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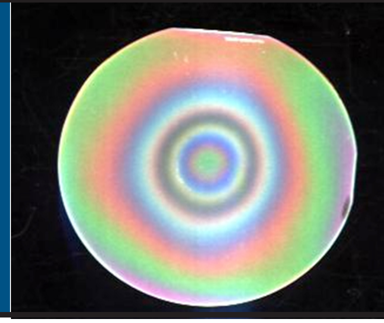
APPLICATION NOTE

Hyperspectral Thickness Measurement



Thin Film Measurement Using Spectral Interference Fringes

Thin films are used extensively in several areas of high-technology industries. The wide range of applications includes semi-conductors, sensors, optical detectors, photovoltaic devices, beam splitters, mirrors, antireflection coatings, and filters. The characterization of thin films including the film thickness, refractive index, reflectivity, and homogeneity is therefore very important in many applications. In addition to single point spectralphotometric measurements, the spatial uniformity is also critical in these processes.

By understanding the interaction between the thin film and light, the characteristics of the thin film can be determined by using the interference pattern (or fringes) created from the partial reflection/transmission of the thin film surfaces.

The thickness of a thin film can be calculated as long as the angle of incidence and refractive index is known. Both sides of the thin film reflect light and have a phase relationship dependent on the two optical path lengths. This will result in fringing and can then be used to calculate the thickness of the thin film. This thickness can be calculated using the following equation:

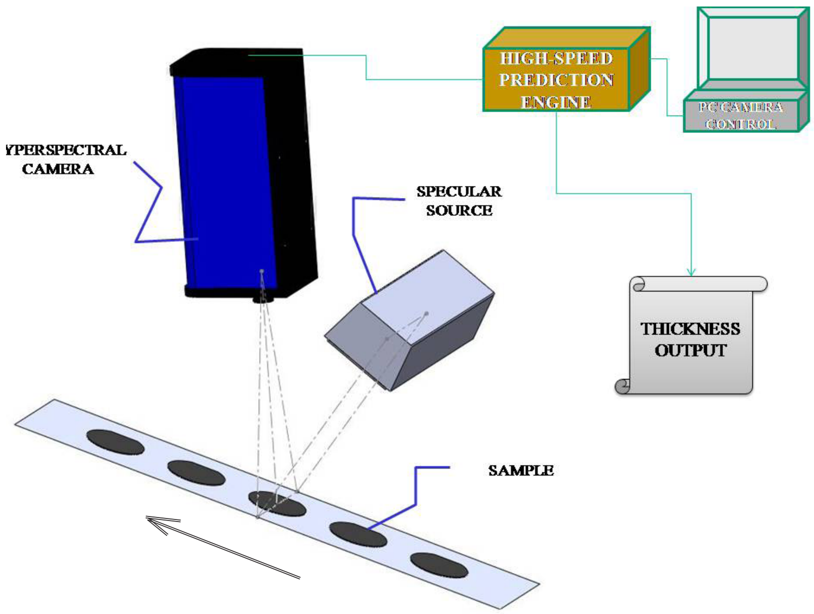
$$d = \frac{m}{2D_n\sqrt{(n^2 - \sin^2\theta)}}$$

Where:
d = film thickness
m = number of fringes in wavelength region
n = refractive index
θ = angle of incidence
Dn = wavelength region used (λ1 – λ2, in wavenumbers)

The same measurement and calculation of thickness can be done using hyperspectral push-broom type cameras covering the whole surface of the samples. The result of the measurement is a hypercube of spectral data, with the full spectrum recorded for each point on the surface of the sample.

Hyperspectral Measurement System

Samples have to be moved at a constant rate in front of the camera in order to scan the whole surface. The camera measures all the spectra of the whole viewing line at the same time at 10-100 frame per second rate. In the example of this application note, a 4" diameter silicon wafer, with a thin but non-uniform diamond coating, was placed on the linear sample stage of a Specim SWIR spectral camera system.

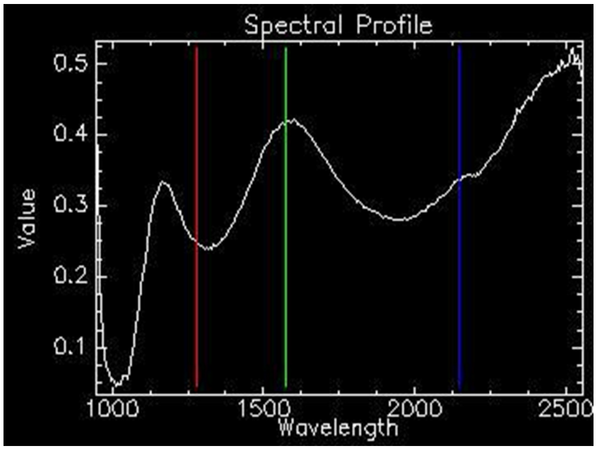


The system consisted of a SWIR camera and an infrared linear specular source and a computer controlled linear stage on which the samples were placed. The camera was controlled by the SpectralDAQ(TM) software running on a PC. The camera output was fed into a Middleton Research High-Speed Thickness Prediction Engine(TM) optimized for the calculation of thickness at the speed of the camera video output.

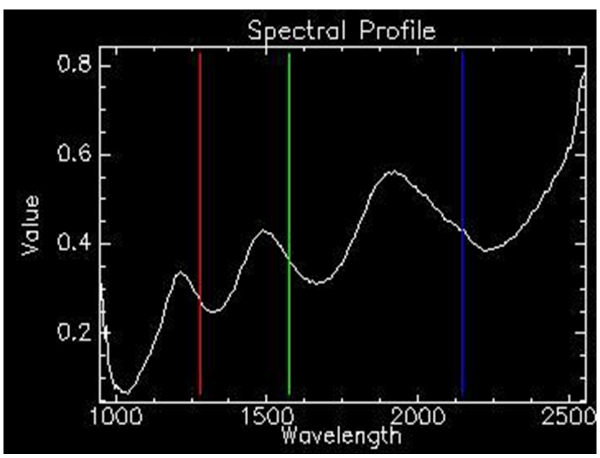
Spectral Imaging Ltd | Teknologiante 18A | FIN-90571 Oulu Finland | +358.8.5514.495 | Fax: +358.8.5514.496 | www.specim.fi
Middleton Research | 8505 University Green, Suite 100 | Middleton WI 53562 USA | 608.831.2141 | Fax: 608.831.3076 | www.middletonresearch.com

Full Surface Thickness Measurement

Typical near infrared spectra obtained from the various points on the wafer showed a strong interference pattern. Thinner layer areas showed interference peaks that were further apart, whereas the thicker layer had closer fringes.

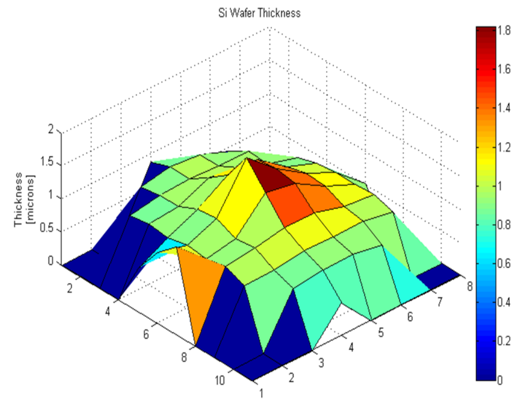


The thickness was calulated using the generic formulas, shown earlier. The diamond coating on the wafer used in this application note was quite uneven, with the layer be-



ing much thicker towards the center. A grid of thicknesses were calculated and are shown on the enclosed surface plot.

In an on-line application however, the thickness values need to be calculated and displayed at the rate of the process requirements, i.e. at the frame rate of the camera output. The raw output from the hyperspectral cameras would be too much data to be saved for anything more than batch operations. For continuously moving samples the camera output has to be transformed on-line and only the compressed data, i.e. the calculated results should be



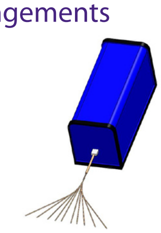
used and saved. The above mentioned High-Speed Thickness Prediction Engine (TM) is an optimized, real-time parallel calculating device with a simple USB output for the thickness results.

Different Wavelength Ranges

For the different film thicknesses, different wavelength ranges are optimal. Using imaging cameras, the spectral regions from the UV to the infrared can be covered. The calculation techniques, system arrangements are similar, with different optics, sources and of course using different types of line-scan cameras.

Camera Type	Detector	Wavelength
UV	UV-Silicon	200-400nm
Vis-VNIR	Silicon	400-1100nm
NIR	InGaAs	900-1700nm
SWIR	TE-MCT	970-2500nm

Non-Imaging Multi-Channel Arrangements



Some applications call for the measurement of thickness data at different discrete points, rather than for the measurement of the full image surface. Hyperspectral line cameras can be fitted with a multi-arm fibe bundle such that each arm can be placed at different sampling points and thus be able to measure a plurality of thickness values simultaneously.

Specifications and Ordering Information

The different applications call for different wavelength ranges, different camera solutions and other system components. Please contact Specim or Middleton Research for further details.

Spectral Imaging Ltd | Teknologiante 18A | FIN-90571 Oulu Finland | +358.8.5514.495 | Fax: +358.8.5514.496 | www.specim.fi
Middleton Research | 8505 University Green, Suite 100 | Middleton WI 53562 USA | 608.831.2141 | Fax: 608.831.3076 | www.middletonresearch.com