Determination of the Refractive Index of Y_2O_3 on Glass and Pre-evaporated Substrates by Spectroscopic Ellipsometry

Céline Marchand - Application Scientist - Thin Film Division

Y_2O_3 films are good materials for use in many applications such as protection of aluminium and silver mirror coatings, intermediate layers in wide band visible AR coatings and for XeCl laser AR and dielectric mirror designs.
The Y_2O_3 films are hard and usually amorphous with high adhesion to glass, germanium, silicon, zinc sulphide and zinc selenide as well as to metals such as aluminium and silver. In some cases, a very thin layer of yttria can serve as an adherence promoter for multilayer coatings on non-oxide substrates. This material is of medium-index and very transparent over the near-UV range (300 nm) to IR (11μm) region.
Many methods have been used to produce yttria films such as reactive thermal deposition, e-beam deposition, ion assisted deposition (IAD) and magnetron sputtering. As the refractive indices are dependent on the process it is important to know with high accuracy the optical constants and the thicknesses of the films, especially when they are used as high refractive index materials and in combination with higher index materials such as TiO_2 and Ta_2O_5.
This note describes how the UVISEL Spectroscopic Phase Modulated Ellipsometer was used to characterize the influence of substrate to growth of Y_2O_3, that is the difference of optical properties of the Y_2O_3 film grown on amorphous glass substrate and the one grown on pre-evaporated layers of ZrO_2.

Sample Preparation

The films were prepared by electron beam evaporation in a reactive oxygen atmosphere. The starting materials were grains of Y_2O_3. The glass substrates were 5 mm thick and were rotated during deposition to improve the uniformity of the films. In the first run two bare glass substrates were put into the chamber and a ZrO_2 film deposited. For the second run one bare glass substrate and the sample from the first run with pre-evaporated ZrO_2 were placed into the chamber and a Y_2O_3 layer was deposited.
Three samples were prepared and characterized as follows.
Sample1: ZrO_2 monolayer (See Application Note, Ref: SE06),
Sample 2: Y_2O_3 monolayer,
Sample 3: Y_2O_3 on ZrO_2 pre-evaporated.

Results

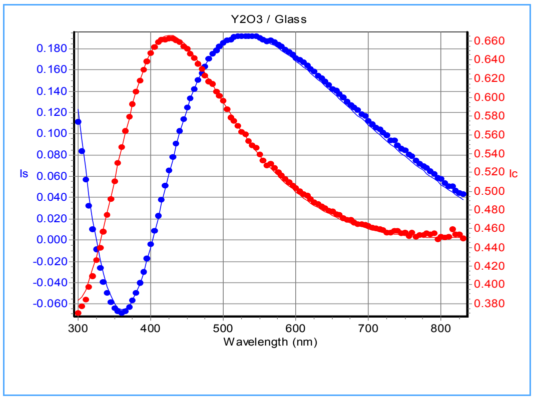
The work was performed using the Jobin Yvon UVISEL Visible Spectroscopic Ellipsometer. The Ellipsometric measurements were made at an angle of incidence of 70° across the spectral range 300-830 nm. Both the refractive indexes and thicknesses were extracted from the SE data analysis. The optical constants were determined using the Lorentz Oscillator formula below:

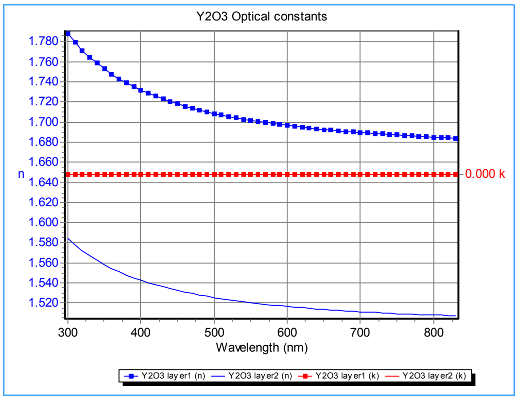
$$n^2 = \varepsilon = \varepsilon_\infty + \frac{(\varepsilon_S - \varepsilon_\infty)\omega_t^2}{\omega_t^2 - \omega^2 + i\Gamma_0\omega}$$

Characterization of Y_2O_3 on glass

Y_2O_3 is a medium-index and low absorption material. Some amount of index inhomogeneity can appear with increasing layer thickness. The effect can be reduced by providing sufficient oxygen backfill during evaporation.
As with the ZrO_2 sample (AN SE-06) a great improvement to the χ^2 value was found with a two layer model, with the top layer being porous. Using the Effective Medium Approximation (EMA) DeltaPsi2 (DP2) software can determine the degree of porosity compared to the layer on the substrate, and in this case it was found to be 25%.

Layer	Thickness
75% Y_2O_3 / 25% void	174 Å
Y_2O_3	1365 Å
Glass substrate	

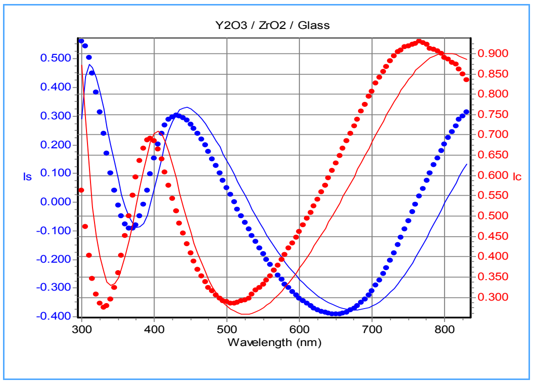


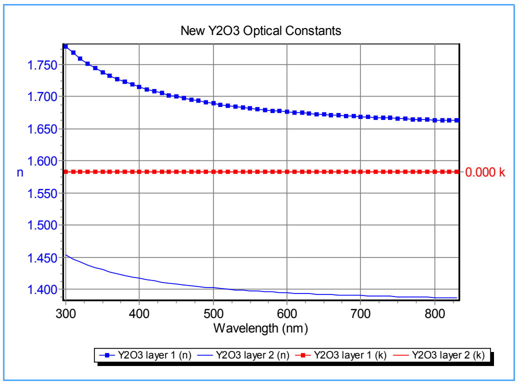


Characterization of Y_2O_3 on ZrO_2

As a first step this sample was characterized using the optical constants found from the previous results. Good values for the films were obtained, but it was found that the results could be improved by the use of a slightly more complicated structure.
Several approaches were followed (interface layer between the two films,...), but the final model that significantly improved the fit, was the optimisation of the Y_2O_3 thicknesses, indices and porosity parameters. In the final results the Y_2O_3 variation in refractive index between two samples was about 0.02.

Layer	Thickness
60% Y_2O_3 / 40% void	141 Å
Y_2O_3	1322 Å
92% ZrO_2 / 8% void	198 Å
ZrO_2	955 Å
Glass substrate	





Conclusion

The deposition conditions have generated inhomogeneous porous layers that have been observed by the UVISEL Spectroscopic Phase Modulated Ellipsometer. Moreover, the spectroscopic measurements allow determination of the small discrepancies between the optical constants of a Y_2O_3 film grown at bare substrate and the one grown on a ZrO_2 film.

HORIBA JOBIN YVON

(All HORIBA Jobin Yvon companies were formerly known as Jobin Yvon)

Find us at www.jobinyvon.com or telephone:

USA: +1-732 494 8660
Germany: +49 (0)89 462317-0
China: +86 (0)10 6849 2216
France: +33 (0)1 64 54 13 00
UK: +44 (0) 20 8204 8142
Other Countries: +33 (0)1 64 54 13 00
Japan: +81 (0)3 3861 8231
Italy: +39 02 57603050