CCI – non-contact techniques

Accurate measurement of Diamond-Like Carbon (DLC) coating thickness

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"Precise control of Diamond-Like Carbon coating thickness and its uniformity is important for optimising the coatings for both R&D and industrial purposes. Coherence Correlation Interferometry (CCI) provides exceptional measurement accuracy for a wide range of coating thicknesses."

What is DLC coating and its properties?

Diamond-Like Carbon (DLC) coating is a single layer of hard carbon, deposited using highly specialised coating methods. DLC coatings are used to modify the surfaces of materials and improve the tribological and other properties. DLC coatings have many advantages because of their low cost and their abilities to provide diamond-like properties to different surfaces.

The carbon layers are mainly used to improve the wear properties of components due to the diamond- like hardness, low friction, and high resistance to wear and corrosion. These properties, as well as the achievable high electrical resistivity, infrared-transparency, high refractive index and excellent smoothness of the DLC coating can match well with the criteria of a good biomaterial for biomedical applications such as in orthopaedics, cardiovascular, contact lenses, and dentistry.

In addition, they can exhibit sufficient, low absorption and scattering to deliver good BBAR (Broadband Anti-reflective) performance on both silicon and germanium.

However, DLC must be used with caution on ferrous metals despite its favourable tribological properties. The substrate may carbonise if it is used at higher temperatures, which lead to loss of function due to a change in hardness.

Important to control the DLC coating thickness

The carbon layer requires a specific thickness to achieve the desired surface properties, for instance DLC coatings are often optimised for a specific wavelength region by adjusting the layer thickness during the coating process to deliver good BBAR (Broadband Anti-reflective) performance. Precise control of the DLC film thickness is important for optimising the coatings for both R&D and industrial purposes.

Measurement techniques

Various approaches have been employed to measure film thickness. These include conventional methods such as spectrophotometry, ellipsometry and physical step measurement in addition newer techniques such as Coherence Scanning Interfererometry are becoming more common. Other methods have also been used to investigate coating thickness, such as wavelength interferometry, prism couplers and thermal wave detection with a laser beam.

Non-contact Coherence Correlation Interferometry (CCI) instrument is an advanced coherence scanning interferometer which provides fast and accurate high-resolution 3D surface measurements and film thickness measurements.

Industrial applications for Diamond-Like Carbon coating

Automobile industry

DLC is widely used in the automobile industry such as in bearings, cams, cam followers and cam shafts to reduce wear and the need for lubrication.


Cam and cam followers


Bearings

Space vehicles

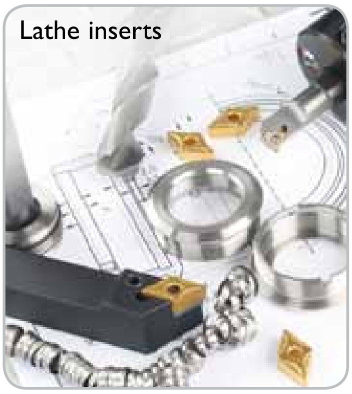
DLC can also be used to prevent wear during launch, orbit, and re-entry of land-launched space vehicles because it can provide lubricity both at ambient atmosphere and in vacuum.


Land-launched space vehicles

Extreme contact pressure

Excellent tribological properties make DLC coatings suitable for use in applications that experience extreme contact pressure, both in rolling and sliding contact. For example, DLC is often used to prevent wear on metal cutting tools and razor blades.


Razor blades


Lathe inserts


Cutting tools

Optical coating

DLC may be the strongest **optical coating** in the world and offers excellent resistance to abrasion, salts, acids, alkalis, and oil. Military vehicles and outdoor thermal cameras often employ DLC coatings to protect the outer optical surfaces from high velocity airborne particles, seawater, oils and high humidity.


Outdoor thermal cameras


Military vehicles

Biomedical applications

DLC is a good choice for biomedical applications such as in orthopaedics, cardiovascular, contact lenses, and dentistry.


Biomedical

Coherence Correlation Interferometry (CCI)

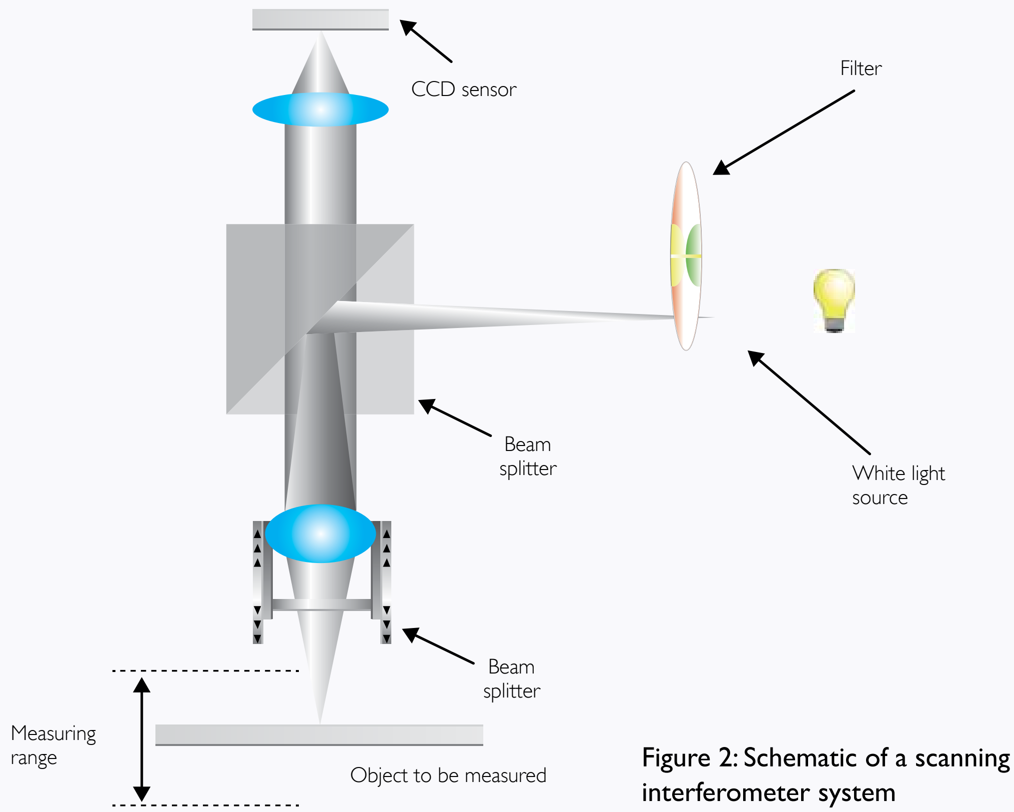


Figure 2: Schematic of a scanning interferometer system

> *"The wide variety of industrial applications mean that Coherence Correlation Interferometry is increasingly important"*
>
> **Dr Mike Conroy, Business Development Manager, Taylor Hobson Ltd.**

A schematic of a scanning interferometer system is shown in Figure 2. Light from the light source is directed towards the objective lens by the upper beam splitter and the light is then split into two separate beams by the lower beam splitter.

One beam is directed towards the sample and the other is directed towards an internal reference mirror. The two beams recombine and are sent to the detector. As the interferometric objective is scanned in the z direction, interference occurs when the path lengths of the two beams are the same. The detector measures the intensity, taking a series of snapshots as the sample is measured.

This creates an intensity map of the light being reflected from the surface, which is then used to create a 3D image of the surface being measured. Different techniques are used to control the movement of the interferometer and also to calculate the surface parameters. The accuracy and repeatability of the scanning white-light measurement are dependent on the control of the scanning mechanism and the calculation of the surface properties from the interference data.

Coherence Correlation Interferometry is becoming increasingly important for measurements in many applications, providing:

- Fully automatic non-destructive measurements
- Accurate and quantitative characterization of surfaces
- Sub-angstrom resolution regardless of the scanning range used
- Fast and convenient sample loading and set-up
- Capability of measuring a wide range of materials
- Highly repeatable measurements
- Roughness and step-height analysis in one measurement
- Film thickness and interfacial surface measurement capability

"With up to 4 million camera pixels with sub-nanometre vertical resolution and less than 1 µm lateral resolution it is now possible to measure thicknesses down to 50 nm or less using the CCI HD with patented film thickness software."

Daniel Mansfield Research Manager/Company Physicist, Taylor Hobson Ltd.

Measurement of film thickness

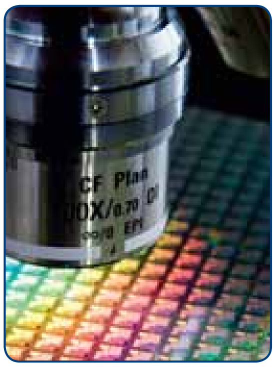
An important extension of interferometry is the ability to measure film thickness. When the interference signals appear at the surfaces of films a special algorithm is used so that the film thickness can be extracted from the interferogram. In some cases the surface information can also be obtained.

The advanced CCI HD has 4 million camera pixels and each individual pixel will act like its own 1 µm optical probe enabling high speed measurement of multiple film thicknesses with an independent thickness measurement at each point (Figures 3 and 4).

The combination of Film Thickness software and Coherence Correlation Interferometry (CCI) gives unrivalled thin film measurement capability.

Figure 3: The CCI HD

Figure 4: CCI HD close-up



CCI technology provides two different film thickness measurement solutions:

- Thick Film (> 1.5 microns)
- Film Thickness Analysis (down to 50 nm or less)

Traditional thick film measurement

When the thickness of a film is larger than ~1.5 µm (depending on refractive index), SWLI interaction with the layer results in the formation of two fringes, each arising from a surface interface (Figure 5)

The thickness of the film can be determined by locating the positions of the two maxima and applying the refractive index. In addition, the surface information of the two interfaces (air/film and film/substrate) can be obtained from the individual fringes (Figure 6).

Figure 5 Single pixel measurement from a 7 µm thick film

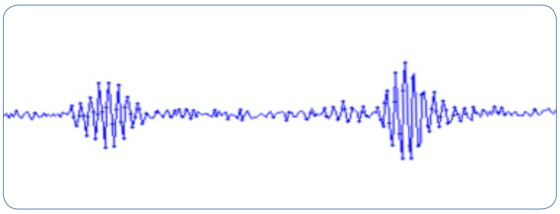
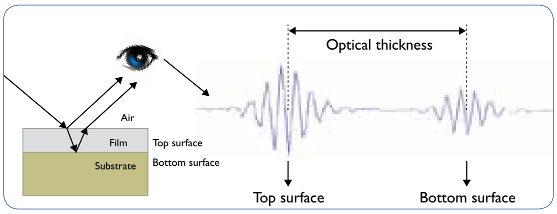


Figure 6: Determination of film thickness



Film thickness analysis – the solution

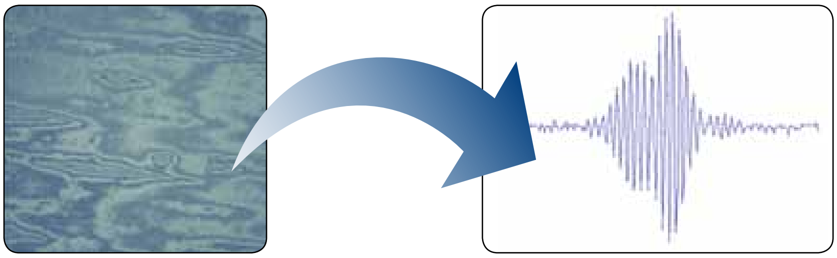
As the film thickness reduces, the interferogram sequence bunches condense. To address this problem (HCF) a new solution has been developed to extract the film information. Through the application of the HCF function, coherence correlation interferometry (CCI) has become the ideal method to obtain film thickness information. HCF can be used for thickness measurement with better than 1% accuracy within the range of ~ 5 µm to ~ 300 nm. Films thicknesses down to 50 nm have been measured; however, care needs to be taken with these very thin films as the accuracy depends on the optical properties of the material.

Case studies of DLC (Diamond-Like Carbon) coating

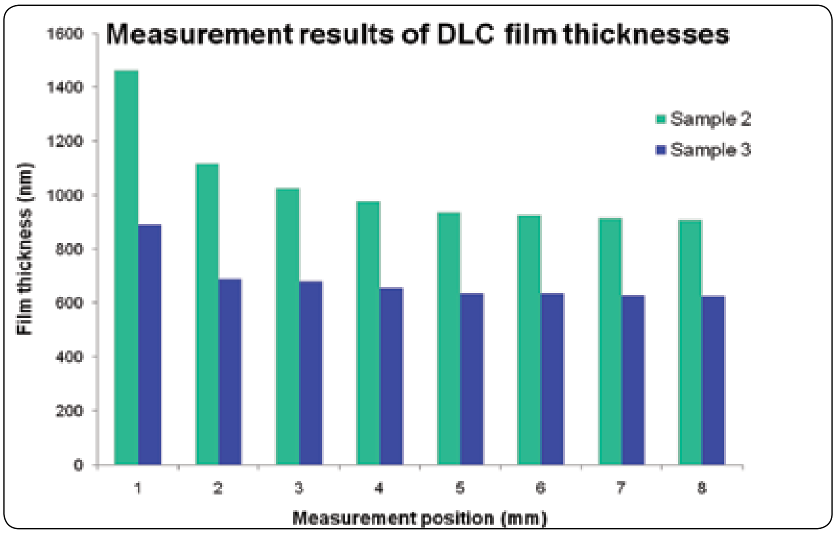
A series of case studies were carried out using DLC (Diamond-Like Carbon) coating on different substrates. Some of the results were also compared to ellipsometry.

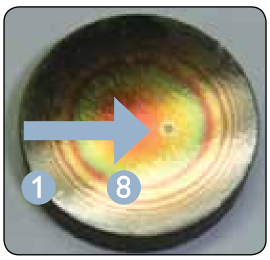
Case study 1:

Two samples with DLC films on nitrided steel substrate were measured using CCI HD

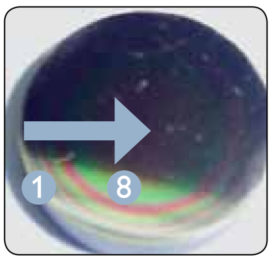


Single pixel measurement fringe of DLC film on nitrided steel base





Sample 2



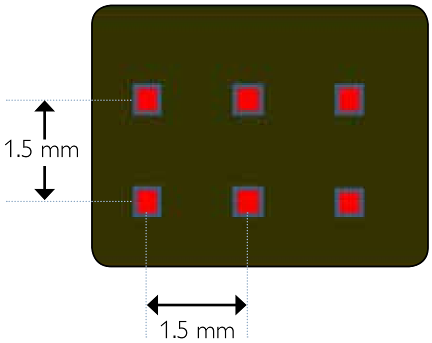
Edge

Centre

Case study 2:

Measurements of DLC coatings on silicon substrate

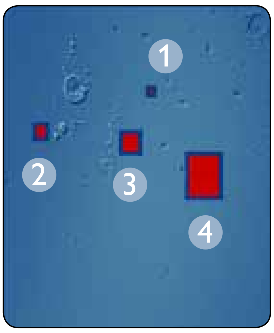
Sample 1: Auto-pattern measurements were made on a sample with DLC coating on silicon substrate



Region	1	2	3	4	5	6
(nm)	575.2	576.6	570.1	576.6	575.2	568.9

Ellipsometer results: ~ 570 nm

Sample 2: Multiple measurements were made with different measurement spot sizes at different regions using a sample with DLC coating on silicon substrate



Region	Measurement area	Thickness (nm)
1	9 um x 9 um	302.8
2	48 um x 48um	304.8
3	90 um x 90 um	302.5
4	160 um x 160 um	301.7

Ellipsometer results: ~ 300 nm

The results for case study 2 clearly show very good correlation between film thickness analysis and ellipsometry.

Multiple measurements can be used to quickly measure coating thickness over a wide area at high resolution. A combination of multiple analysis at each measurement position and multi-site measurement can be used to automatically investigate a large area without any user intervention.

Conclusions

The film thickness techniques together with Coherence Correlation Interferometry provides us with the ideal metrology tool to make fast and accurate DLC coating thickness and uniformity measurements. It allows characterisation of the coating enabling optimizations of the surface for both R&D and production.

References

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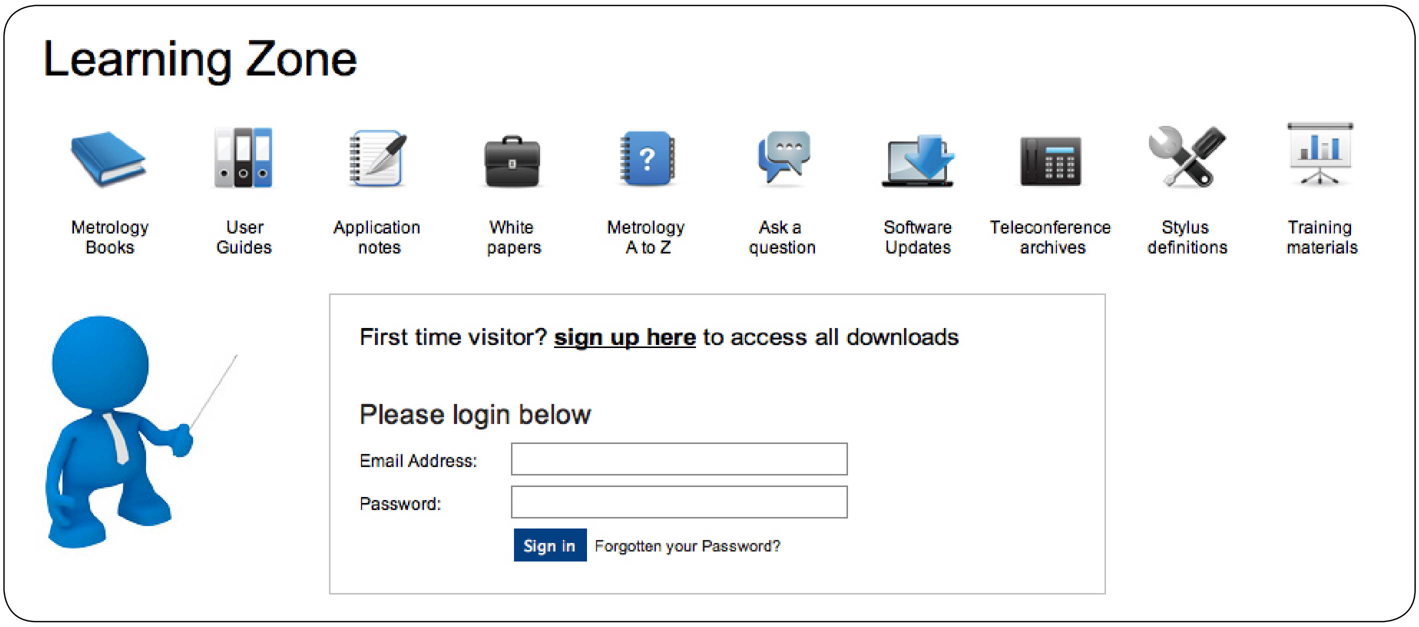
4. Mansfield D, 'Thin Film Extraction from Scanning White Light Interferometry', Proc. of the Twenty First Annual ASPE Meeting, Oct 2006
5. Daniel Mansfield, "Extraction of film interface surfaces from scanning white light interferometry", Proc. SPIE 7101, 71010U (2008)

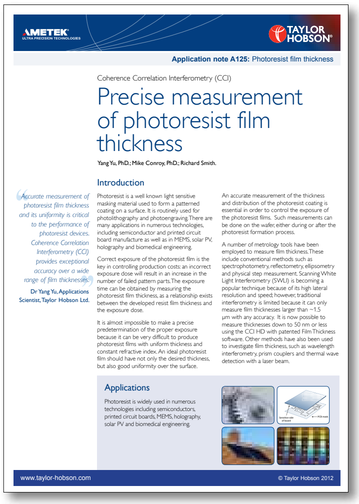
6 The authors acknowledge CREST of Loughborough University for their ellipsometry measurement results.

Application notes are available for download at www.taylor-hobson.com/learning-zone

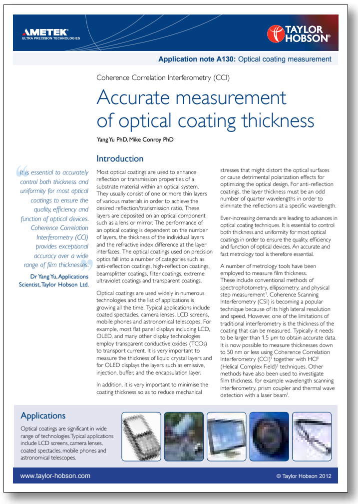


Some other relevant application notes

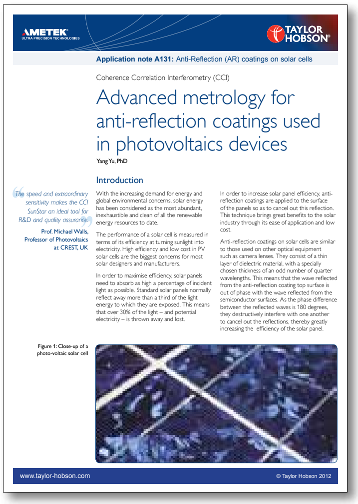
A125
Precise measurement of photoresist film thickness



A130
Accurate measurement of optical coating thickness



A131
Advanced metrology for anti-reflection coatings used in photovoltaics devices



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