Application Note

Thin Layer Measurement of Car Headlight Lens Lacquer

The lenses of car headlights are coated with a special lacquer system to increase their robustness and endurance. This coating prevents damages from UV-radiation, micro impacts, and scratches.

The advantage of modern UV curable coatings is that those coatings can develop an interpenetration layer, which guarantees a very good adhesion of the hard coating on the PC lens. Both, interpenetration layer and hard coating are fundamental to the quality of the coating.

The quality of those coatings must be constantly controlled during the coating process, in order to guarantee the functionality of the layers and thus to comply with customer requirements. The testing of samples from the ongoing production process can be performed as random sampling or as on-line measurement.

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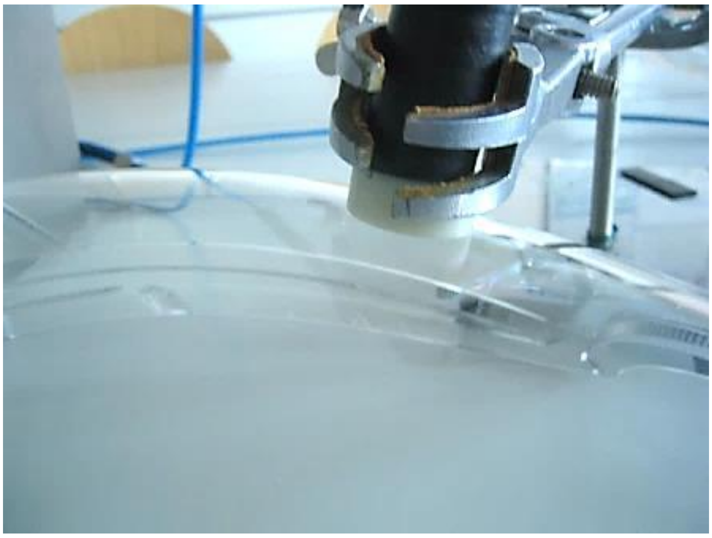

The thickness of those layers is normally in the range of 1 to 5 µm for the IPL, and 7 to 25 µm for the hard coating.

When white light is incident on optically transparent layers, interference occurs, as the path difference between specific wavelengths is exactly a multiple of the optical layer thickness. A high absolute accuracy of the wavelength ensures an exact measurement result. Only spectrometers with high performance optics, such as the TIDAS-S guarantee reliable results - especially when it comes to multiple layer systems.

A user friendly, intuitive software package completes the setup. TIDASDAQ3 is designed for at-line and in-line application, and communicates via OPC with any PLC.

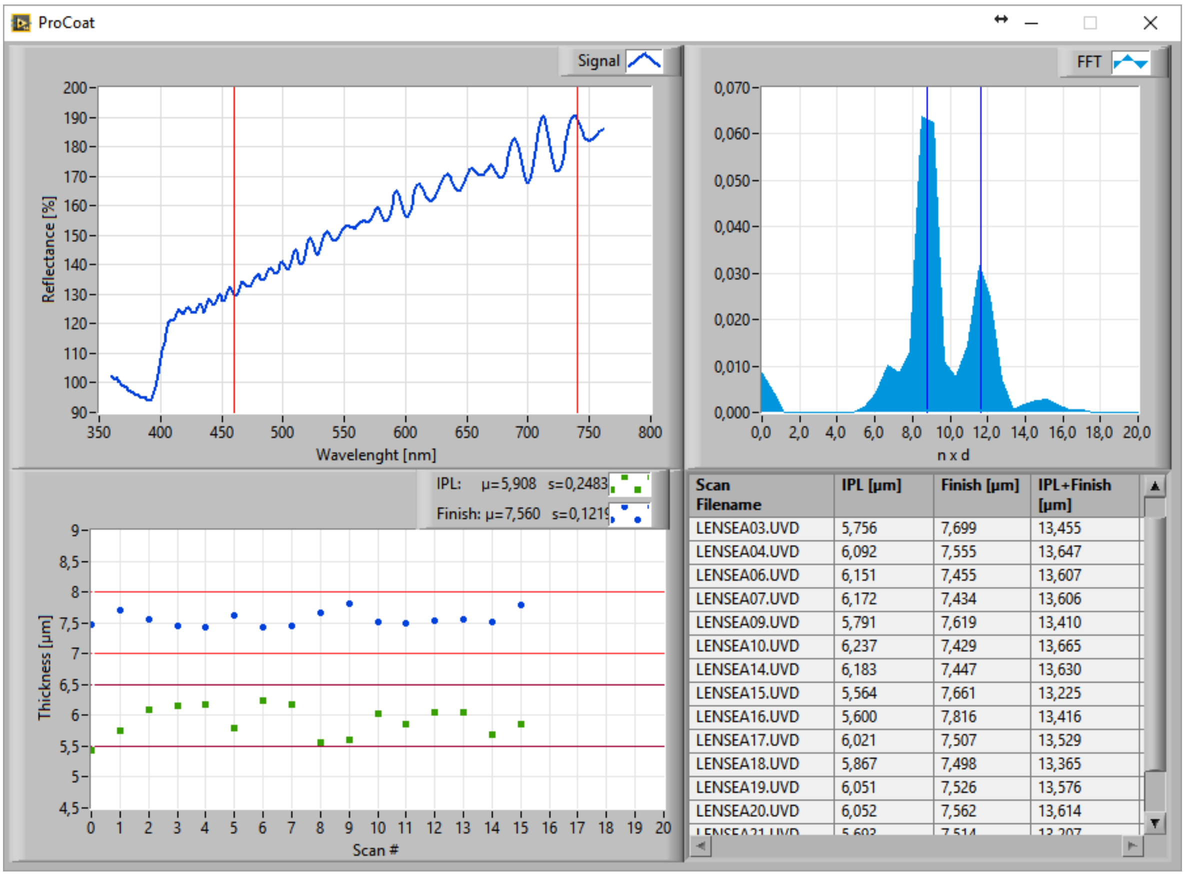

Figure 1: ProCoat software

History of Layer Thickness Measurement at J&M

J&M is a pioneer in the field of thin layer measurement. In 1987 J&M Analytische Mess-und Regeltechnik GmbH launched the first commercial system for thin layer measurement with white light interference. The spectrometer was a Carl ZEISS MCS 110 with a Y-fiber guide. The first PC software for thickness measurement was SDICKM.

Four years later J&M launched the first spectrometer with parallel data processing based on transputers, the TIDAS (Transputer Integrated Diode Array Spectrometer). With this technology a high performance FFT could be implemented directly into the spectrometer, and the first online system for thickness measurement with white light interference was born. This system was meant to replace methods with radioactive isotopes, like beta backscattering.

The same year Carl ZEISS took over the business line of thickness measurement from J&M. Since then the SDICKM software was sold all over the world to laboratories for both online and at-line applications. Still J&M remained active in this field and continued improving the technology.

In 2013 J&M Analytik AG implemented new mathematic methods for thin layer measurements, which guarantees a higher precision and reliability many with multi-layer systems.

Theory

By illuminating samples with white light, interference spectrums are created as a function of the geometric layer thickness and refractive index of the materials. When white light is incident on optically transparent layers, interference occurs, as the path difference between specific wavelengths is exactly a multiple of the optical layer thickness. The maximum measurable thickness is linked to the spectral resolving power, the minimum thickness to the spectral range to be covered. The measurement of even thinner layers requires that the absolute intensity value is known. A high absolute accuracy of the wavelength ensures an exact measurement result.

Depending on layer condition, the thickness can be calculated using one of these two methods:

Peak Method	Fast-Fourier-Transformation (FFT) Method
The layer thickness is derived from the maxima and minima of the interference spectrum. This method is very accurate and fast, however, noise-sensitive. It is suitable for single layers < 5 µm.	The layer thickness is calculated from the periodicity of the interference spectrum. This method is insensitive to noise and suitable for thick layers. However, it requires a large computational effort and is less accurate. It is suitable for single and multi-layer systems from 1-200 µm.

Table 1: Methods of Thickness Calculation

Generation of Interferences

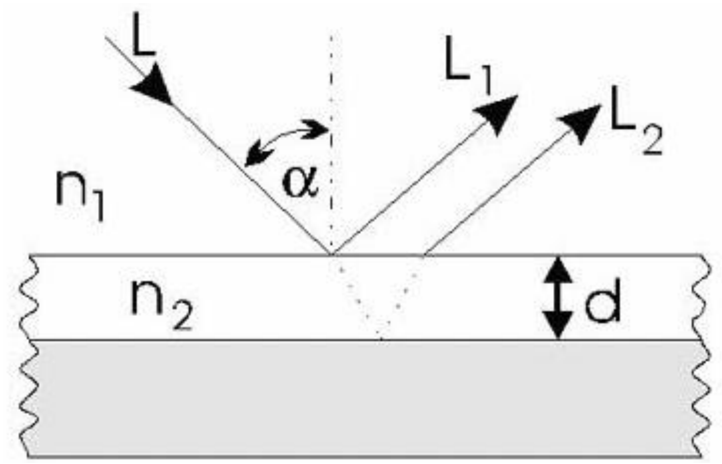

Figure 2: Generation of Interferences

The following is based on the in theory simplest case of a plane-parallel layer with the refractive index n and the geometrical thickness d. Starting from the point light source, a ray L is partially reflected (ray L1 at angle α) and partially refracted into the layer (at angle β). At the lower boundary of the layer, the ray is reflected again at point B and refracted at point C. Finally, the ray L2 leaves the upper boundary layer parallel to L1 and exits into the air again. Further reflections in the layer refract the ray L infinitely and divide it into parallel rays with strongly decreasing intensity. Since all reflected and refracted rays have their origin in the L ray, they are coherent and can thus interfere with each other. Depending on the path difference Γ, the two main reflected rays L1 and L2 may interfere with each other.

The path difference is calculated:

$$\Gamma = 2 \times d \times \sqrt{n_2^2 - \sin^2 \propto}$$

For vertical light incidence the formula is simplified to:

$$\Gamma = 2 \times d \times n_2$$

Maximum interference occurs under the condition:

$$\Gamma = i \times \lambda$$

The variable i stands for the interference order and consists of a prime number (i = 0, 1, 2, etc.).

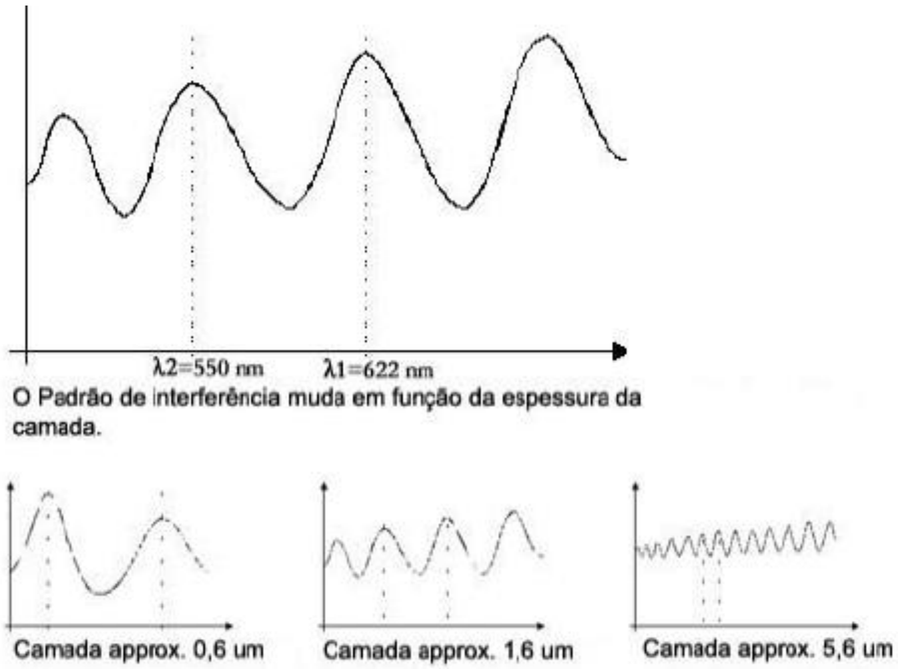

Figure 3: ???

$$2 \times d \times n_2 = i \times \lambda_1 = (i+1) \times \lambda_2$$

$$d = \frac{1}{2 \times n_2} \times \frac{\lambda_1 \times \lambda_2}{\lambda_1 - \lambda_2}$$

$$= \frac{1}{2 \times 1.49} \times \frac{622 \times 550}{622 - 550} nm$$

$$= 1590\, nm \approx 1.6\, \mu m$$

About J&M

Since our foundation in 1987, J&M Analytik AG has offered innovative solutions and analytical systems for both laboratory and process analytics. J&M has gained a reputation in the field of fiber-optic measuring systems in the area of UV/VIS and NIR spectroscopy. The TIDAS® series of spectrometers are used with suitable accessories such as tailored measuring cells and fiber- optic probes in the chemical, pharmaceutical and food industry. Typical applications are the monitoring of cleaning, drying, and mixing processes as well as the determination of concentration of ingredients like fat and protein content in milk. Innovative products are constantly developed by working closely with both customers and partners. Our new developments in the area of networked, miniaturized fiber-optic probes based on LED technology will further advance the integration of spectroscopic analytics in the mass market.

To learn more, visit the J&M website at www.j-m.de.