Standard Applications by Spectroscopic Ellipsometry

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Ellipsometry is a very versatile optical technique that has applications in many different fields, from the microelectronics and semiconductor industries (for characterizing oxides or photoresists on silicon wafers, for example) to biology. This very sensitive measurement technique provides unequalled capabilities for thin film metrology, and has the advantage that it is non-destructive as it uses polarized light to probe the dielectric properties of a sample.

Through an analysis of the state of polarization of the light that is reflected from the sample the technique allows the accurate characterization of a range of properties including the layer thickness, optical constants, chemical composition, crystallinity, anisotropy and uniformity. Thickness determinations ranging from a few angstroms to tens of microns are possible for single layers or complex multilayer stacks.

The ellipsometry technique has been known for almost a century and is well established in the semiconductor, flat panel display, optical coating, and polymer film industries. However, ellipsometry is now under intense investigation in other disciplines such as biology and medicine as its sensitivity to small changes in the properties of a sample surface make the technique suitable for probing material transport across membranes.

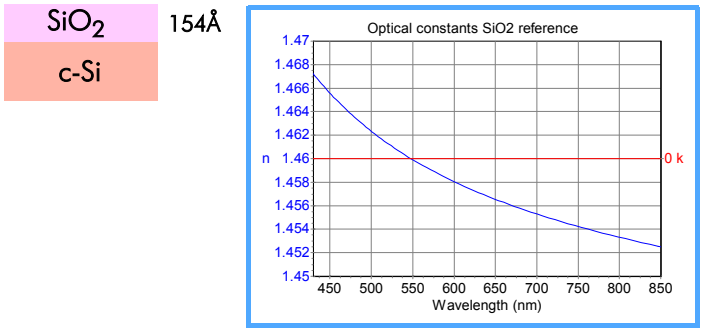
Experimental

This note shows how the Spectroscopic Ellipsometry is particularly suitable for the accurate characterization of many standard thin film applications. The ellipsometric data were measured using the HORIBA Jobin Yvon MM-16 spectroscopic ellipsometer across the spectral range 430-850 nm.

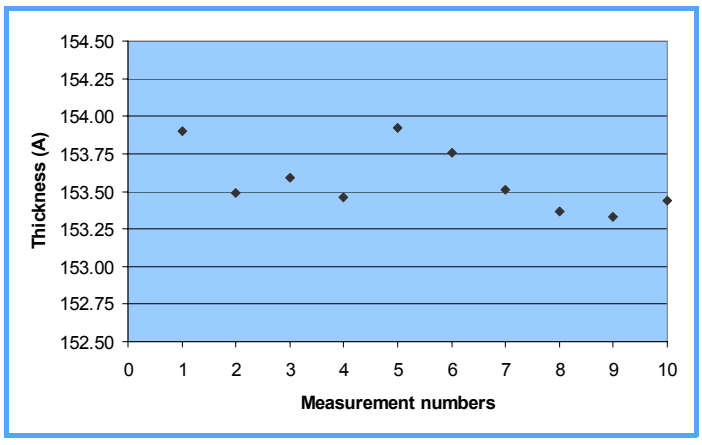
The MM-16 uses innovative technology based on liquid crystal modulators to modulate and detect polarization shifts without any mechanical movement. This technology provides an ellipsometer that is very fast, very accurate, very compact and very simple to operate. A large of accessories is available to match the instrument to the needs of the application.

Transparent Layer Characterization: SiO_2/c-Si

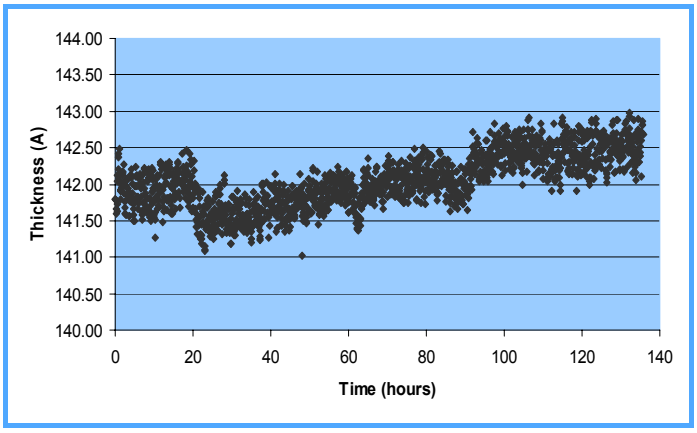
A classic sample which is often characterized by ellipsometry consists of a layer of SiO_2 on a Si substrate. The analysis consists of finding the correct thickness of the film only, and does not involve any determination of optical constants as they are available in tabular form, included in the reference library of the DeltaPsi2 spectroscopic ellipsometry software - the tabulated optical constants are listed at various values of wavelength.
An additional test has been performed on a NIST standard sample - 150 Å thermal oxide on silicon - consisting of 10 static measurements at the same spot location in order to qualify the repeatability of the MM-16 spectroscopic ellipsometer.



Once the appropriate optical model has been developed it is very straightforward to include it in routine recipes for simple automation of data acquisition and analysis including statistics.
The liquid crystal modulation technology proves to deliver very high performance and the graph below shows the excellent repeatability of the MM-16 spectroscopic ellipsometer. The standard deviation found (1σ) is 0.21 Å.



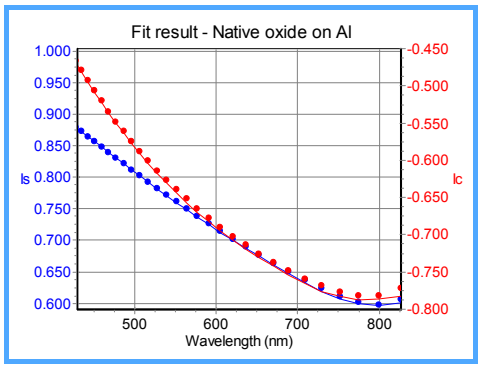
The graph below shows the very high long term stability of the MM-16 instrument tested during 5 days on the basis of one measurement every five minutes. The standard deviation found (1σ) is 0.37 Å.



High Sensitivity to Ultra-Thin Film: Natural Al_2O_3 / Al

Spectroscopic ellipsometry is a very sensitive technique that allows the detection of native oxide naturally grown such as a native Al_2O_3 film covering an Aluminium substrate. A monolayer model used fits perfectly the experimental data.
The MM-16 provides very high sensitivity and is able to accurately characterize ultra-thin films.

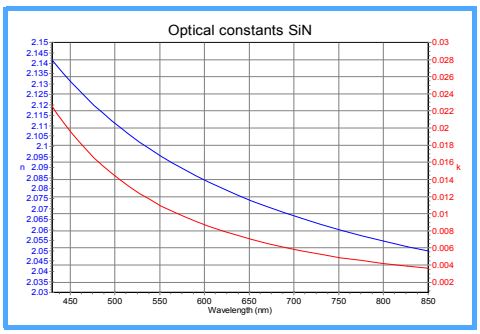
Al_2O_3	42Å
Al	

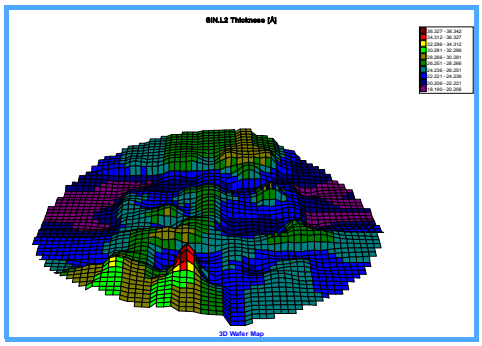


Simple Automation of the Data Acquisition, Analysis and Mapping

Combining the use of the motorized X/Y stage and the user-friendly recipe feature it is very simple to automate the acquisition and analysis at different positions on the sample to build thickness / optical property map of your sample.
In this example the sample characterized was a layer of SiN on a Silicon substrate. The following structure has been used to model the sample. It takes into account a rough overlayer which was found to be very inhomogeneous over the sample area ranging from 18 to 36 Å.
Both film thickness and optical properties of each layer were extracted from the SE data analysis. The optical properties of the SiN layer were calculated using the new amorphous dispersion formulae included in the materials library of the DeltaPsi2 software. The overlayer is described by a mixture of 50% of SiN and 50% of void calculated using the Effective Medium Approximation.

Roughness	18-36Å
SiN	675Å
c-Si	





Conclusion

This application note illustrates the ability of the MM-16 spectroscopic ellipsometer to cover a variety of standard applications, simply and accurately. The liquid crystal modulation technology guarantees fast, precise and reliable measurements. The power of the MM-16 spectroscopic ellipsometer in terms of superior performance and extensive application capabilities combined with a user-friendly software control make it the most cost effective spectroscopic ellipsometer currently available.

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