Optical properties of AlN characterized by MM-16 Spectroscopic Ellipsometer

Céline Eypert - Application Scientist - Thin Film Division

AlN has been identified as a promising material for a wide range of electronic, optoelectronic and acoustic applications, due to its chemical, mechanical and thermal stability, wide direct bandgap (6.2eV), high thermal conductivity, high sound velocity, and high electron drift velocity. Furthermore, AlN is interesting because it can be alloyed with GaN over the whole composition range and multilayers find roles in optical lasers such as blue lasers. AlN can be also used as a substrate for growth of optoelectronic devices emitting at wavelengths ranging from blue to deep UV.

Epitaxial growth and reactive magnetron sputtering techniques have been routinely used to grow III-Nitride compounds, and accurate measurement of the film thickness and thickness uniformity is an essential step for the process and production control of these materials. To perform this work non – destructive characterization methods such as ellipsometry are used for in-situ monitoring of thickness and refractive index of the growing film. Spectroscopic ellipsometric information is vital for this determination as a single wavelength is inadequate for the characterization of multilayered films.
In this note, spectroscopic ellipsometry (SE) was used to determine optical properties of thick and thin AlN films.

AlN characterization:

Spectroscopic Ellipsometry was performed using the HORIBA Jobin Yvon MM-16 instrument across the wavelength range of 430-850nm.

The MM-16 uses liquid crystal modulators to detect the polarisation state of the reflected light beam. Two liquid crystal modulators are used as the polarization state generator on the input arm of the ellipsometry, and two further modulators are used as the polarization state analyzer on the output arm of the ellipsometer. This arrangement provides a full picture of the polarisation state of the sample, and as a result enhances the accuracy and precision of the measured ellipsometric angles Ψ *and* Δ. The MM-16 also provides all 16 coefficients of the Mueller Matrix allowing simple access to anisotropic modelling functions.

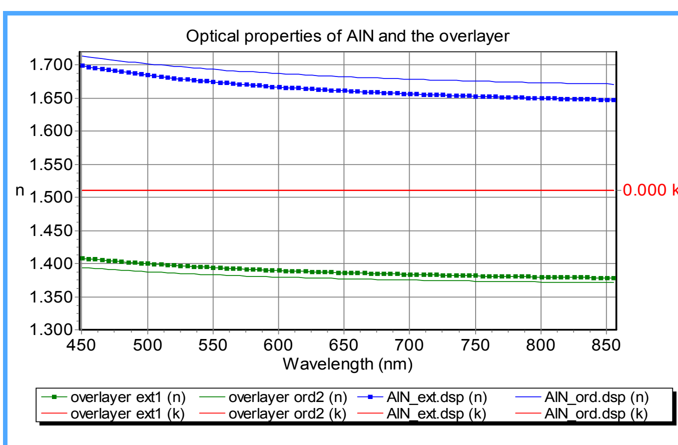
Experimental data were collected at an angle of incidence of 70° and the data acquisition time was 30s.

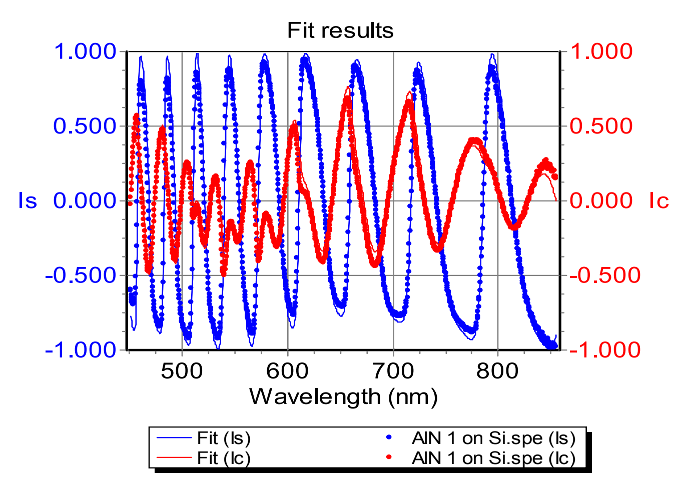
Thick Film:

The following structure has been used to model this sample. The introduction of a thick surface layer improves the goodness of the fit parameter ($\chi^2 = 500 \rightarrow \chi^2 = 160$). This surface layer is described using the Bruggeman Effective Medium Approximation with anisotropic mixing. The MM-16 provides as a standard feature the full Mueller Matrix, and 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 plane).
Several tests were carried out, and we found that the AlN layer was anisotropic with its axis orthogonal to the sample plane ($\chi^2 = 160 \rightarrow \chi^2 = 48$). For the work performed here there is an uniaxial anisotropic material with its optical axis orthogonal to the sample plane, and when the measurement is made in the optical axis direction or rotated at 90° the off-diagonal elements become equal to 0. The ability to measure this condition simplifies modelling of the sample.

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

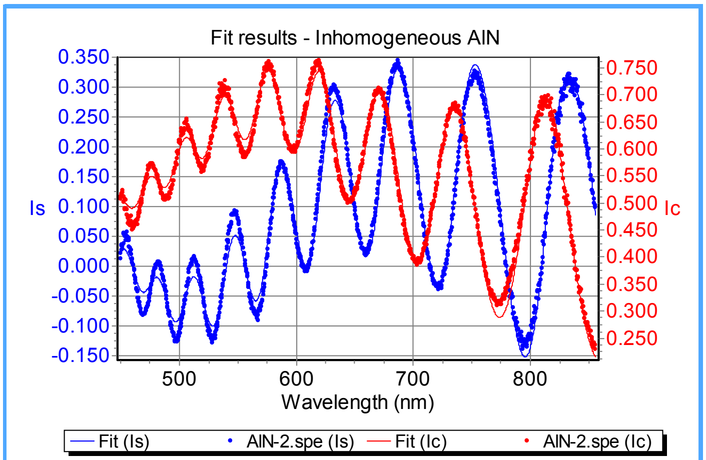
$$\varepsilon = 1 + \frac{(\varepsilon_s - 1)\,\omega_t^2}{\omega_t^2 - \omega^2 + i\Gamma_0\omega}$$





The MM-16 enables the characterization of inhomogeneous films with high accuracy. For example, the following example uses a three-layer model to fit the experimental data perfectly.

overlayer	6nm
75% AlN - 35% void	318nm
AlN	2160.3nm
c-Si	

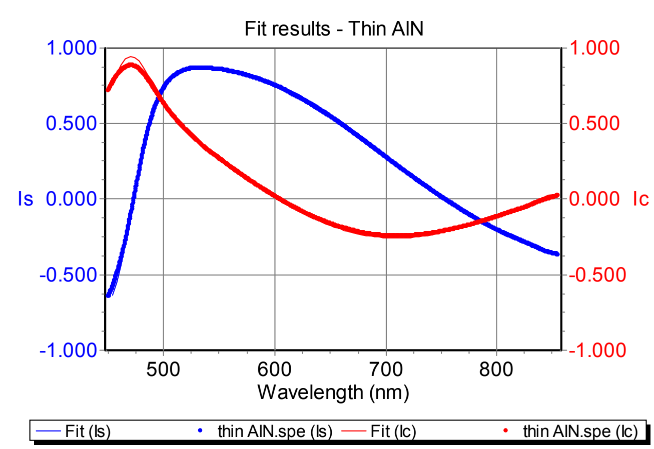


$\chi^2 = 2.5$

Thin film

The following structure has been used to model this sample. Once again, the model shows that the AlN material has an overlayer present.

overlayer	46.4nm
AlN	162.5nm
c-Si	



Conclusion

The feasibility of using the MM-16 SE in measuring thickness and refractive index of AlN thin and thick films has been demonstrated. Non destructive measurement of thickness was successfully applied to films as thick as 3μm deposited on Si. The multi-layer models with a surface layer with void and the simple dispersion gave useful information about surface roughness, film density and oxygen contamination.

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