Fraunhofer IPM

Film-Inspect
Inline characterization of barrier layers

Extremely thin functional coatings on food packaging prevent, for example, odors from getting out or unwanted substances from getting into the packaging.

100 percent inspection of extremely thin coatings

Inspecting functional coatings between 10 and 100 nm in thickness during production plays an important role in the quality assurance of modern-day plastic products. Fraunhofer IPM's Film-Inspect inspection system measures these extremely thin coatings quickly, accurately and without damage – even for 3D surfaces. The system can be expanded for parallel inline process monitoring.

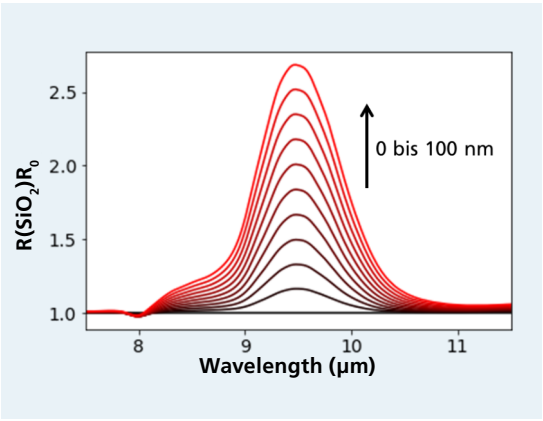
Inline, non-destructive inspection

Packaging materials, as well as medical products, are coated in order to create a barrier or to achieve particular surface characteristics. These barrier layers – such as SiO_x or AlO_x – are crucial for the quality of packaged contents and products, which is why inline, non-destructive inspection of the coatings is so essential. Due to the physical properties and the thinness of the coating material, conventional image processing is not possible. Other typical optical methods for measuring thin films, such as reflectometry or ellipsometry, also don't quite meet the requirements.

Film-Inspect uses specific, thickness-dependent infrared optical characteristics of the coating to achieve a 100 percent inspection. Using the appropriate infrared wavelength enables the resonant excitation of molecules. In turn, this influences the reflective properties at this wavelength (Figure p. 2 top right). Based on the intensity of the reflected light, the layer thickness is determined, allowing even extremely thin barrier layers to be measured. The choice of the wavelength in the infrared spectrum depends on the type of coating material. The beam paths of the sensor are chosen so that minor deviations in the angle of reflection can be captured by the detector. As a result, measurements can even be carried out on convex or complexly shaped components.

Technical data

- **Measurable materials** e.g. SiO_x, AlO_x, Si_3N_4
- **Measuring range (for SiO_x)** 0 to > 100 nm
- **Measuring uncertainty** up to ± 3 nm (depending on the substrate)
- **Time per data point** 0.5 s
- **Spot size** approx. 5 mm
- **Dimension of sensor** 50 × 40 × 95 mm^3
- **Working distance** 5 to 10 mm
- **Surfaces:** able to be used on uneven surfaces



The Film-Inspect sensor in operation (left)

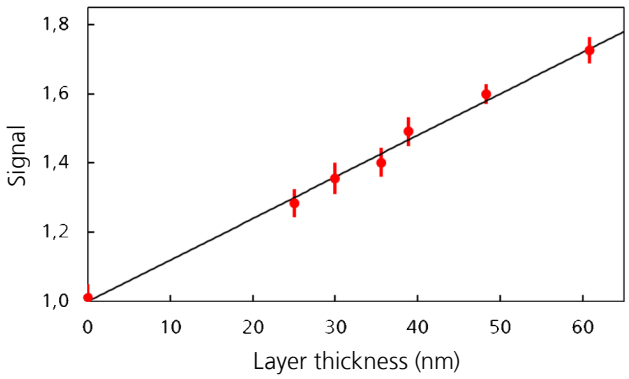
Calculation of a relative change to the reflective properties of a polymer surface in an SiO_2 coating. The layer thickness varies between 0 nm (black) and 100 nm (red) (right).

Compact sensor, accurate measurements

Fourier transform infrared spectrometers (FTIR) can also capture such spectrums. However, they are bulky, expensive and too slow for the typical cycle rates during the production process. Film-Inspect therefore only registers the relevant spectrum, and the sensor is specially configured to the coating material. Due to its compact design, Film-Inspect is also able to measure difficult to reach areas in 3D components. Using a USB port, one or more sensors are connected to a computer, where data analysis is performed by the Surf-Inspect software. Additional ports for system control can be installed as necessary.

Each data point is measured in 0.5 seconds. The image below shows the signals for polymer samples with various degrees of thickness for SiO_2 coatings. The error bars represent two standard deviations (2σ) from 10 single measurements. Measurements using quartz oscillators were used as the reference method for determining the actual layer thickness. Using a regression line (black), it is possible to clearly match measurement data to the layer thickness. The precision of the layer thickness measurements can be determined based on measurement uncertainty (2σ) and the slope of the line. For the samples used here, the average value was ± 3 nanometers. Film-Inspect can therefore be used directly to measure the thickness of coating after the material system has been calibrated. As a result, the values can be fed back immediately to the system controller as control parameters.

In highly complex parallel production processes, several Film-Inspect sensors can also be used in parallel and are able to achieve similarly high measurement speeds compared to those of individual, serial high-end infrared components. Since the sensor uses inexpensive components, it is still cost-effective when several sensors are used.



Intensity of the reflected infrared radiation as a function of the thickness of the SiO_x coating. The error bars show the statistical error of the method. This corresponds to a measurement uncertainty of ± 3 nm.

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