Aquila Optical Metrology

Thin film measurement – *in a league of its own*

Aquila Research

User Newsletter No. 3 – January 2006.

In this issue:

1. New *high speed* data acquisition and mapping
2. New UK support team
3. The *nkd* "arrives" in India
4. Featured application – *Distributed Bragg Reflector analysis*
5. Ask the expert – *how to measure birefringent polymer substrates*
6. Upcoming events

Dear User,
Aquila Instruments is pleased to present our latest *nkd* Newsletter. The Newsletter is published quarterly, to provide you with the latest information on our range of thin film measurement systems. It features details of new developments, upgrades, activities and example applications.

If you do not wish to receive future bulletins, please e-mail us at info@aquila-instruments.com with the word unsubscribe in the subject or body text. Alternatively if you know someone who would like to receive this bulletin, please let us know and we will add their name to our circulation list.

If you missed the previous newsletter, a copy can be downloaded from the news and events section of our website. Please visit www.aquila-instruments.com.

1. New *high speed* data acquisition and mapping.

4 X faster data acquisition and 10 X faster stage movement.

In your busy lab, time for measurement is important – that's why we at Aquila are committed to providing you with the best solutions for all your thin film measurement requirements. We are constantly updating and improving our technology to suit the latest and most demanding applications.

This month we are pleased to be launching our high speed data acquisition package for the *nkd*-Series which incorporates the latest developments in electronic technology, to bring you a tenfold increase in stage speed and better than five times faster data acquisition.

When sample turnaround is critical, in a busy QC lab, the benefits of this new option can be seen immediately.

The new high speed data acquisition brings you:

- *Faster sample turnaround*
- *Outstanding signal/noise*
- *Faster sample mapping*

The nkd is already the quickest way to obtain refractive index(n), absorption(k) and film thickness(d) from a film owing to its ability to extract all three variables, n, k and d from one spectral measurement. With the new high speed data acquisition, that process is made even quicker and firmly establishes the Aquila system as the fastest way to obtain, n, k and d of your films.

The new electronics package is also available as an easy upgrade option for existing *nkd7000* and *nkd8000* users and includes a software upgrade to the latest release version of Pro-Optix™.

In addition to the new high speed data acquisition package, Aquila is also releasing Version 5 of our Pro-Optix™ control and analysis software soon. More on this in the next edition of the newsletter. Version 5 is a major release above the latest iterative release 4.5. and features a number of significant developments which are often driven but our customer applications.

If would like the opportunity to increase your sample measurement throughput and would like more information on how you can upgrade your *nkd* system, please contact Andrew Turner at andrew.turner@aquila-instruments.com.

2. New UK support team

Aquila is delighted to announce the appointment of Omniscan Ltd as our distribution agent for the UK. Omniscan, headed by Dr. Russell Evans, provides innovative measurement solutions for academic and industrial customers. Russell has considerable application experience in thin film measurement and surface analysis, allowing him to provide customers with the best possible advice and solutions. We are pleased to have the additional benefit of Omniscan's experience and support in the UK for all our new and existing customers. For more information please contact russell@omniscan.co.uk.

3. The nkd "arrives" in India

Aquila recently extended our geographical user base with a successful flagship nkd installation in India. The nkd-8000, featuring the extra wide band wavelength range was installed at a significant government research lab in Northern India last month.

The instrument is fitted with our unique variable angle system which allows the user to make simultaneous measurements of transmission and reflection from 10 to 80 degrees and measurements of transmission and reflectance at true normal incidence.

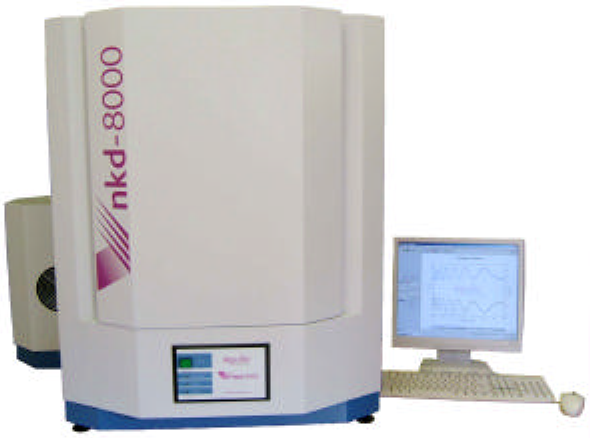

Figure 1. The nkd8000

This *nkd* installation is part of a larger programme of expansion for the site in India, with the extensive purchase of new vacuum coating equipment used for us in the development of a wide range of products, including night vision systems, goggles and ophthalmic lenses.

The nkd is supported in India by Polar Technologies New Delhi, who will be helping to expand our Indian user base and provide valuable local application and user support. For more information, please contact Anshu Verma at Polar Technologies – polart@vsnl.com.

4. Featured application – DBR analysis, 20 layer+ layer analysis with the *nkd Series*.

In this edition we bring you an example of the unique capabilities of the nkd for analysing complex multilayer structures. An excellent example of this are DBR structures which are seeing increasing use today. The following is an excerpt from an nkd application note on this subject.

Distributed Bragg reflector (DBR) gratings are wave guide structures, formed from multiple alternating dielectric layers of periodic refractive index. Each layer boundary causes a partial reflection of the incident light wave. When the light is of wavelengths such that the multitude of reflections interfere constructively, the periodic structure forms a high quality reflector.

DBR's are critical components in vertical cavity surface emitting lasers and other types of narrow-linewidth laser diodes. They are also used to form the optical cavity in fiber lasers. Typical DBR structures can consist of Si_3N_4/SiO_2 pairs on glass, or GaAs/AlAs on semiconductor substrates. An example of this is represented in the image below. For laser cavities this structure is mirrored across a central spacer which forms the active region. Each layer has a thickness of a quarter of the laser wavelength in the material, yielding intensity reflectivities above 99%. The whole assembly can consist of 22 layers or more.

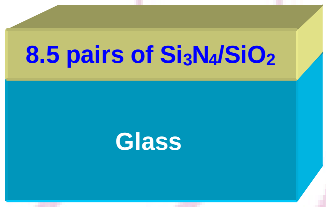

Figure 2. Typical DBR structure

The plot shown in Figure 3. below shows an 8.5 Si_3N_4/SiO_2 pair structure designed around the 1550nm Telecoms wavelength. It has been measured on the nkd for the purpose of evaluating the device performance as well analysing the layer structure, to ensure that the layer deposition is as expected. The graph is a plot of transmittance (in blue) and reflectance (in black) measured at 1 nm intervals, over a wavelength range of 350-2500nm, at normal incidence.

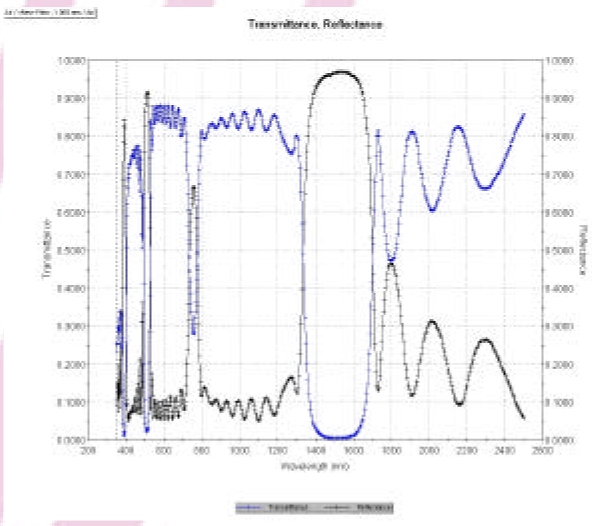

Figure 3. Transmission and reflectance spectrum measured on the nkd for an 8.5 pair Si_3N_4/SiO_2 DBR structure on glass.

The spectrum obtained above provides the user with a great deal of informaiton about the device. We can see immediately how the reflector is performing and can determine whether the structure supports the optical mode or modes required. We can also determine whether absorption has been introduced, giving undesirable effects in the active passband region. The plot also tells us about the efficiency of the reflectors.

We can perform a layer analysis on this structure using our powerful Pro-Optix™ analysis engine. Figure 4. shows a model fitted to the measured DBR structure which has allowed the values of thickness and dispersion of all the layers to vary. For this layer structure of 8.5 pairs of $Si_3N_4/SiO_2/Si_3N_4$ we have been able to extract the film thickness and dispersion from the model fit, which is shown overlaid in the measured spectrum.

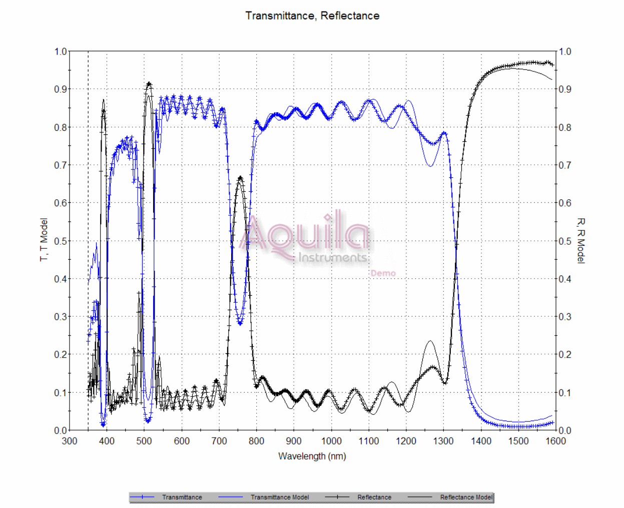

Figure 4. Model fitted to the 17 layer DBR structure. 350-1700nm is shown for clarity. The model is seen as a continuous smooth lines overlaids on the T and R plot.

Figure 5. shows an example of a microcavity structure measured on the nkd. The reflectance only is shown for clarity here. One important unique feature of the nkd-series instruments is the availability of both T and R measurements.

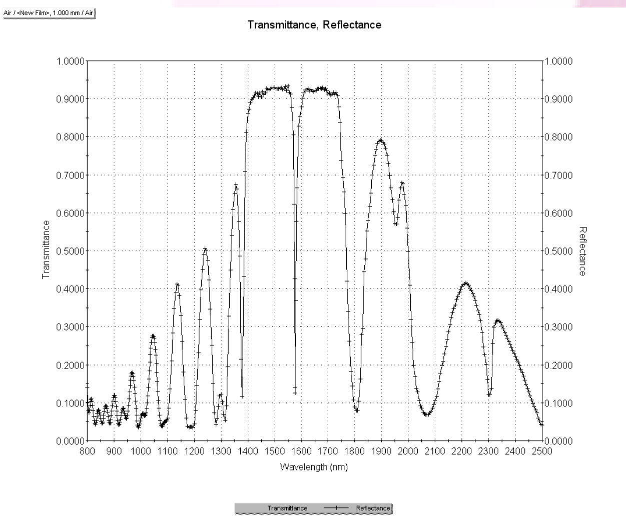

Figure 5. Microcavity structure reflectance from 800-2500nm.

For a sample deposited on a transparent substrate, this unique feature leads also to the availability of a third parameter – namely the absorption. Provided the experimental geometry is properly designed to measure total transmittance (taking account of multiple reflections inside the substrate) and total reflectance, the relationship T+R+A=1 will hold and from this we can determine A. *It is important to note that no sample preparation is required to measure transparent samples on the nkd and we can thus obtain an accurate and reliable measurement of absolute absorption.*

In the case of the resonant cavity filter, this is particularly interesting since at resonance, the electric field in the spacer layer will be an antinode - i.e. maximum. Absorption due to a non-zero k can only occur where the electric field inside the structure is non-zero, i.e. away from the nodes…..

If you would like to view the remainder of this application note, which looks at the SiO2 absorption and also DBR structures on opaque substrates with GaAs/AlAs layers, – we would be pleased to send you a complete copy.

There are a number of strong characteristics of the nkd which make it ideally suited to analysing this type of sample. Firstly the nkd measures transparent samples easily with no sample preparation required. Secondly the range of photometric data available from the *nkd* measurements allows the user to derive more optical information about the layer structure, without the ambiguity seen in other techniques. When you have the powerful combination of precise photometric data and advanced analysis software available on the *nkd*, you have everything you would ever need in a thin film analysis instrument.

Additional application notes are available for download from our website. If you would like any further information on this topic or any of our other applications notes, please contact Louise Stonebridge at louise.stonebridge@aquila-instruments.com and we will be pleased to provide you with the information you require.

5. Ask the expert

This is a new feature intended to bring you guidance in solving common issues encountered when measuring thin films.

What is the best way to obtain film thickness and n, k of layers on thin birefringent polymer substrates?

When I measure my organic layer on PET I get a different transmittance or reflectance spectra each time. Why is this and how can I guarantee obtain accurate analysis?

Thin layers of optical quality PET (5-60µm), or any thin polymer film substrate, behave like thick, mostly coherent films rather than incoherent substrates. This can be seen by the fact that they support interference effects which can be viewed in the transmittance and reflectance data, seen as high frequency oscillations in the spectra, with a periodicity proportional to the thickness of the PET. In addition to this, the spectrum will be altered with the orientation of the substrate in relation to the incident beam. This is because the PET is birefringent and will have different refractive indices depending on its orientation to the incident beam. If we were to measure the PET with unpolarised incident light and in any random orientation of the film, then we would see a low frequency oscillation overlaid on the high frequency trace from the thickness. This low frequency oscillation results from the different spatial refractive indices of the film giving rise to different path lengths and thus interference.

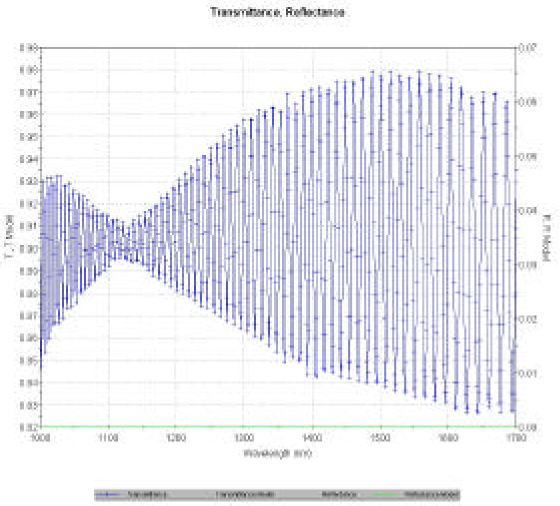

Figure 8. Transmission of 56µm PET film, normal (0°), unpolarised incident light.

This effect is clearly illustrated in Figure 8, which shows the transmission measurement at normal incidence for a low haze PET film, 56µm thick, measured with unpolarised incident light.

These low frequency oscillations are best avoided as they confuse the analysis and can mask structure in the spectrum resulting from other coatings, especially if those layers have a refractive index close to the substrate refractive index.

The best way to measure PET or other polymer substrates in flexible film form is to define the incident beam polarisation well.

The polarisation should be set to s- or p – and the reflectance and transmittance measured at normal incidence. The substrate polymer also needs to be set at a particular orientation with respect to the incident beam, so that there is no spatial variation in refractive index over the area probed by the polarised beam.

To set this orientation we can use crossed polarisers, so that no light is transmitted through and use this to orientate the PET. If we mark the axis of this orientation on the PET, we now have a reference to use for aligning the sample on the measurement platform with the incident beam. In the case of the nkd this relates to the X Y stage. We should stress that the incident light polarisation must be well defined. Using unpolarised light - such as with fibre probe measurements - will not lead to a good analysis of the PET.

Figure 9. below shows the same PET sample as in Figure 8. but this time measured in the correct orientation to the beam axis and with s- polarised incident light.

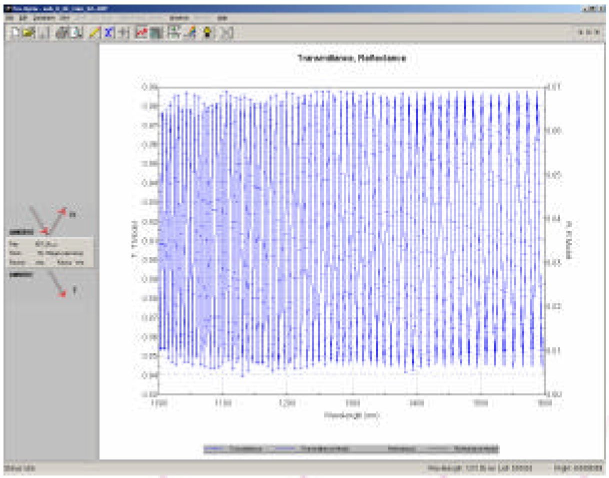

Figure 9. Transmission of 56µm PET film, normal (0°), s-polarised incident light, sample orientation selected using crossed polarisers. Analysis model overlaid on measured data.

Now we see just the oscillation effect arising from one value of dispersion for the PET and the analysis is straightforward. Subsequent analysis of any layers on the substrate is also made easy.

Using this technique on the nkd we can obtain refractive indices for both orientations of the film, giving a measure of the birefringence of the material.

If you would like more information or to ask our expert a question, please call or e-mail: info@aquila-instruments.com.

6. Upcoming Events – 2006

Aquila attends a number of conferences exhibitions throughout the year. These provide an opportunity to discuss your application in person and to see the nkd in operation first hand.

Location	Details
Netherlands	*NEVAC April 27th*
Strasbourg	*EMRS May 31st-June 2nd*
Dresden	*ICCG June 18-22nd*
Singapore	*Thin Films 2006 Dec 11-15th*

Each year Aquila Instruments holds a number of **workshops** in various locations around the world. Most feature a background on thin film measurement techniques, a demonstration of the nkd and an opportunity to measure your own samples. For more information and to book a place at one of these events, please contact the relevant distributor or Aquila directly and we will be happy to assist you.

Coming up in the next issue!

* Confocal analysis for films on curved surfaces
* Pro-Optix^{TM} 5 release