Characterisation of single layer Ta_2O_5 coatings on the Aquila nkd Spectrophotometer

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Instruments

The ability of the Aquila nkd to obtain the important optical information from a typical single layer laser coating such as Tantalum Pentoxide on a variety of substrates is presented.

Optical thin film coatings have many applications, from band pass filters to high reflectivity coatings and anti-reflection coatings. The requirements for superior optical and mechanical properties of these films increase all the time. Temperature stability is also an important requirement, especially for high power laser optics.

For the thin film designer there are three important material parameters which need to be known: refractive index (n) and extinction coefficient (k), as a function of wavelength and the thickness (d). These three parameters determine completely how a thin film responds to incident light. While n, k and d are important parameters for designers and manufacturers of coatings, users of coated optics may be more concerned with the end result: the actual transmittance and/or reflectance of a coated component, perhaps at a specified angle of incidence and polarisation state.

The Aquila nkd Spectrophotometer is aptly suited to providing this important information quickly and easily. It measures transmittance (T) and reflectance (R) spectra simultaneously from the same area of a sample over a wide wavelength range and both the polarisation and the angle of incidence are accurately defined. Powerful analysis software then extracts the optical constants and film thickness by fitting the measured spectra to a theoretical model.

A particular benefit of measuring both T and R is that losses in the sample, due for example to absorption, become immediately apparent, because in the presence of losses the sum of T plus R will be less than one.

The temperature stability of an optical coating depends strongly on the packing density, as water vapour may penetrate porous coatings, causing n and k to vary. The packing density and refractive index of a film are highly dependant on the deposition conditions, and need to be monitored to avoid unacceptable variations in thickness and coating density.

There are wide range of coatings commonly used in Laser optics. Tantalum Pentoxide is an important high index material for optical components operating in the UV-A, visible and near IR regions. Its high laser damage threshold and low scattering make it one of the most frequently used materials, and it is also suitable for multi-layer broadband coating systems. In manufacture, Ta_2O_5 may be baked after deposition to improve the stoichiometry of the film. Measuring the optical properties quickly and easily is an essential aspect of process control for these films.

Figure 1 is a plot of T and R spectra at 30° incidence angle for a layer of 589nm Ta_2O_5 on Quartz, measured between 300 and 1000nm using the Aquila nkd-7000 . These spectra took only a few minutes to measure using the nkd, and provide all the optical information required to evaluate the film.

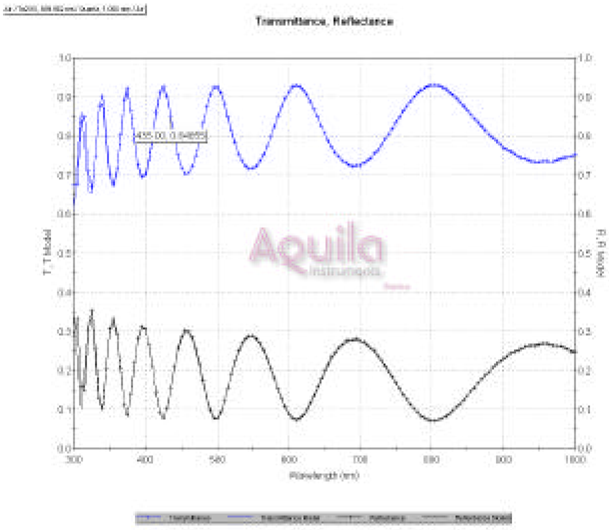

Figure 1. T and R spectra for 590nm Ta_2O_5 on quartz + fit

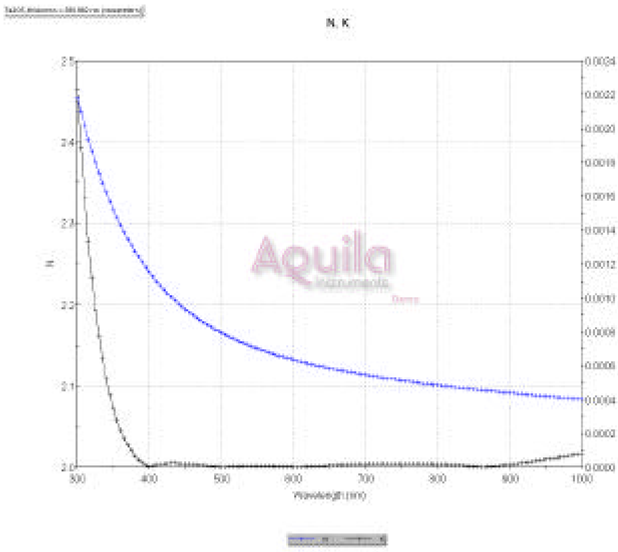

Figure 2. n and k curves for 590nm Ta_2O_5 on quartz

The dispersion curve presented in Figure 2, was obtained from analysis of the data in Figure 1. Low absorption can be seen in the range from 350-1000nm, illustrating the suitability of Ta_2O_5 for use in the UV-A, VIS and NIR laser ranges.

In evaluating coatings, the substrate needs to be taken into consideration, as the overall performance of an optical component is highly dependant on the substrate. Glass transmittance is affected by thermal history and manufacturing stresses, and there may be inhonogeneity within the melt. Impurity content may also affect the index and absorption rather strongly.

Substrates can be characterised and stored in the Pro-Optix™ database for use in analysing other layers.

Figure 3 shows the n and k curves for the quartz substrate of the sample, as measured and modeled by the nkd. Each layer (including the substrate) can be considered individually in the analysis. Substrate preparation which is often required by other techniques is unnecessary with the nkd. In fact, transparent substrates are an advantage as the transmittance data improves the accuracy of the analysis.

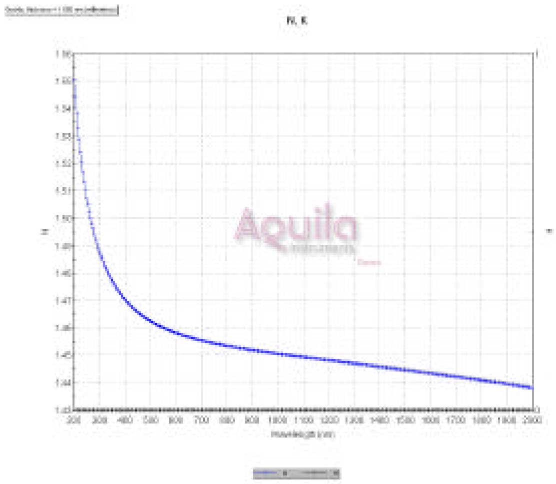

Figure 3. n and k curves for 1.05mm quartz substrate

Comparing Ffigure 3 with Figures 1 and 2, we can see that all the absorption in the sample is a result of the film and not the substrate, which transmits well in the UV.

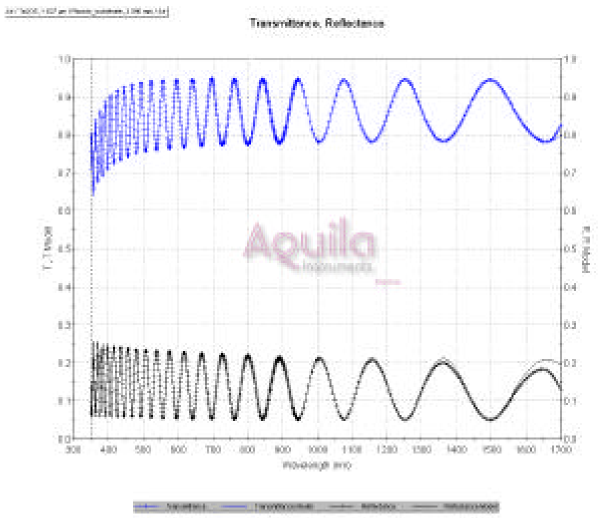

Figure 4. T and R Spectra for 1.827mm Ta_2O_5 on proprietary substrate

Figure 4 is a plot of T & R for a layer of Ta_2O_5 on an experimental substrate measured from 350 to1700nm. The resulting n and k curves for this can be seen in Figure 5 below.

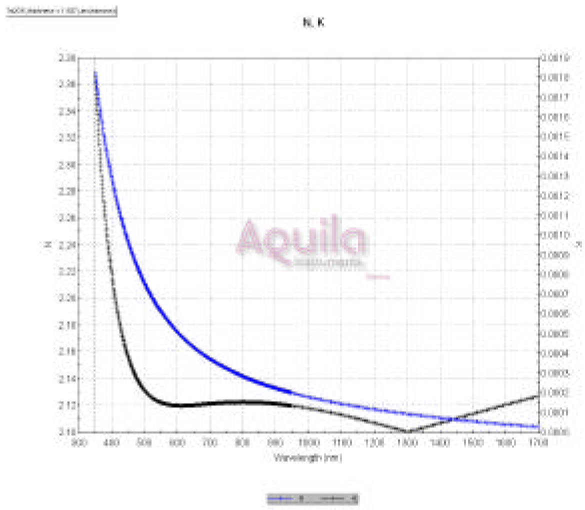

Figure 5. n and k curves for Ta_2O_5 on proprietary substrate

An overall reduction in refractive index in the UV can be seen in this second sample, as well as increased absorption in that region, compared to the first sample.

A tantala film might be required to work on a number of different substrates according to the application. Common substrate materials are present in the Pro-Optix™ database and the system can extract n and k of unknown substrates, provided an un-coated sample is available.

Figure 6 shows T and R spectra taken from a sample of BK7 coated with a 448nm layer of Ta_2O_5. Higher absorption for the system can be seen overall with reduced transmittance in the UV as seen in the R and T spectra. The resulting dispersion curves (Figure 7) show high transmission in the visible region with some absorption occurring in the infrared.

As well as calculating n and k for the films and substrates, the nkd has also calculated the film thickness, crucial to the operation of the films.

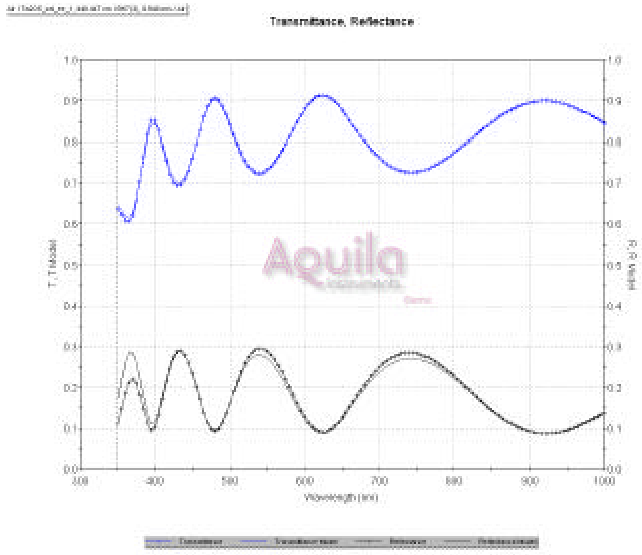

Figure 6. T and R spectra for 448nm Ta_2O_5 on BK7

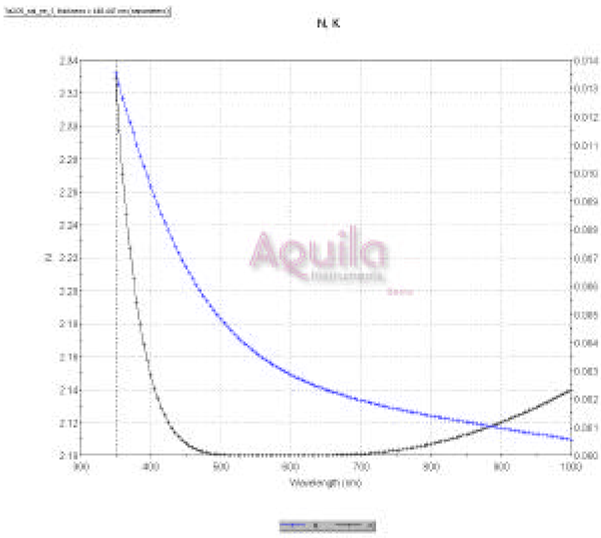

Figure 7. n and k curves for 448nm Ta_2O_5 on BK7

In addition to the measurements presented here, the nkd can also measure T and R at varying angles of incidence. For laser applications, we are often interested in the optical properties of a film at 45° and at a particular wavelength. The nkd-7000 can be manually configured to measure at 3 different angles, and a continuous range of angles is automatically available in the nkd-8000. Thermal stability can also be investigated using the optional heated sample chuck. Thus the functionality offered by the nkd provides a convenient method of characterising optical coatings for laser applications, from design to production.