphology of the coatings by sliding in contact across the measured surface, which may create minor scratches on the delicate and sensitive optical device. Moreover, such a technique is impossible to measure the thickness of the film that covers the whole coated surface. The Nanovea 3D Non-Contact Profilometers utilize chromatic confocal technology with unmatched capability to provide a comprehensive analysis of transparent coatings.

IMPORTANCE OF COATING INSPECTION FOR QUALITY CONTROL

Surface finish on both the top and bottom surfaces of the transparent film as well as its thickness and uniformity is critical for product quality and performance. For example, in CD, DVD and Blu-Ray Disc (BD) production, precise control of the thickness and uniformity of the transparent cover and space layers plays an important role in avoiding focus errors of the laser. Improper injection molding process during CD and BD production may lead to stress-induced birefringence and unreliable data reading. An accurate thickness measurement of the transparent film ensures reliable product inspection and quality control.

MEASUREMENT OBJECTIVE

The optical thickness and uniformity of the transparent coatings on CD and BD were measured and compared using Nanovea PS50 optical profilometer. We would like to showcase the capability of Nanovea optical profilometer in measuring the thickness and homogeneity of the transparent films.

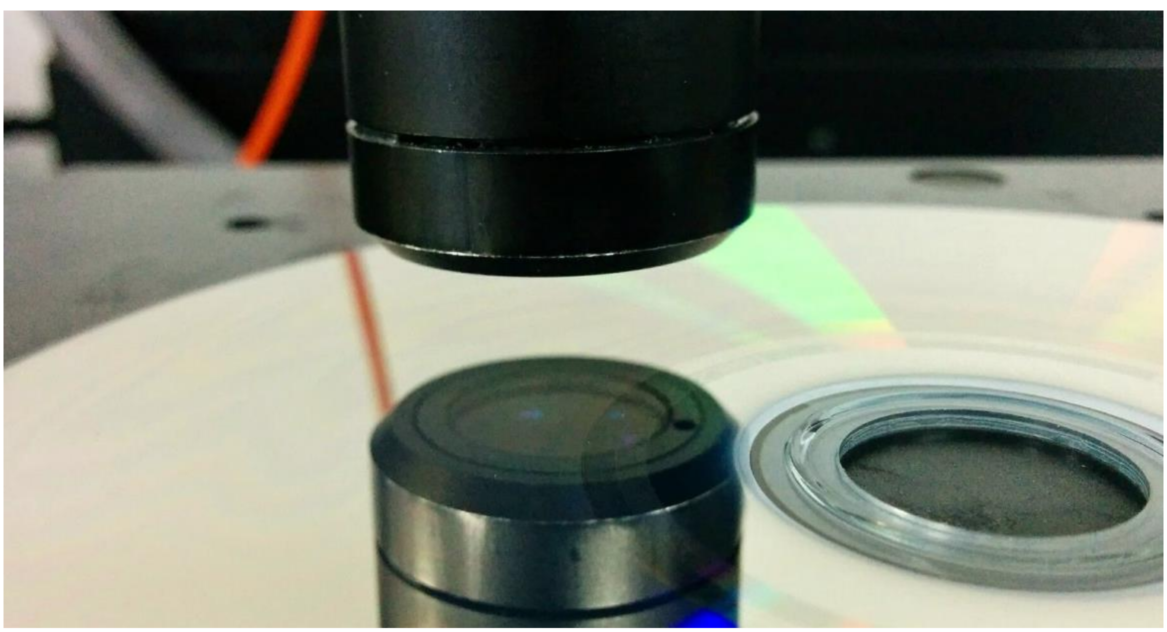


Fig. 1: Non-contact optical pen scanning on CD.

RESULTS AND DISCUSSION

Fig. 2 compares the spot size, wavelength and layer architecture of CD and Blu-ray disc (BD)[i]. Compared to CD, the BD technology decreases the wavelength from 780 to 405 nm, increases the numerical aperture from 0.60 to 0.85, and makes the cover layer thinner from ~1.1 to ~0.1 mm, resulting in a reduction of the pit size from 600 to 130 nm, and of the track pitch from 1.6 µm to 320 nm. Such an improvement substantially increases the storing capacity of BD to 25 GB per layer, compared to 700 MB for CD. The transparent cover coating plays a vital role in data reading and scratch protection for the recording layer beneath. In this study, the thickness and uniformity of the cover layer of CD and BD are measured using Nanovea PS50 profilometer in Thickness Mode.

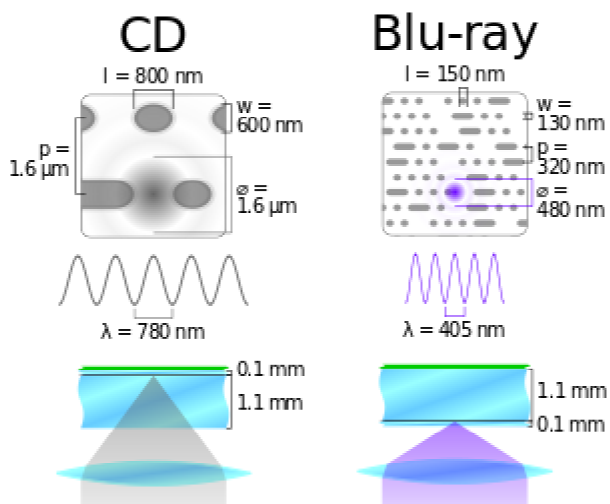


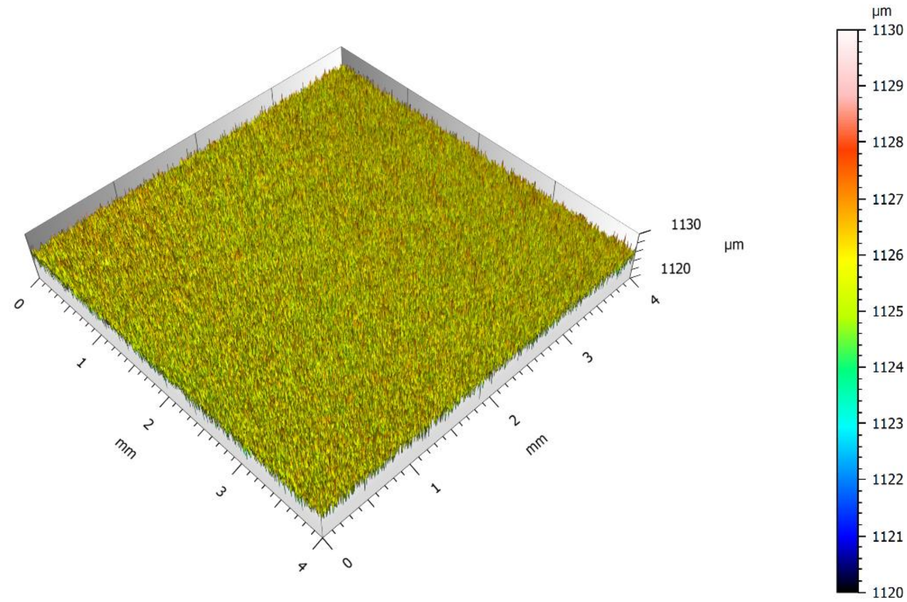
Fig. 2: Comparison of CD and BD.

The optical thickness and uniformity of the transparent cover coatings on CD and BD were obtained by subtracting the measured profiles of the surface and bottom of the cover coatings. The refractive index *n* of the polycarbonate cover layer is 1.585. The thickness of only the transparent film with a known uniform refractive index can be measured at this stage.

The 3D View of the optical thickness and uniformity of the transparent coatings on CD and BD are compared in Fig. 3. The BD shows a more uniform cover coating thickness compared to CD. This can be attributed to their difference in the physical structure. BD uses a coating only ~0.1 mm thick, compared to ~1.1 mm for CD. The thinner protective coating of BD causes less diffusion of blue laser travelling through it during data reading, allowing for greater track density and hence higher capacity. Such diffusion of the light contributes to the higher thickness variation measured for the thicker CD coating in this test.

Fig. 4 confirms the above conclusion. It can be observed in the Abbott-Firestone curves that the thickness of the CD and BD cover coatings are about 1125.0 and 102.3 µm, respectively, in agreement with the diagram of the layer architecture shown in Fig. 2. The thickness of the CD cover layer varies from ~1121.5 to ~1128.5 µm (~7 µm difference), compared to a range from ~101.9 to ~102.5 µm (~0.6 µm difference) for BD. This is also reflected on the height variation parameters such as the S_a value, where S_a are 0.842 and 0.081 µm, respectively, for CD and BD cover layers. The 2D thickness profiles shown in Fig. 5 also confirm the better quality of the BD cover layer.

(a) 3D View of CD cover layer thickness:



(b) 3D View of BD cover layer thickness:

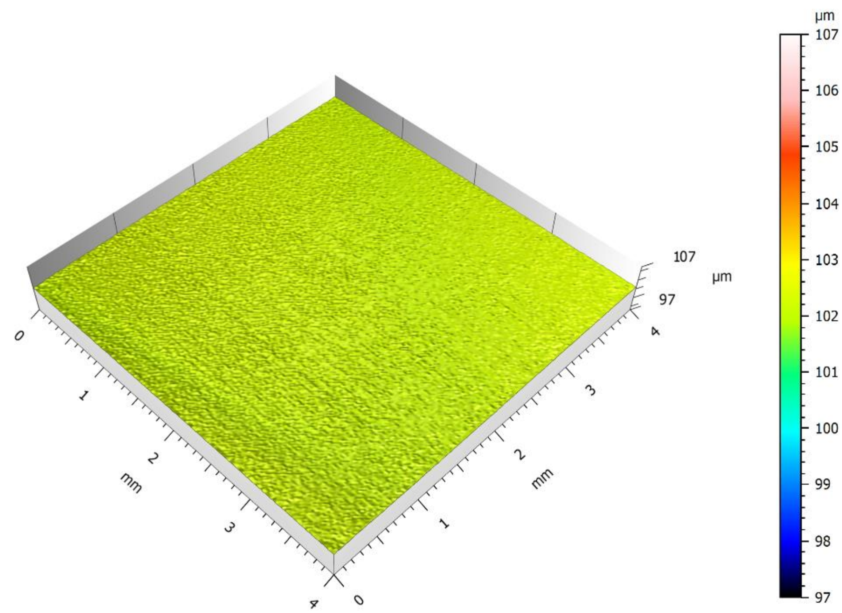
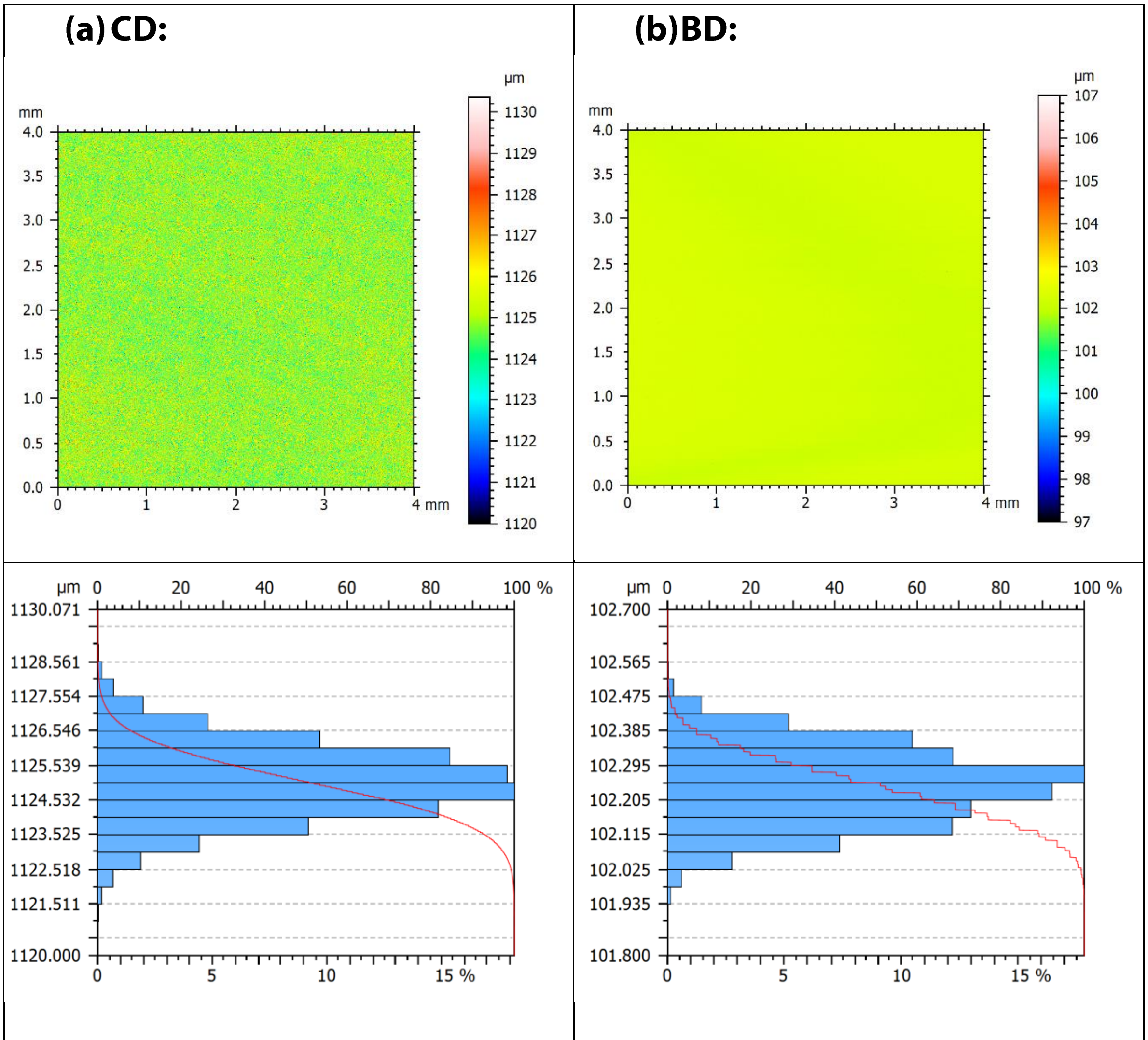


Fig. 3: 3D views of CD and BD cover layer thickness.



ISO 25178

Height Parameters

Sq	1.756	µm	*Root-mean-square height*
Ssk	-410.069		*Skewness*
Sku	262763.139		*Kurtosis*
Sp	5.017	µm	*Maximum peak height*
Sv	1125.161	µm	*Maximum pit height*
Sz	1130.177	µm	*Maximum height*
Sa	0.842	µm	*Arithmetic mean height*

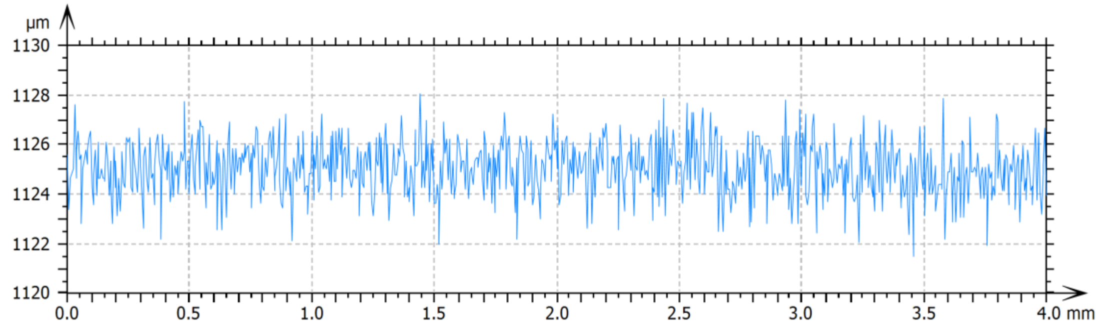
ISO 25178

Height Parameters

Sq	0.099	µm	*Root-mean-square height*
Ssk	0.949		*Skewness*
Sku	68.170		*Kurtosis*
Sp	7.624	µm	*Maximum peak height*
Sv	1.557	µm	*Maximum pit height*
Sz	9.180	µm	*Maximum height*
Sa	0.081	µm	*Arithmetic mean height*

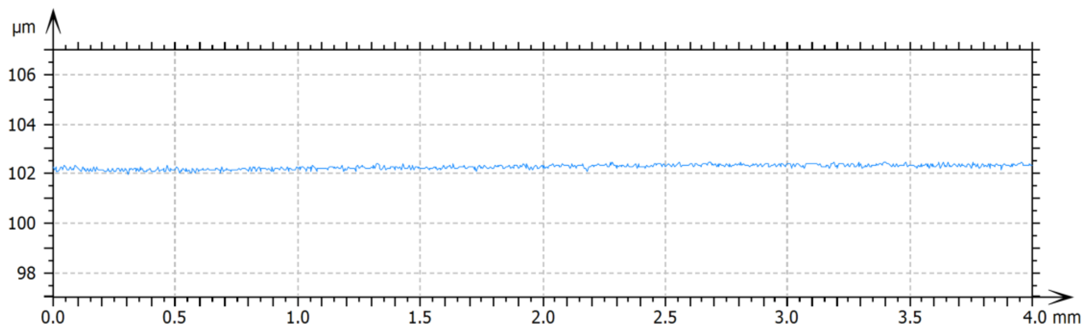
Fig. 4: False color view and statistics of the CD and BD cover coatings.

(a) CD cover layer thickness 2D profile:



ISO 4287			
Amplitude parameters - Roughness profile			
Ra	**0.646**	**µm**	***Gaussian filter, 0.762 mm***
Rz	**4.257**	**µm**	***Gaussian filter, 0.762 mm***

(b) BD cover layer thickness 2D profile:



ISO 4287			
Amplitude parameters - Roughness profile			
Ra	**0.032**	**µm**	***Gaussian filter, 0.762 mm***
Rz	**0.239**	**µm**	***Gaussian filter, 0.762 mm***

Fig. 5: 2D thickness profiles of CD and BD cover layers.

CONCLUSION

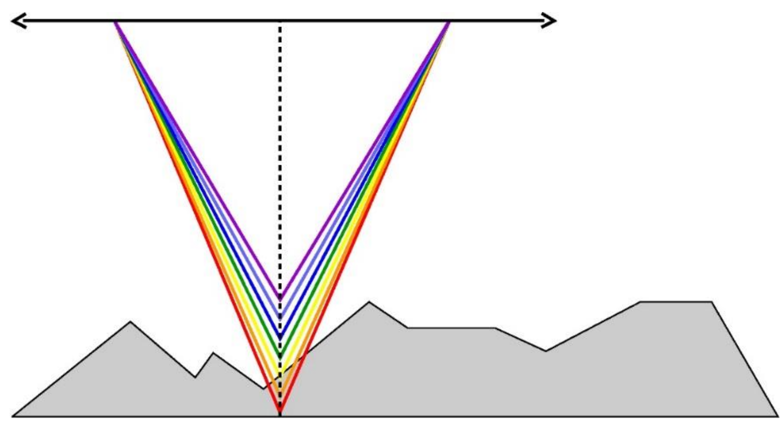
The thickness and uniformity of the CD and Blu-ray disc transparent cover coatings are measured using Nanovea PS50 non-contact profilometer, showcasing the accuracy of this technique. Such a measurement provides a useful tool in both development phases and quality control of the homogeneous transparent coatings used in a variety of industries, including optics, semiconductor, solar cells and many others. The analysis software provides measurements such as coating thickness, uniformity and roughness, enabling users to have a comprehensive understanding of the coating properties.

The data shown here represents only a portion of the calculations available in the analysis software. Nanovea Profilometers measure virtually any surface in fields including Semiconductor, Microelectronics, Solar, Fiber Optics, Automotive, Aerospace, Metallurgy, Machining, Coatings, Pharmaceutical, Biomedical, Environmental and many others.

Learn more about the Nanovea Profilometer or Lab Services

APPENDIX: MEASUREMENT PRINCIPLE

The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



Chromatic Confocal White Light Measurement

Unlike the errors caused by probe contact or the manipulative Interferometry technique, White light Axial Chromatism technology measures height directly from the detection of the wavelength that hits the surface of the sample in focus. It is a direct measurement with no mathematical software manipulation. This provides unmatched accuracy on the surface measured because a data point is either measured accurately without software interpretation or not at all. The software completes the unmeasured point but the user is fully aware of it and can have confidence that there are no hidden artifacts created by software guessing. Nanovea optical pens have zero influence from sample reflectivity or absorption. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent or opaque, specular or diffusive, polished or rough.

[i] http://en.wikipedia.org/wiki/Blu-ray_Disc