Thin Film Thickness Determination

A large number of components are coated by thin layers of material, e.g. glass panes, headlights, wafers, foils. Determining the thickness of such layers is an important task during manufacturing and for final quality control. As long as the layer dimensions are in the range of few nanometers to about 100 µm, optical spectroscopy can be applied as a non-contact, non-destructive and fast method to determine the film thickness.

**Principles**

There are two main principles used to determine the layer thickness of thin films: white light interference/minimum reflectance and modeling/pattern comparison. Both techniques require back reflected light from the film to be spectrally analyzed. At the boundaries of thin film, one against the substrate, the other against air, light is reflected due to a change in the index of refraction, n. At the photodetector, the reflected light interferes and causes a modulation of the overall reflected signal across the wavelength axis, λ. This intensity modulation over λ is analyzed can be analyzed to determine film thickness.

**White-light interference method:** At large optical layer thickness, the back-reflected spectrum shows a fringe pattern, and the distance of the peak positions can be used to determine the thickness. As the film thickness is increased, the spacing between the fringes decreases. Therefore, the maximum thickness of the film is given by the resolution of the spectrometer. The minimum thickness limit of this method is given by only a fraction of a fringe detected by a spectrometer. To analyze very thin films, a wide-range spectrometer is necessary. An additional consideration is the film has to be transparent over this range. In cases where the fringes can be clearly discriminated, the fringe spacing can be directly used to calculate the optical thickness n x d (n is the index of refraction and d is the thickness),

\[ n \times d = 0.5 \times \lambda_1 \times \lambda_2 / (\lambda_1 - \lambda_2) \]

where \( \lambda_1, \lambda_2 \) are the wavelengths of neighboring peaks. A more sophisticated approach is to run a Fourier analysis of the modulation.

One example is the determination of the perfect thickness of an AR coating. The index of the coating material, \( n_C \), has to be matched to the substrate material, \( n_s \), and the environment \( n_E \) (typically air):

\[ n_C = \sqrt{n_E \times n_s} \]

Then the reflection is 0 at

\[ n_C \times d = 0.25 \times \lambda_{\text{min}} \]

The index of refraction depends on the wavelength and must be considered for accurate thin film determinations.
Application Note

**Pattern Comparisons:** Fractions of fringes can be analyzed if a model is created to simulate the spectrum and performs a pattern comparison between the real and the theoretical spectrum at a given optical film thickness. More information on a thin layer can be acquired by measuring the back-reflected signal in dependency of the polarization (ellipsometry).

**Technical Solution**

Requirements for a spectrometer system can be derived from the measurement principles: for relatively large film thicknesses, a high resolving spectrometer is necessary. tec5 AG spectrometer systems can measure films up to 150 µm thickness.

For thin layers, the tec5 UV-VIS-NIR wide-range versions are ideal as they cover a large spectral range, from 190 nm to 1 µm, and can measure very fast. Pattern comparison requires high reproducibility and low noise. These features are also valuable for the interference method. Important features of a spectrometer for thin film analysis are: high data throughput, high sensitivity of the spectrometer, and also the synchronization of measurements to the process. tec5’s expertise in electronics allows the user to synchronize the movement of stepper motors or polarizers with high precision.

**Requirements:**
- High reproducibility
- High Sensitivity
- Large Signal/Noise
- Fast acquisition
- Synchronized operation

**Products**

![MultiSpec Spectrometer System](Figure 2: MultiSpec Spectrometer System)

![Compact Spectrometer System](Figure 3: Compact Spectrometer System)

MultiSpec spectrometer system and CompactSpec system with MCS CCD wide-range spectrometer and D2-Hal source.

For faster detection: CGS and MCS CCD series spectrometer units

Various light guides for light delivery and pickup, also for use in vacuum (incl. feed-through)

**Examples of Use:**
- Headlight protection coating
- Protection foils with coated filters
- In-line pane coating for architectural glass
- Ellipsometry (at-line wafer insepection)