KLA INSTRUMENTS

How Many Layers Can You Measure?

Measuring Film Thickness for Massively Multilayer Dielectric Stacks

Introduction

Multilayer dielectric stacks are used in a variety of applications where precise optical filtering is required, such as military, aerospace, architectural glass, and optical metrology equipment of all types, including Raman spectroscopy and 3D optical profilometry. These dielectric stacks are used to selectively manage the reflectance and/or transmittance of light. By manipulating the thickness of the constituent film layers, individual high-pass (HP), low-pass (LP) and band-pass (BP) filters can be combined to create a very specific filter. Typically, 2-3 different materials are layered in an alternating fashion to produce the desired filter effect. When only two materials are used, the structure is referred to as an "AB" stack.

Measurement Setup

A common question is: "How many layers can you measure?" There are various factors influencing this number, but in this Massive Multilayer case, a Filmetrics® system demonstration addresses a film stack where the number of alternating layers and material types of those layers were unknown. While typical measurements involve 2-10 layer film stacks, Filmetrics FILMeasure® software algorithms can accommodate many more. What was known was that the sample was a commercially-available dielectric stack on a fused silica substrate, represented in Figure 1, with a scattering layer applied to the bottom of the sample.

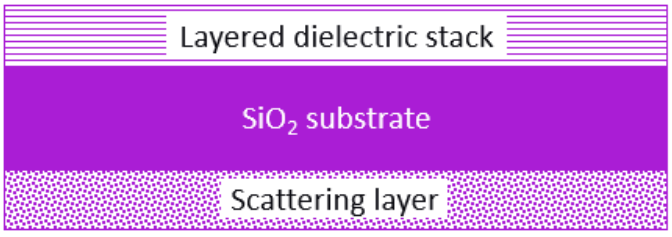

Figure 1. Rough schematic of the multilayer dielectric stack sample. Due to the presence of the back scattering layer, not much light was initially transmitted through the sample - more on that later.

To accurately measure a film stack of unknown total thickness, the Filmetrics® F10-RT-UVX Thin-Film Analyzer was selected, due to its significant spectral range of 190 – 1700nm. For thick and/or complex films stacks that require modeling with many variables, a wider wavelength range provides additional data necessary for determining a unique measurement solution.

Results and Discussion

The reflectance spectrum of the sample is shown in Figure 2. The wavelength range between 400nm and 620nm was sensitive to the thicknesses of the alternating layers, and the range greater than 620nm was sensitive to the total thickness of the stack. For alternating layer stacks such as this one, the ratio of the average thickness of layer A to the average thickness of layer B determines both the position and width of the reflectance response. Figure 2 shows near-100% reflectance in the 450nm – 600nm wavelength range, indicating that the film stack designer was attempting to make a strong reflector in this range.

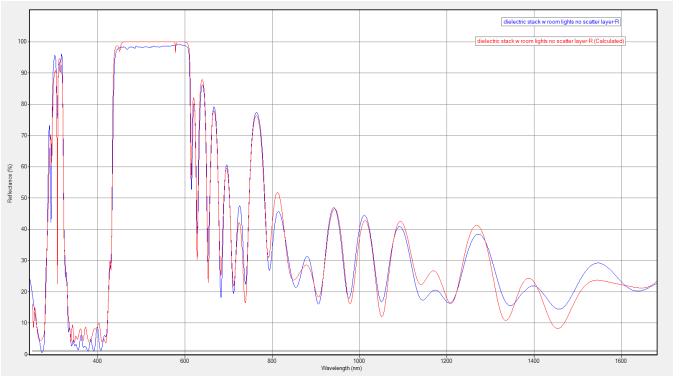

Figure 2. The sample's reflectance spectrum (measured = blue, calculated = red), where the 400-620nm wavelength range is sensitive to the alternating layer thicknesses, and > 620nm is sensitive to the total thickness of the stack.

In this case, only two materials were required to describe the spectrum: the low index material was SiO_2, while the high index material was likely TiO_2, Ta_2O_5, HfO_2, or other similar material, based on materials typically used for this application.

By adjusting the number of layers in the stack, it was quickly found that significantly more than 10 layers were required to match the right side of the spectrum, and additional

adjustment was required to determine the details of the individual layers. The FILMeasure® software returned a unique solution consisting of individual layers of varying thickness, where the average SiO_2 layer thickness measured 107nm, and the average thickness of the (unknown) high-index layer measured 36nm.

To analyze the stack further, a portion of the scattering layer was removed as shown in the Figure 3 schematic and the Figure 4 video image, to allow light to pass through the sample. With this layer removed, it was then possible to obtain the transmission spectrum, shown in Figure 5. The F10-RT-UVX collects both the reflectance and transmittance spectra simultaneously, and the FILMeasure spectral fitting is simultaneously applied to both spectra to improve the accuracy of the results. For this example, using both reflectance and transmittance data made for a more physically realistic model, and is a definite advantage for this type of application.

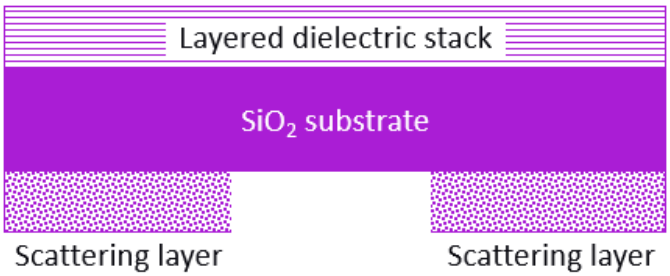

Figure 3. Schematic of the multilayer dielectric stack sample with a portion of the scattering layer removed to facilitate light transmission through the stack and substrate.

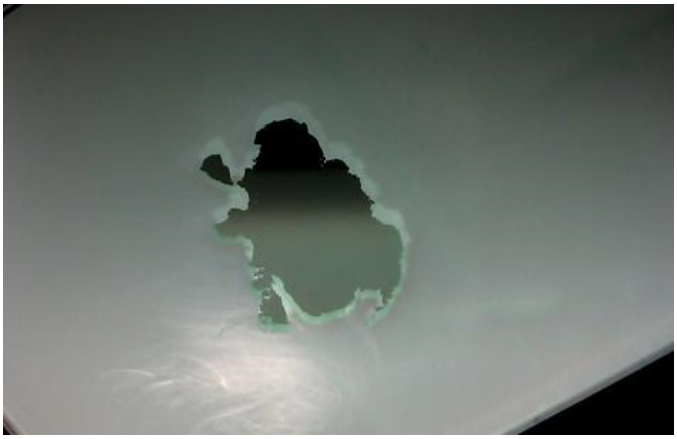

Figure 4. A close-up view of the video image from the F10-RT-UVX shows the removed area of the scattering layer.

For the modeling algorithms, it should be noted that there was not a multiplicity of thickness solutions returned by the algorithm (which is a real possibility when working with a large number of varying parameters) – the end solution was unique. The combined goodness of fit (GOF) for the reflectance and transmittance spectra was > 0.99.

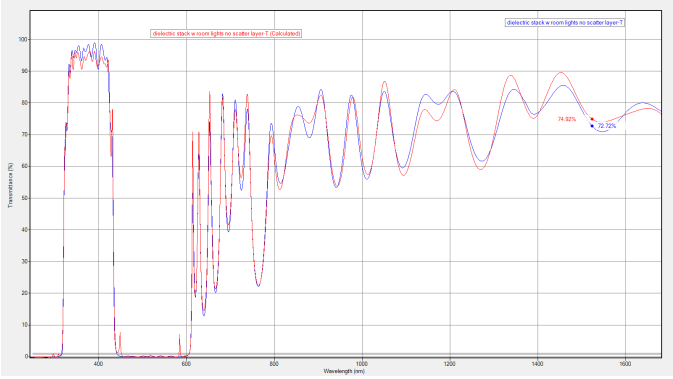

Figure 5. The sample's transmission spectrum (measured = blue, calculated = red) simultaneously provides additional data for the FILMeasure model.

Conclusions

The Filmetrics F10-RT-UVX Thin-Film Analyzer with FILMeasure software successfully measured a complicated, unknown dielectric film stack - resolving not only the number of layers and the index of refraction of the high index material, but the thickness of each of the fifty-three (53) individual layers! There is now an answer to the initial question: how many layers can you measure? The answer, in this case, is 53. With 53 demonstrated, our customers can confidently measure 5, 10, 15 layers, and more.

About the Filmetrics F10-RT-UVX

The Filmetrics F10-RT Thin-Film Analyzer requires just a mouse-click to simultaneously capture both reflectance and transmittance spectra by eliminating the need for hardware configuration changes between measurements. The F10's true normal incidence design is critical for accurate characterization of display films, and the video camera with image capture makes measurement location easy and recordable. The industry-standard FILMeasure software brings the power of Filmetrics analysis to provide accurate measurement for many different types of applications.

Please contact us to schedule thickness measurement on your thin film samples, or 3D surface topography using the Filmetrics Profilm3D® optical profiler, which quickly and easily generates surface measurements of roughness, step height, or other features of interest.

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