Characterisation of Aluminium Anodised Surfaces using the MM-16 Spectroscopic Ellipsometer

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The capacity of aluminium to respond to anodising, the most familiar of finishes, makes aluminium a most important metal in a quite fundamental way. The fact that aluminium can take on this attractive, durable and hard-wearing finish makes it possible to exploit its strength and lightness in a large number of applications, particularly in building construction and in the automotive industry.

Anodising is an induced thickening of the natural protective oxide film on the metal's surface. It is a conversion of the parent metal and thus is not a 'coating' in the usual sense. Variation of the conventional electrolyte composition and process variables produce anodic coatings with distinctive functional properties. Thus, very hard anodic films are developed to provide abrasion resistant surfaces on gears, pistons, bearings, and similar components.
Anodic films may also be coloured by a variety of methods. Conventional sulphuric acid films are microscopically porous, and organic or inorganic dyes and pigments may be incorporated and sealed into the film.

The functional and decorative potential on the metal can therefore be widely exploited in applications ranging from building components to domestic cookware. Being able to characterise the aluminium oxide non-destructively is very important, and the use of spectroscopic ellipsometry allows on-line monitoring of the anodised surface on a production line.

Results:

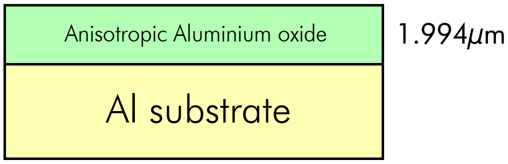
Ellipsometric measurement were performed using the HORIBA Jobin Yvon MM-16 Spectroscopic Ellipsometer (SE) across the spectral range 450-850nm (1163 wavelengths).

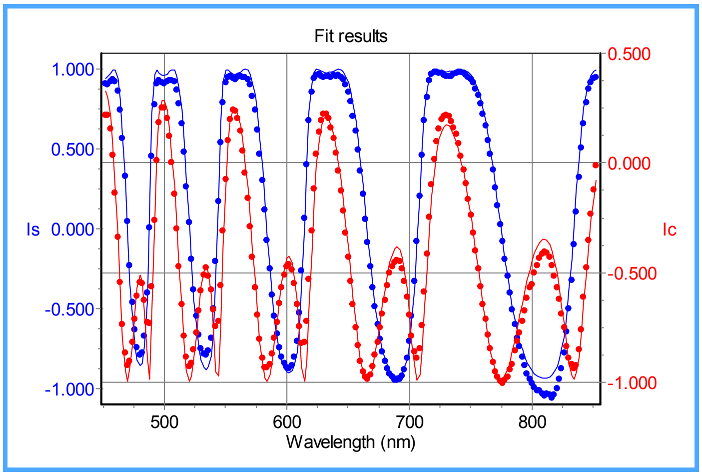
The measurement was performed at an angle of incidence of 70°. The acquisition data was collected in 30s and the MM-16 provides the full polarisation state of the sample with one measurement cycle, without the need for several hardware configurations. As a result the ellipsometric angles Ψ and Δ are determined with very high accuracy and precision.

The MM-16 also provides the full 16-element Mueller Matrix and this feature has major advantages for characterising depolarizing and often anisotropic samples with complex structure or geometry, where conventional ellipsometry is inapplicable. This feature can be also applied with success and accuracy to all cases currently covered by conventional ellipsometry.

Aluminium oxide, Al_2O_3, is a medium refractive index and low absorption material that often exhibits anisotropic behaviour. A feature of the Mueller Matrix is that the off-diagonal elements are not equal to 0 when the sample exhibits anisotropic behaviour and especially when the measurement is done in a random position, that is away from the direction of the optical axis and at rotation of 90° from this optical axis, and when the optical axis is not orthogonal to the sample plane. In this example we can see the off-diagonal elements are not equal to 0 as it is shown on fig. 1. This standard feature of the MM-16 simplifies characterisation of such materials.

The anisotropic model is illustrated below:





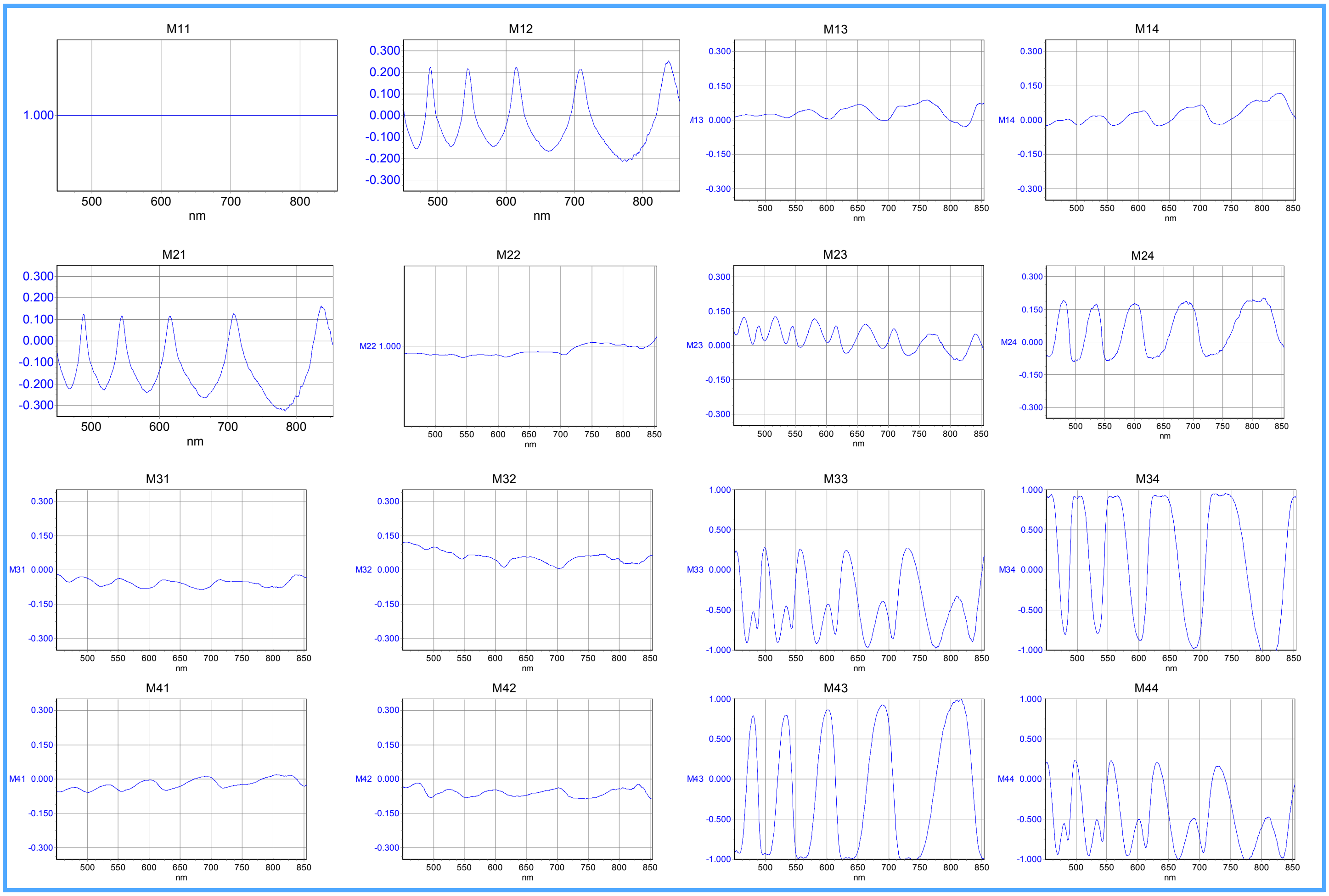
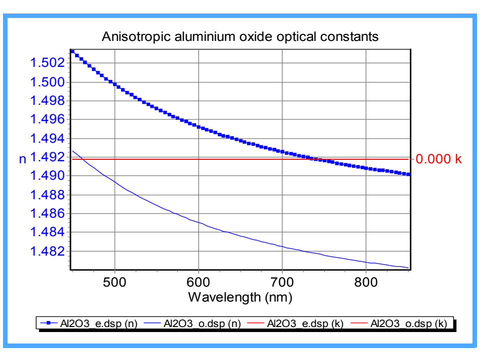


Figure 1: The Mueller Matrix for an anisotropic alumina film measured in one direction with the MM-16 ellipsometer in reflection mode.

The optical properties of the aluminium oxide have been determined using the Lorentz Oscillator:

$$\varepsilon = 1 + \frac{(\varepsilon_s - 1)\,\omega_t^2}{\omega_t^2 - \omega^2 + i\Gamma_0\omega} \qquad \text{with } \Gamma_0 = 0$$

One can observe that the birefringence is $\Delta n = 0.01$, where Δn is the difference between the ordinary and extraordinary refractive indices.



Note that the Al_2O_3 layer is porous explaining the low index found.

Conclusion:

The aluminium anodised layer has been successfully characterised by the MM-16 Spectroscopic Ellipsometer with very high speed and accuracy.

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