NOVACAM TECHNOLOGIES INC.

Application Note for Industry

Multi-Layer Thickness Measurement

with Fiber-Based Low-Coherence Interferometry

Keywords: thin film coating, thick film coating, coating thickness measurement, tube dimensional measurement, 3D industrial inspection, low-coherence interferometry (LCI), hard-to-reach spaces.

Introduction

High-precision thickness measurement is required in a variety of inspections applications, such as in production of medical devices, contact lenses, optical fibers, high grade thin tubing, curved glass display screens for mobile phones, thick-film coating of MEMS devices, and other high-value glass or polymer components.

Novacam non-contact 3D metrology systems provide reliable and highly precise 3D thickness measurements for both single and multilayer films. Scanning in a point-by-point manner and at high speed (up to 100 kHz), the systems capture reflected light signal to obtain 3D (A-scan) data from which thickness of each film as well as 3D topography of inner surfaces can be calculated. Defects such as bubbles can be identified and characterized. The systems are suitable for both lab and high-volume inline production setup.

How Multilayer Thickness is Measured

Low-coherence interferometry uses broadband light in the infrared range (1,310 nm). The interferometer splits source light into two paths, directing one beam via a fiber-based probe to a sample surface and the other to a reference mirror. Light signals returning from the sample and reference arms are recombined, creating an interference pattern (Figure 1).

Interferometer software separates and analyzes the interference peaks. It can use each material's index of refraction (IR) to calculate layer thickness. When required, the upper and lower surface of each substrate can be programmatically separated and its characteristics such as roughness or waviness calculated.

Fiber-based vs. Full-field Measurement Systems

Optical measurement systems are either fiber-based (and modular) or full-field (microscope-like). A full-field optical measurement system is limited to inspecting fixed samples that fit onto its stage and acquires one small area at a time. For bigger areas, images must be stitched together.

This is not a limitation for Novacam 3D metrology systems; these systems are fiber-based, meaning their small optical sensor probes can operate continuously and far from the interferometer enclosure, with only an optical fiber (up to 1 km long) connecting the probe to the interferometer.

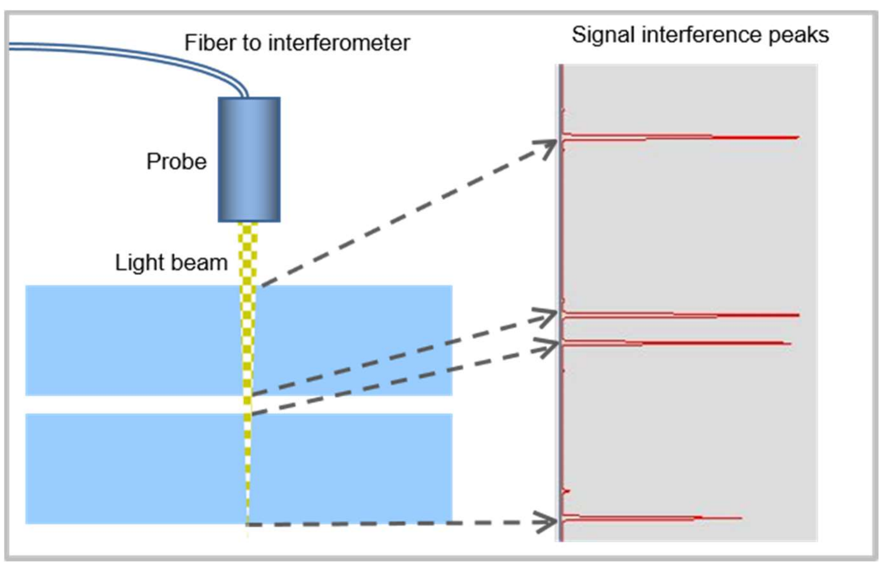

Figure 1: Multi-layer film scanning: Optical probe scans through two sheets of glass, each 0.95 mm thick, separated by a 0.2 mm air gap. Total optical length is 3.05 mm.

In the corresponding interference peak graph, peaks occur at the interfaces of substrates, where the index of refraction changes. The height of each peak is proportional to the magnitude of change of index of refraction. Two adjacent peaks locate the top and bottom of each substrate. The optical thickness of each substrate can be calculated.

These systems offer significant advantages:

- **To measure,** probes are typically displaced by precision stages or robot arms to acquire linear or area profiles even outside of lab environments.
- **The probes come in range of models and sizes** to support a variety of applications. They are front-looking, side-looking, rotational, or galvo scanning (for raster measurement).
- **Moving surfaces can be measured continuously and in real time** since the probes can acquire long profiles at high speed, and at a standoff of up to 1 m. Examples include measurement of multi-layer glass or polymer sheets on production webs, and cross-sectional inspection of optical fibers or tubing at the point of extrusion.
- **Hard-to-reach surfaces are easily measured with rotational probes.** IDs of tubes or bores can all be inspected.
- **The probes can operate in hostile environments**, such as in radioactive or high vacuum chambers, or in extreme temperatures, ranging from cryogenic to very hot. Molten or evaporating materials can be measured.
- **Multiple probes may be time-multiplexed to a single interferometer** with an optical switch, such that thicknesses are measured in multiple locations, lowering the overall inspection station cost.

Data Processing

The system software converts optical interference data into micron-precision thickness measurements. In production context, this stream of data is typically forwarded to process control software.

Scan Depth and Resolution

Novacam 3D metrology systems scan through objects from 15 µm to 7 mm thick (optical thickness), with depth resolution better than 1 µm. This is superior to ultrasound scanning, which reaches the precision of only 30 to 100 µm. Coatings thicker than 7 mm can be measured by combining measurements of multiple optical probes.

Acquiring Thin Tubing Dimensions

Thin tubing such as medical catheter tubing (<1.5 mm thick) is an excellent candidate for multi-layer optical profiling. Figure 2 shows one possible setup for cross-sectional profiling of such tubing. See an example of measurements obtained with this setup in Table 1.

Table 1: Catheter tubing measurements

Tubing dimensions	Measurement
thickness of upper wall	0.131 mm
thickness of lower wall	0.162 mm
inner diameter	0.852 mm
outer diameter	1.145 mm
calculated index of refraction (at 1310 nm)	N=1.512

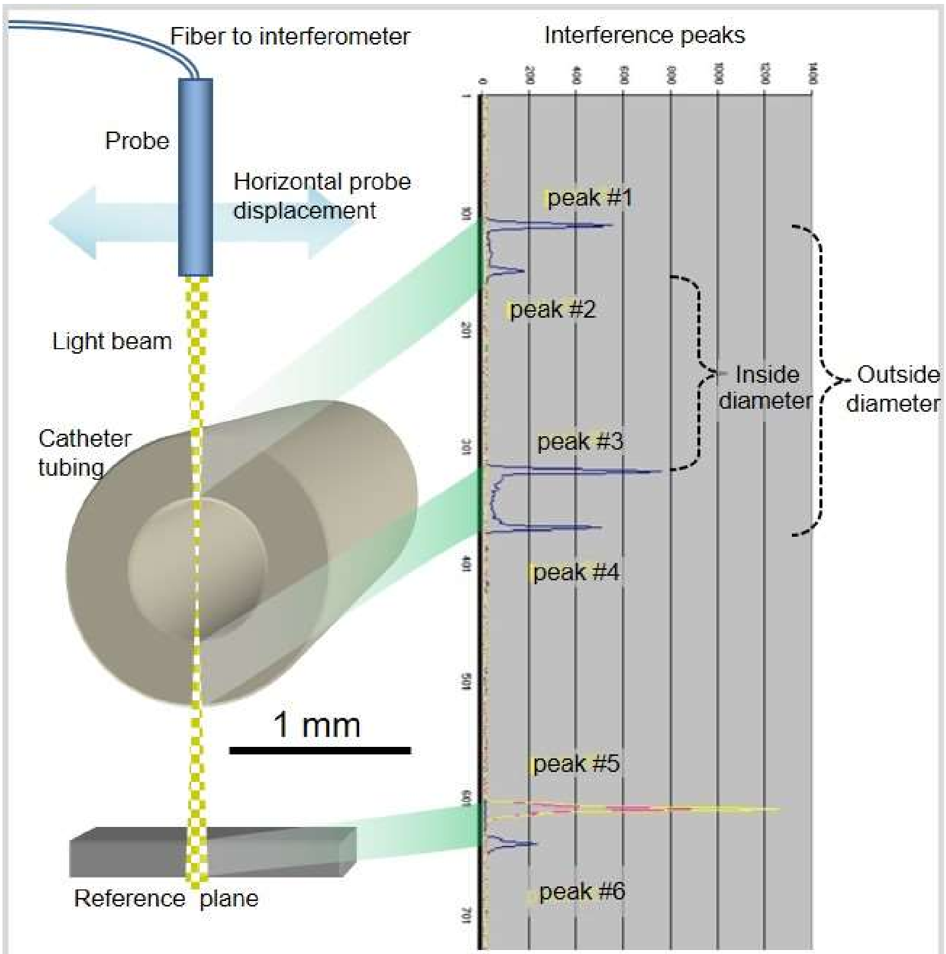

Figure 2: Cross-sectional thickness measurements of thin catheter tubing.
If, as in this installation, a reference plane is set up and scanned at the same time as the measured object, both the thickness and the index of refraction may be captured in a single measurement.

Continuous measurement of optical fiber and its coatings

Novacam 3D metrology systems are being used in the production of optical fiber where thickness of the fiber and its two semi-transparent coatings must remain uniform. The setup (Figure 3) involves two galvo raster scanners fixed at right angle to each other and to the advancing fiber. The two galvo scanners are multiplexed to a single interferometer.

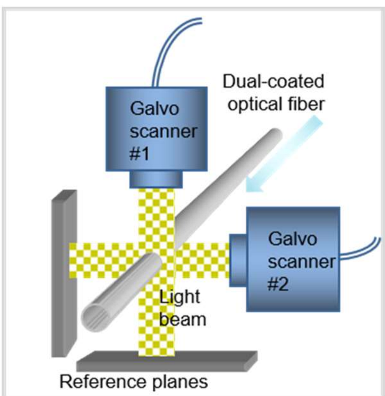

Figure 3: Dual probe setup for long profile scanning of optical fiber. With continuous scanning, the entire fiber cross-section is acquired in real time.

Application software compares the acquired real-time cross-sectional measurements to user-specified criteria and provides automated feedback to process control and to the operator display (Figure 4).

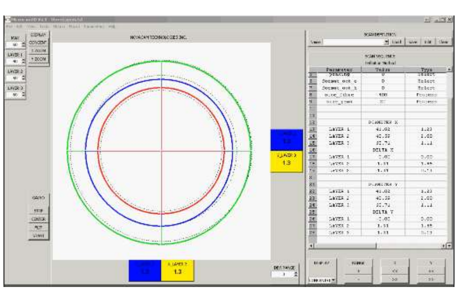

Figure 4: Real-time display of cross-sectional measurements of optical fiber (outlined in red) and two coating layers (in blue and green).

Measuring Thick Film Photoresist Coating

Photoresist is generally applied

Figure 5: Profile of 6” diameter wafer with unevenly applied thick film of photoresist coating (~250 µm thick, equivalent to approx. 400 µm optical thickness). The X:Y aspect ratio is 10:1.

onto electronic wafers by spray coating or spin coating. Thickness uniformity of this coating is critical to avoid subsequent under- or over-exposure to UV radiation during the patterning process of photolithography. Novacam 3D metrology systems measure film thickness of up to several millimeters, surpassing ellipsometers, whose thickness measuring tops out at 250 µm. The systems provide micron-precision thickness measurements as well as surface roughness analysis and imaging of photoresist coating (Figure 5). Measurements are obtained in real time, even, if needed, during coating application.

Inspecting Optical Lenses

Novacam metrology systems also measure the thickness of contact and intraocular lenses (Figure 6). Volume density maps and 3D isosurfaces are analyzed for cracks, bubbles and other defects, and lens curvatures can be calculated.

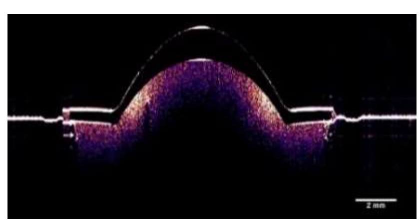

Figure 6: Cross-section image of intraocular lens on its supporting lower mold

Measuring Thick Film in Evaporation Chambers

Radiography plates and electronic wafers are commonly coated with a thick film of a semi-conductor (e.g., amorphous selenium) or metal (e.g., aluminum or gold). Even a micron imprecision in thickness application is costly in this process; plates with overly thin coating are discarded, whereas unnecessarily thick coating is wasteful and expensive. To achieve uniform coating, manufacturers install plates or wafers on a rotating mechanism inside a vacuum evaporation chamber that contains the material to be evaporated. Gradual heating induces evaporation and deposition of the coating material on the plates. Typically, the thickness of the coating, and therefore the stopping point of the deposition process, is estimated from the rate of deposition, resulting in occasional costly waste.

Novacam’s 3D metrology systems replace thickness estimation with reliable high-resolution thickness measurement. The non-contact probes that scan surfaces up to 1 m away offer continuous measurement options for this hostile environment. A probe positioned outside the chamber can measure through its window. Alternately, a probe can operate inside the chamber when protected by an extra glass plate. By measuring the deposition thickness on the rotating plates continuously, the system determines the optimal process stopping time. Within the same inspection station, and for not much additional cost, clients can deploy several probes that are time-multiplexed to the same interferometer. Such probes may provide measurements of the same plate from a different angle or measurements from different plates or evaporation chambers.

Measuring Thickness and Hidden Defects in Balloon Catheters

Quality inspection is paramount in the production of balloon catheters used by cardiologists in vascular procedures such as coronary angioplasty. Novacam systems are currently being employed in the measurement of balloon catheter thickness.

Besides high-resolution thickness and GD&T measurement, defect detection is possible. During catheter-balloon assembly, production quality control must verify and guarantee extremely high quality of adherence between the catheter surface and the tail of the balloon (Figure 7). Novacam systems can measure balloon-catheter joints to facilitate detection of hidden joint defects.

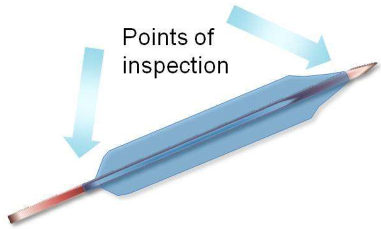

Figure 7: The joints of balloon catheters must be inspected for high quality adherence

Conclusion

Novacam 3D metrology systems offer high speed, micron precision, reliability, and versatility of installation in many thickness measurement applications. New applications for this technology are constantly emerging, and include measurements of:

- medical coating
- semiconductor coating
- conformal coating
- fuel cell coating
- solar cell coating
- high grade glass such as in the optical industry
- multi-layer plastics and films
- high grade (single layer or multilayer) polymer tubing
- BoPET film
- multi-layer lid stock: OPET films, adhesive layers, heat-seal films
- cast film
- curved glass
- multi-layer label stock.

Novacam encourages technicians and engineers in charge of thickness measurements to contact us to discuss your application.

Novacam 3D metrology systems for thickness measurement

System name	Type of optical sensor	Thickness measurement
Microcam Profilometer	Front-looking or side-looking probe	In most environments – very versatile
TubeInspect	Side-looking probe	In hard-to-reach spaces
BoreInspect	Side-looking rotational probe	In hard-to-reach spaces
SurfaceInspect	Galvo (raster) scanner	On open surfaces or on the bottoms of blind slots and holes
EdgeInspect	Galvo (raster) scanner	Edge radius measurements

- All Novacam 3D metrology systems include Microcam-3D or 4D interferometer (19" rack-mountable instrument) and a mini desktop-size PC or laptop that hosts Novacam data acquisition software and, typically, data analysis software.

More information:

- Learn more about Novacam 3D metrology systems here: https://www.novacam.com/products/
- See more examples of thickness measurement with Novacam systems: https://www.novacam.com/applications/thickness/

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