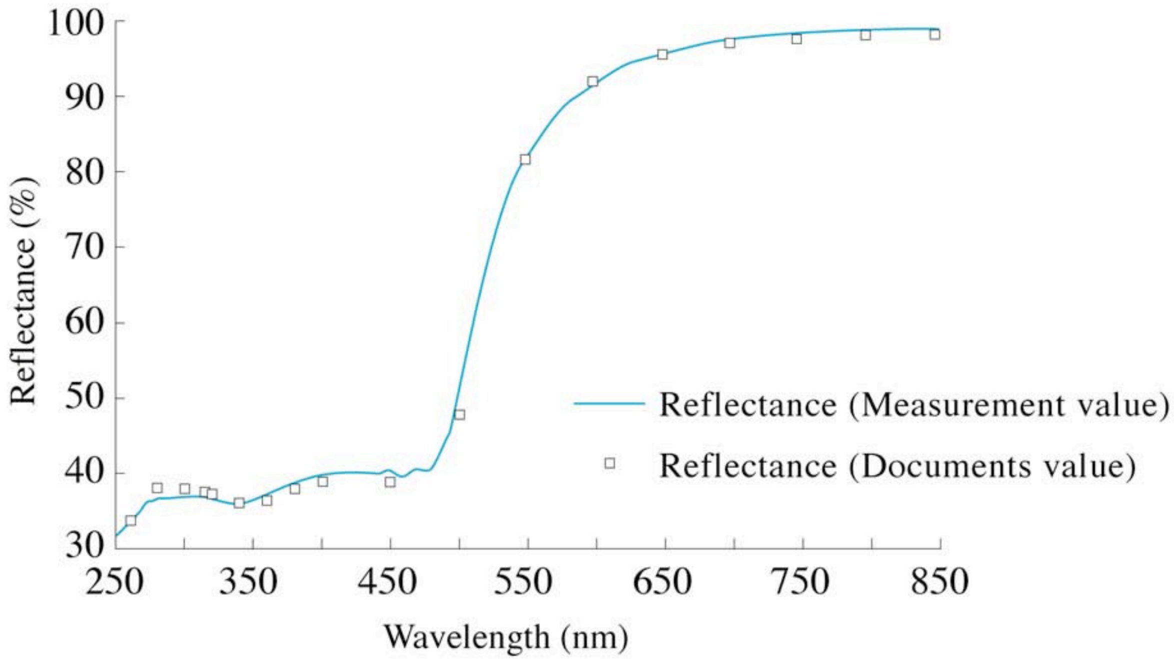
Reflectivity Calculation Program

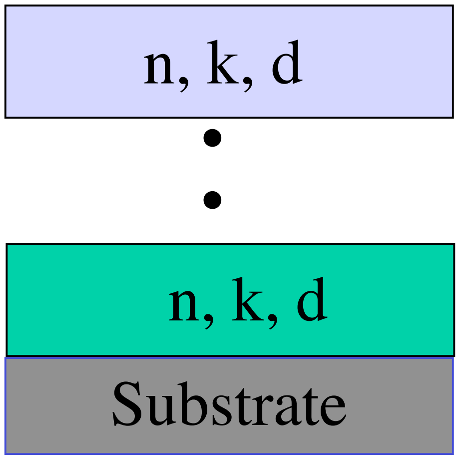
This optional program allows calculation of the reflectivity spectrum at any incidence angle from the wavelength distribution of the sample n and k values. Additionally, for complex samples such as optical components with multilayer films or anti-reflective coatings, the software can determine the reflectivity spectrum of the whole sample, including the coating.

Reflectance of Au



Multilayer Analysis

Multilayer Model



Substrate: $(n)_s \bullet (k)_s$

Film: $(n) \bullet (k) \bullet (d)$

(n): refractive index

(k): coefficient of extinction

(d): Film thickness

(d) and (n,k) of each layer is determined

$\left| (\Delta, \Psi)_{measured} - (\Delta, \Psi)_{calculated} \right| = \text{minimum}$

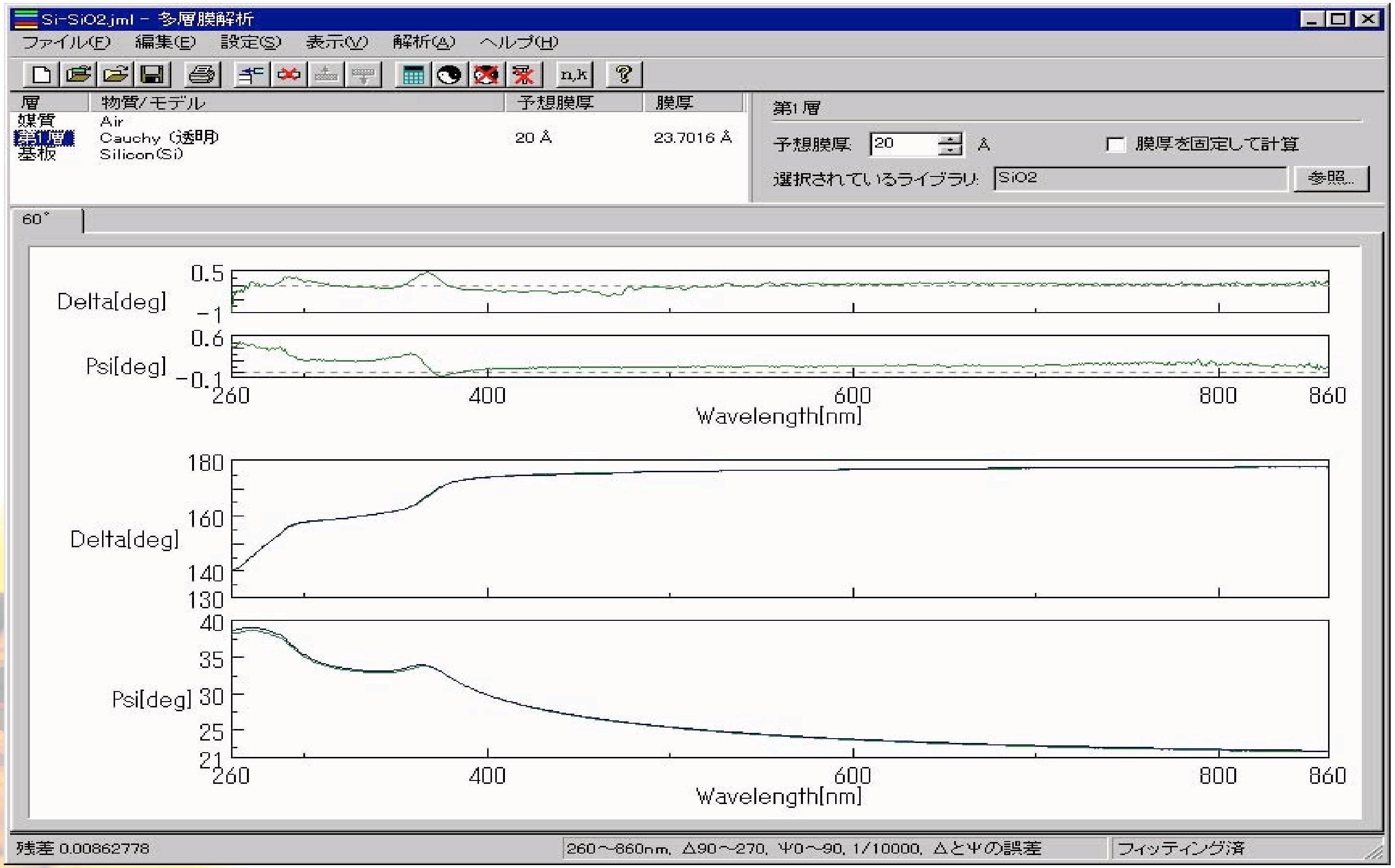
using Least square method.

Multilayer Analysis

SiO_2 ultra thin film (~20Å) on Si

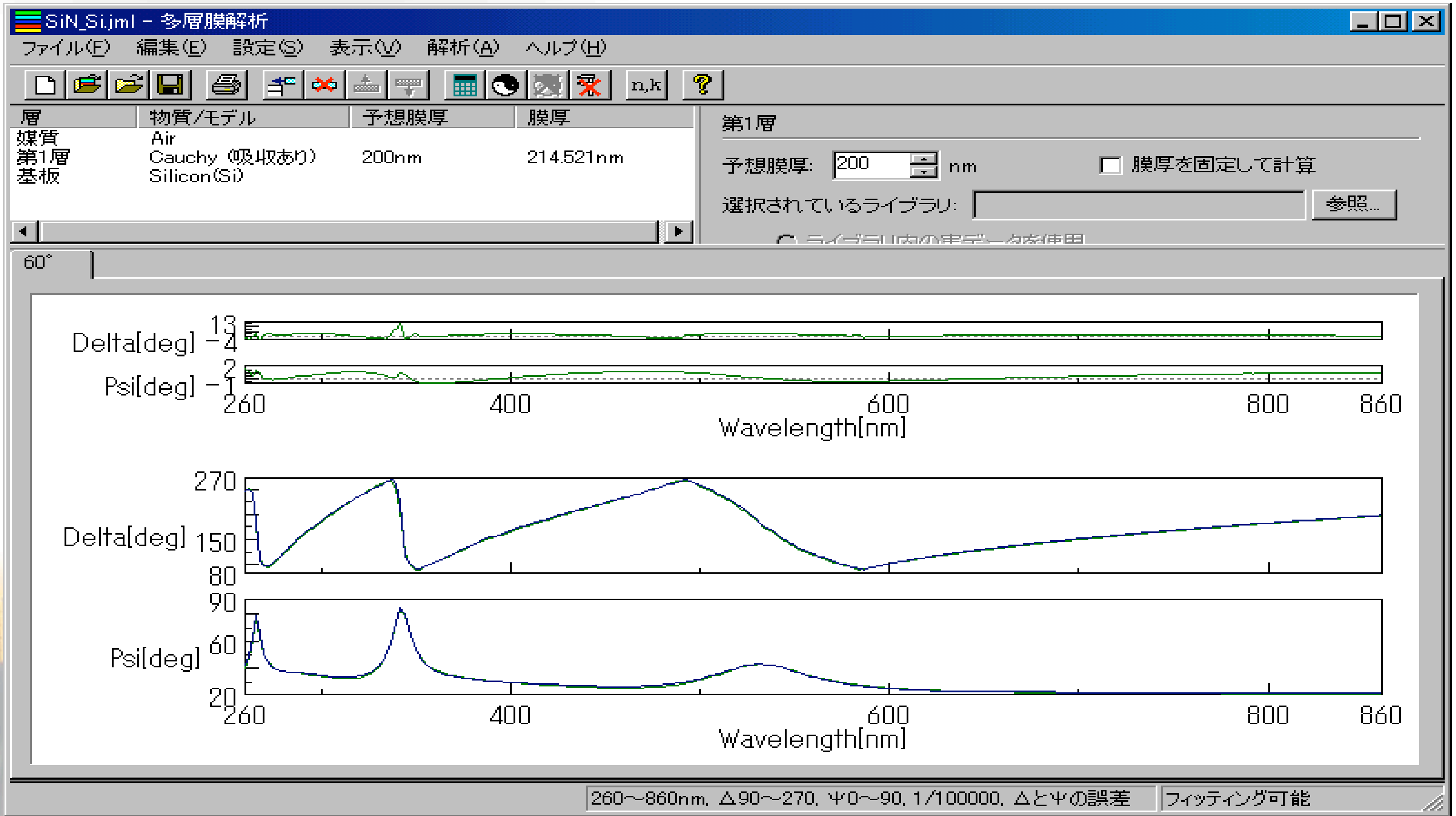
Thickness

<u>d=23.7Å</u>



Multilayer Analysis

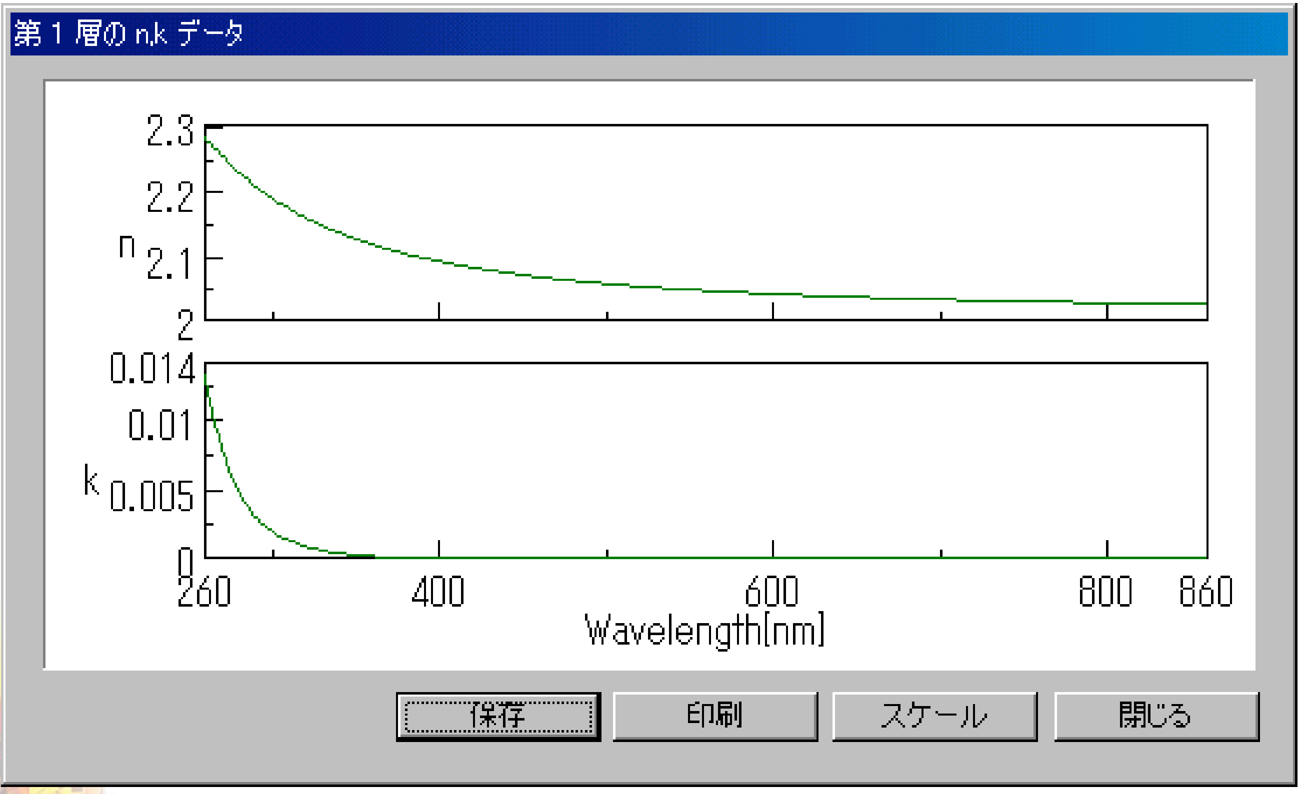
SiN film (~200nm) on Si Thickness d=214.5nm



JASCO developed a special program for calculating the film thickness and optical constants for each layer of a multilayer film based on the ellipsometric dispersion parameters (, y)l for the material. A multilayer film model is developed for the sample, the film thickness and optical constants optimized to minimize the error for the measured values.

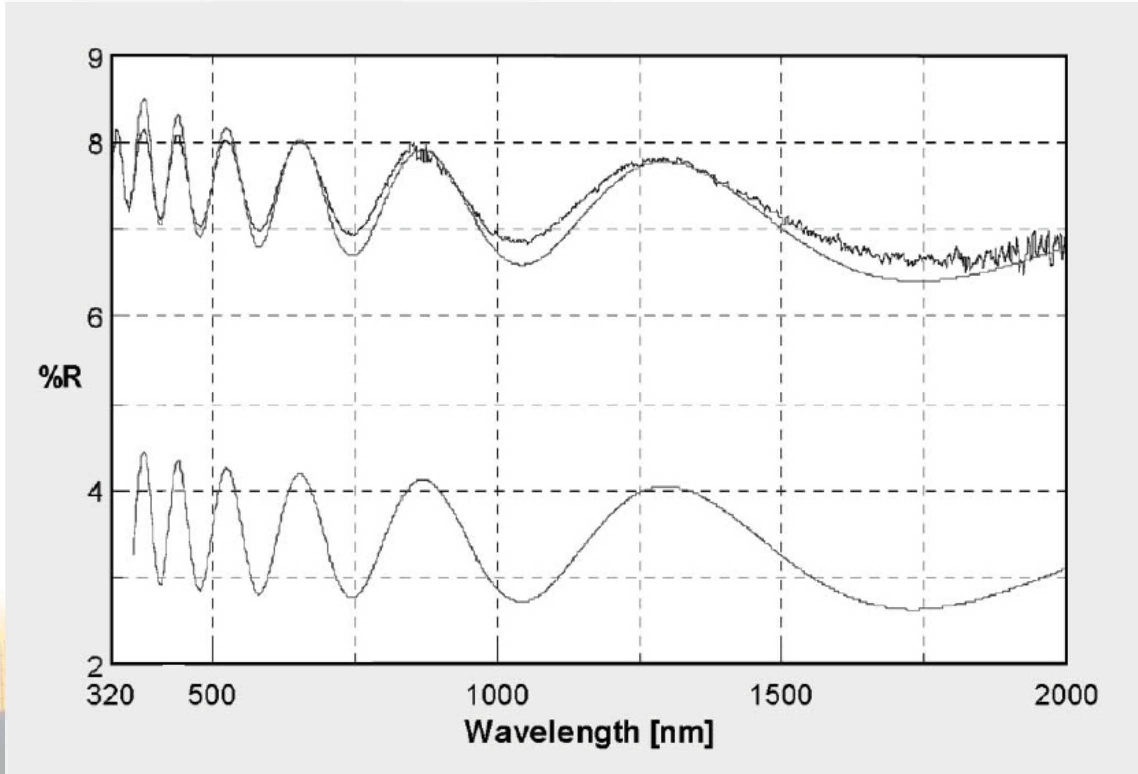
Multilayer Analysis

Complex refractive index (n, K) of SiN



Reflectance analysis of transparent substrates

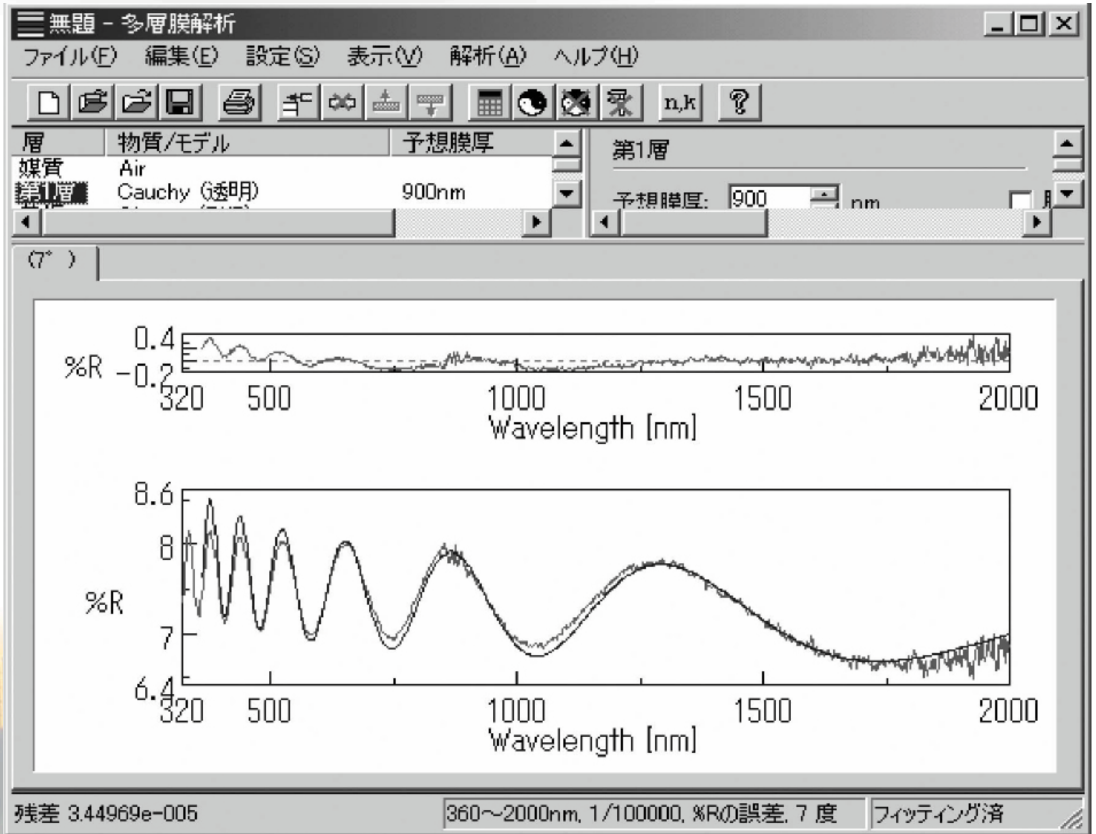
Measured reflectance and calculated reflectance of a 900 nm quartz film on optical glass (BK7)



This figure shows the measured reflectance of an approximately 900 nm thick quartz film on optical glass (BK7), the calculated result using the conventional multi-layer film analysis technique and the calculated result for reflectance analysis of a thin film on a transparent substrate. The latter technique shows a close match to the actual measurement, while the conventional technique shows reflectance that is about 4% lower.

Reflectance analysis of transparent substrates

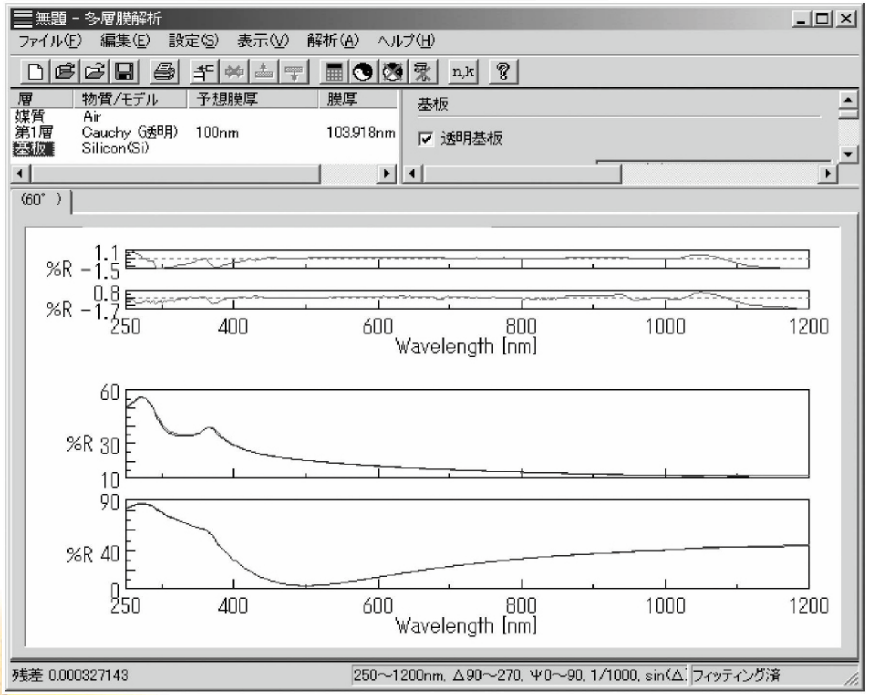
Measured reflectance and fitting result of 900 nm quartz film on BK7 glass



This figure shows the results optimized using the thickness of the quartz film and Cauchy refractive index dispersion. The results were a refractive index 1.48 at a film thickness of 893 nm at 360 nm and 1.46 at 633 nm.

Analysis of S and P polarization reflectance

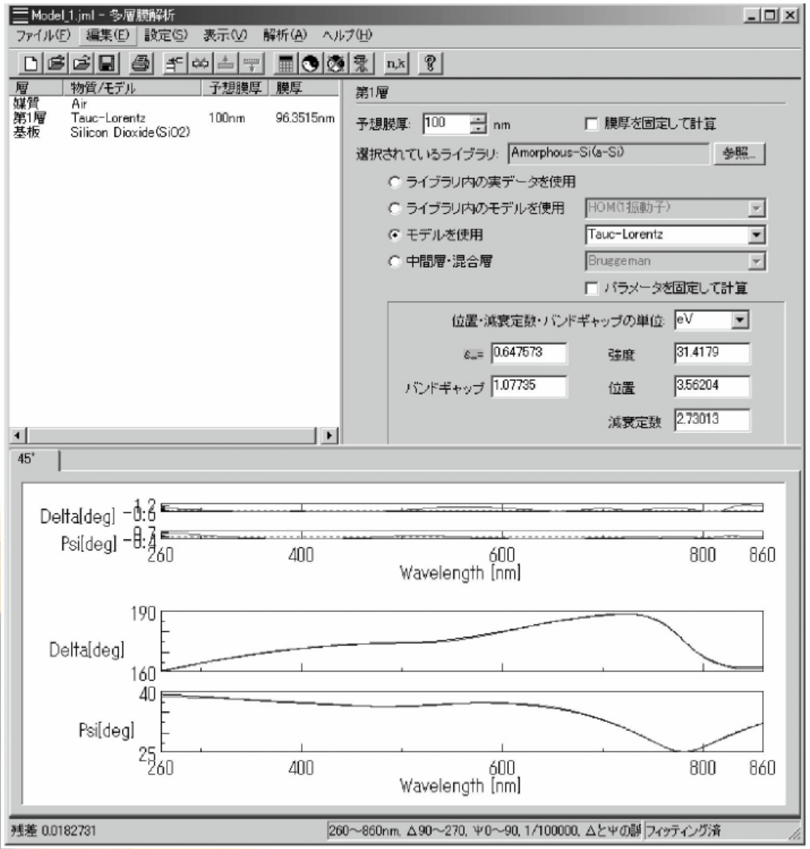
Measurement result of 60° incident S and P polarization reflectance for a 100 nm SiO_2 film on a silicon substrate



This figure shows the measurement result for a 100 nm SiO_2 film on a silicon substrate. Comparing film thickness to the wavelength, it is difficult to analyze such thin films with good precision without interference bands in the reflection spectrum. However, it is possible to determine the thickness and refractive index of a thin film with good precision in a relatively simple manner, by adding a variable angle absolute reflection measurement system and a polarizer to a general purpose spectrophotometer. Measurements are then made using an incidence angle near Brewster's angle.

Analysis Example for Tauc-Lorentz Dispersion Model (Non-Crystalline Thin Films)

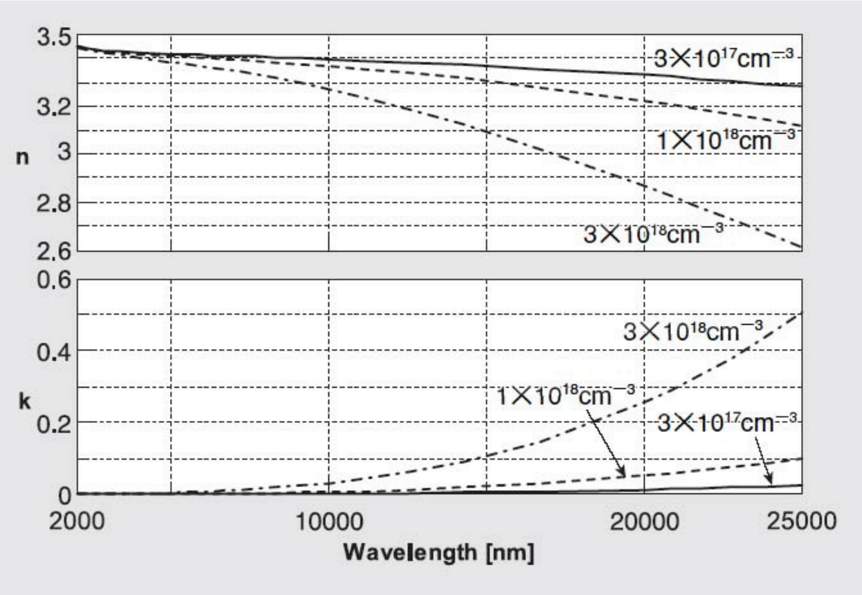
Analysis results for approximately 100 nm thick amorphous silicon deposited on a glass substrate



This figure shows the analysis result for an approximately 100 nm thick amorphous silicon layer deposited on a glass substrate as an example of non-crystalline thin film analysis using the Tauc-Lorentz dispersion model. The measured value and the value calculated using this model match very well. The film thickness was 96.4 nm and the band gap, excluding the optical constants, was 1.08 eV.

Impurity concentration dependency of optical constants in semiconductors

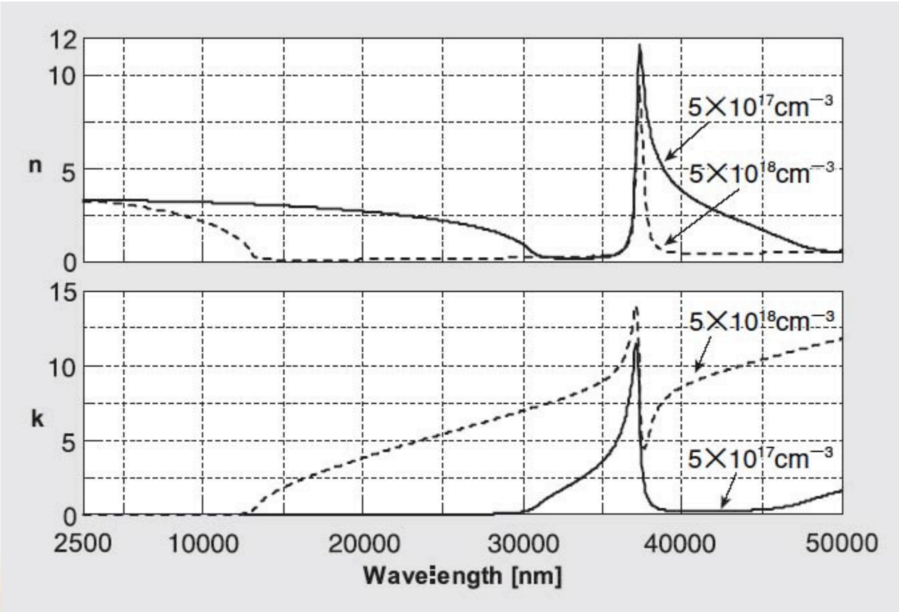
Carrier concentration dependence of optical constants for n-type silicon.
Carrier concentration (3×10^{17} cm^{-3}; 1×10^{18} cm^{-3}; 3×10^{18} cm^{-3})



To measure the film thickness of impurity-doped semiconductors with good precision using an optical technique requires accurate optical constant values. Furthermore, the doped impurity concentration is extremely important for the characteristics of semiconductors. This figure shows the carrier concentration dependence of optical constants for n-type silicon. The large contribution of the free carrier to the optical constants can be seen from the near-infrared region to the infrared region.

Impurity concentration dependency of optical constants in semiconductors

Dependence of optical constants on carrier concentration for GaAs (calculated values). Carrier concentration (5×10^{17} cm^{-3}; 5×10^{18} cm^{-3})

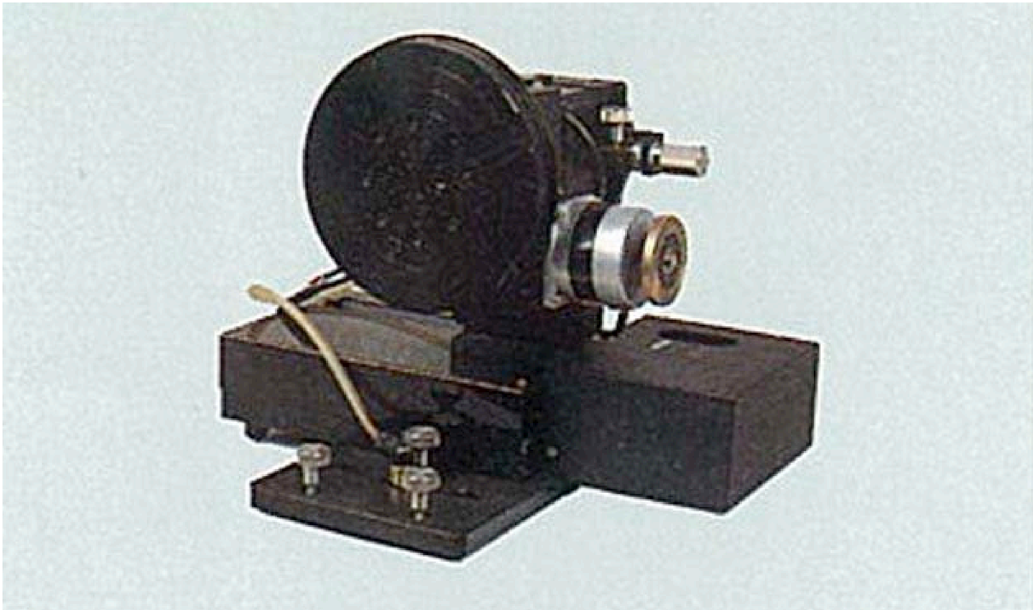


The contribution of the free carrier to conductivity is given by a Drude equation and with polar compound semiconductors, such as GaAs and InP, conductivity in the infrared region is represented by the contribution of lattice vibrations and a Drude equation. If the lattice vibration and the various parameters in the Drude equation can be determined from a variety of optical measurements, such as reflectance, the wavelength dependence of optical constants for semiconductor thin films doped with impurities can be determined and higher precision film thickness evaluation will be possible. This figure shows the results of simulating carrier concentration dependence for GaAs.

Optional sample stage

AXQ-100 Automatic X-θ mapping stage

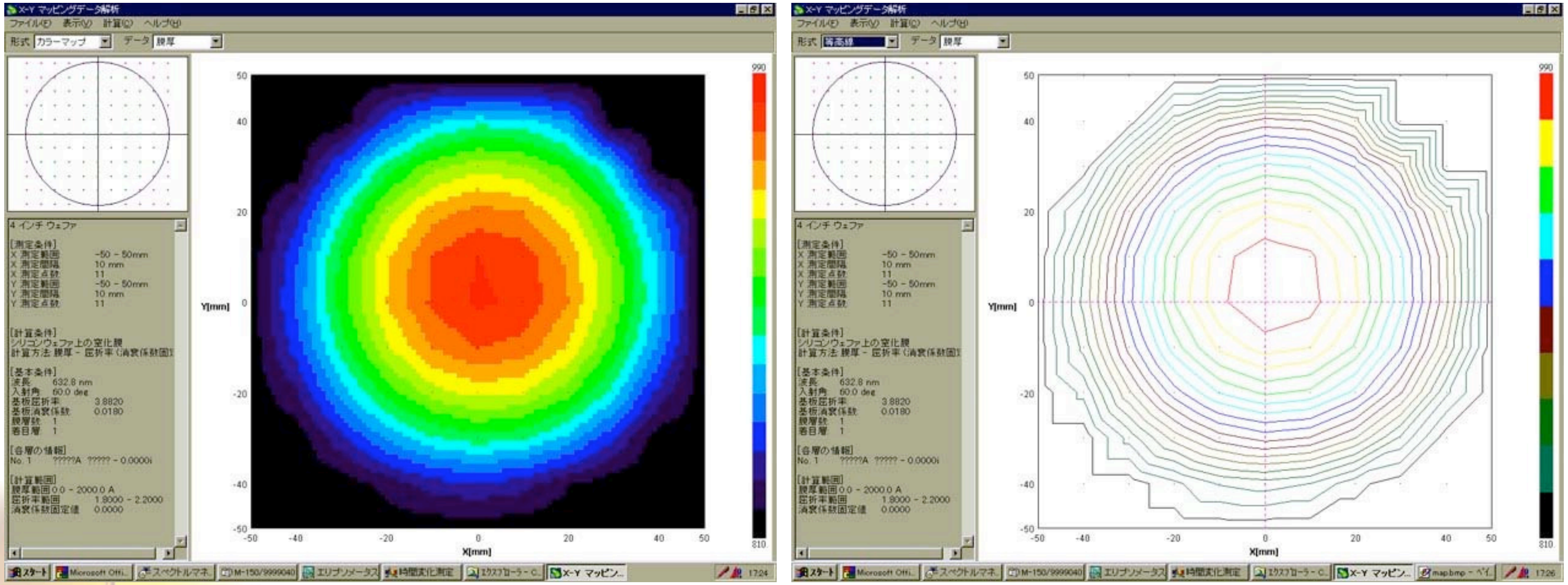
Sample size: 3 to 8-inch round or rectangular sample
Sample thickness: Max. 10 mm
Holding method: Held upright by vacuum suction



Mapping Measurement (Option)

Takes advantage of the PEM system's high speed to enable film thickness and refractivity distribution measurement within a maximum of ϕ8 inches of sample surface. The mapping measurement program offers display features including 3-D representation, contour map, and color map. The figure shows the thickness distribution of silicon oxide on a four-inch substrate. An average film thickness and average refractive index of 902Å and 2.01, respectively, is obtained. The film is thicker towards the center and thinner toward the periphery.

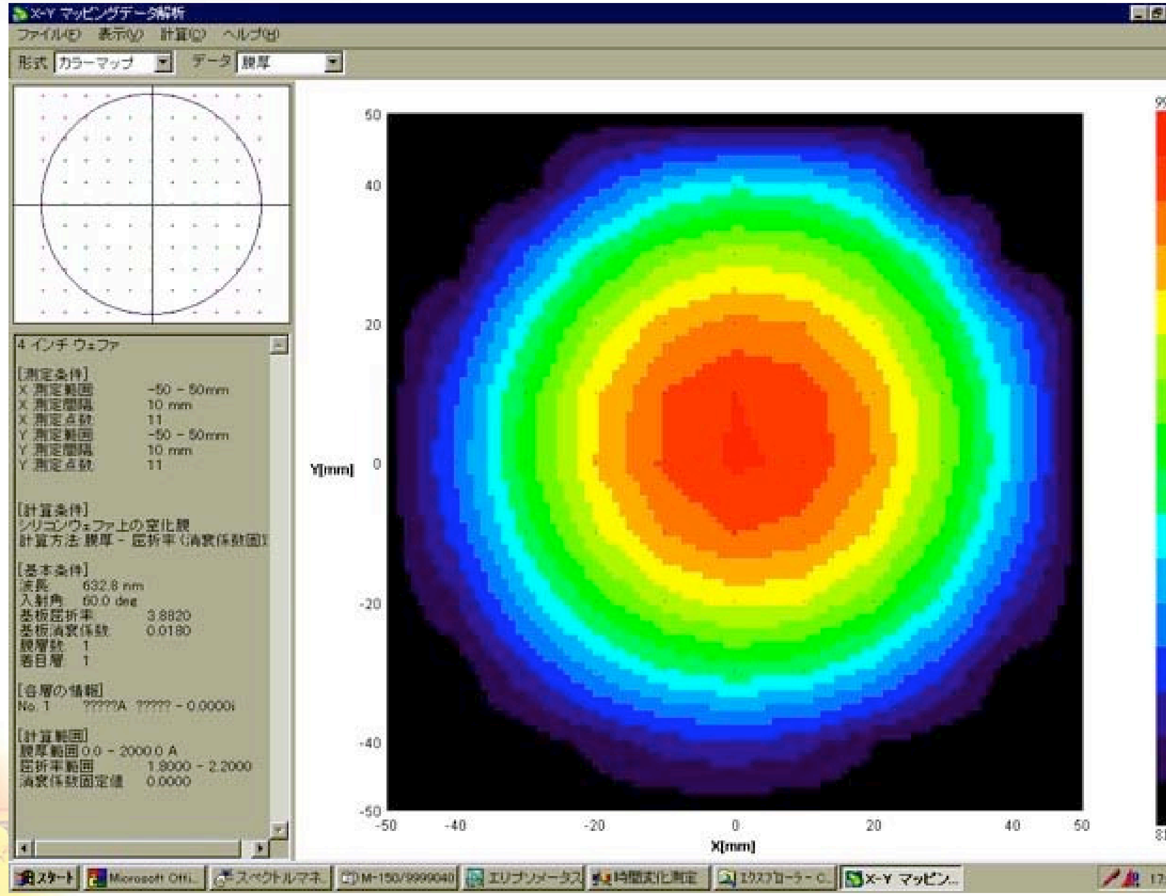
Si_3N_4 Film on Si



Optional AXQ-100 Automatic X-θ mapping stage includes above mapping measurement software.

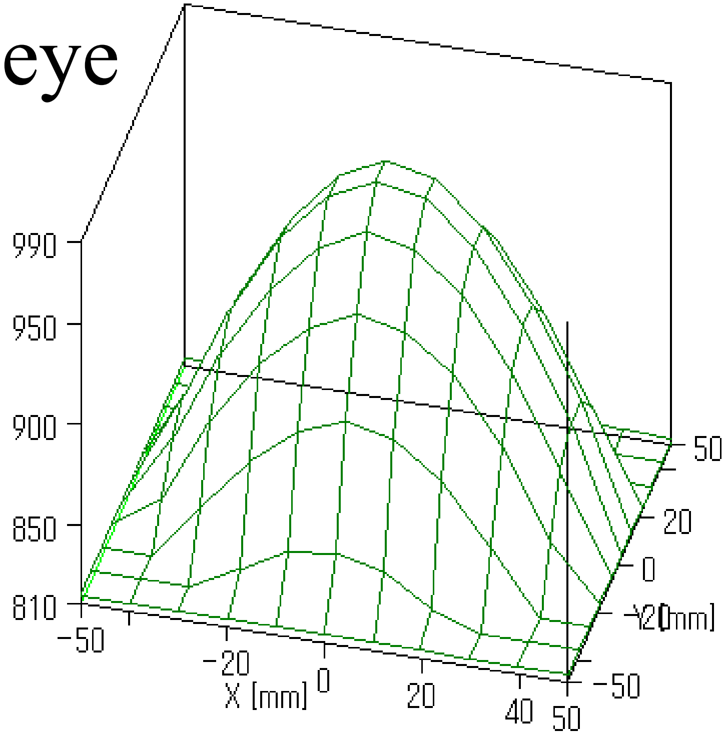
Thickness Map

Si_3N_4 Film on Si



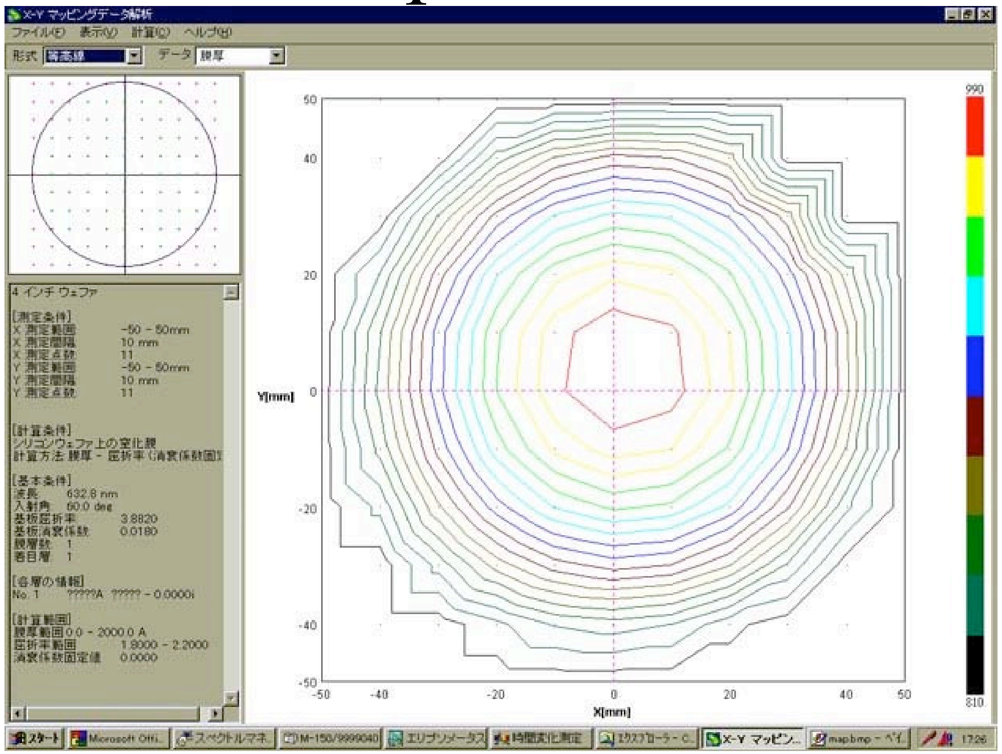
Si_3N_4 Film Thickness

Bird's-eye



Si_3N_4 Film Refractive index

Contour Map



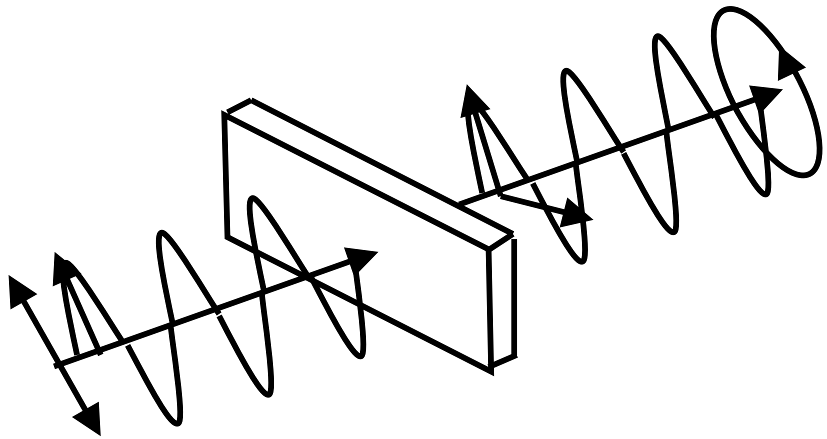
Optional sample stage

MDR-102 Birefringence measurement stage

Sample size: 50 mm x 80 mm to 2-inch round or rectangular sample
Sample thickness: Max. 5 mm

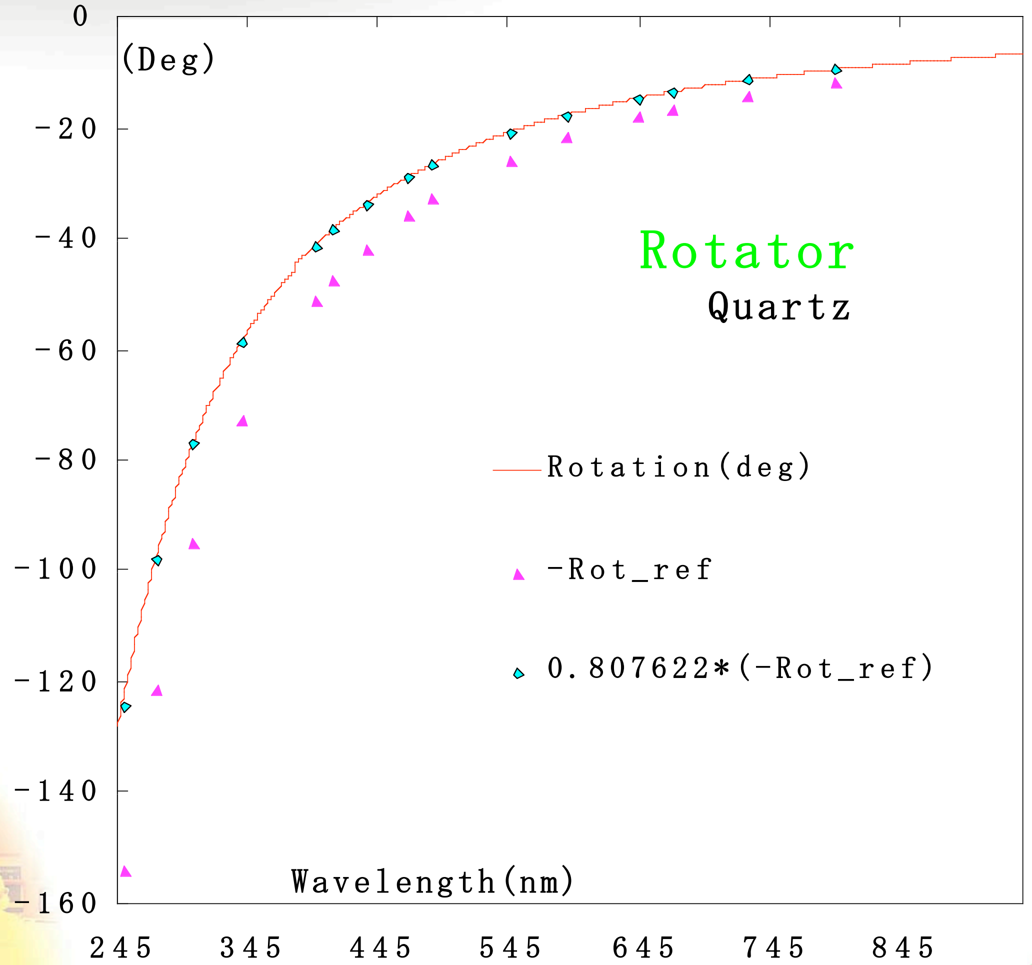
Birefringence of Optical material and Film

Residual strain in Optical glass
Optical films for LCD(Liquid Crystal Display)

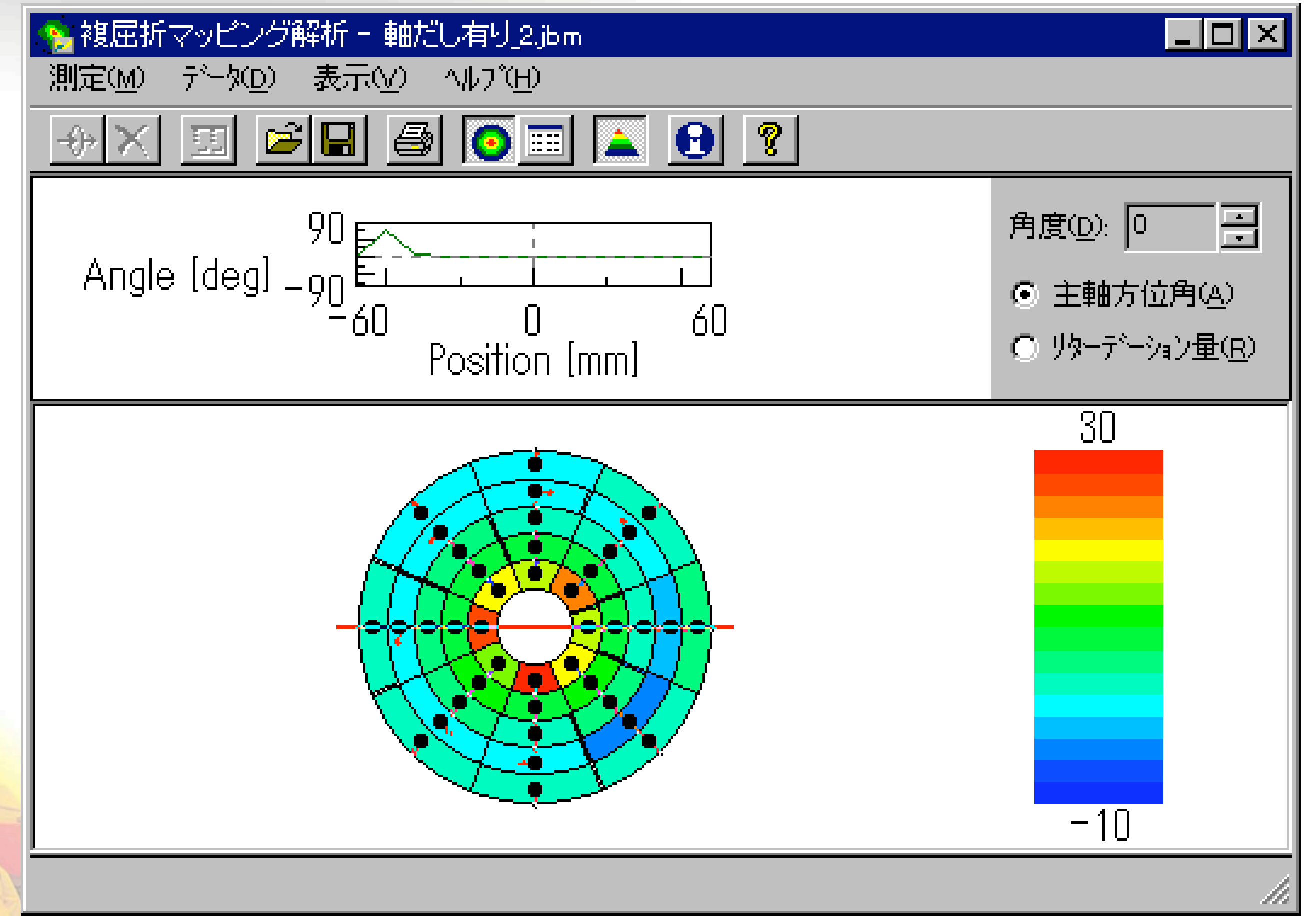


Photoelasticity, Birefringence, Polarization characteristics

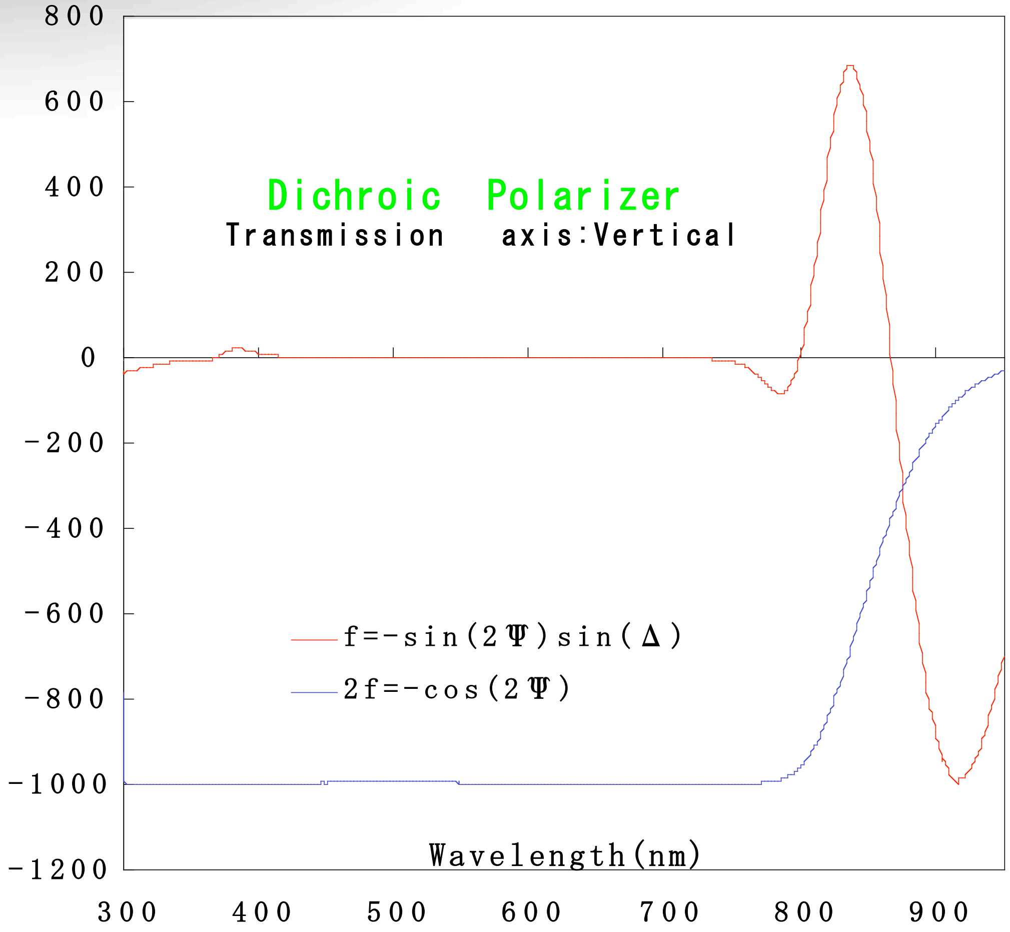
ORD: Optical Rotatory Dispersion



Birefringence Mapping

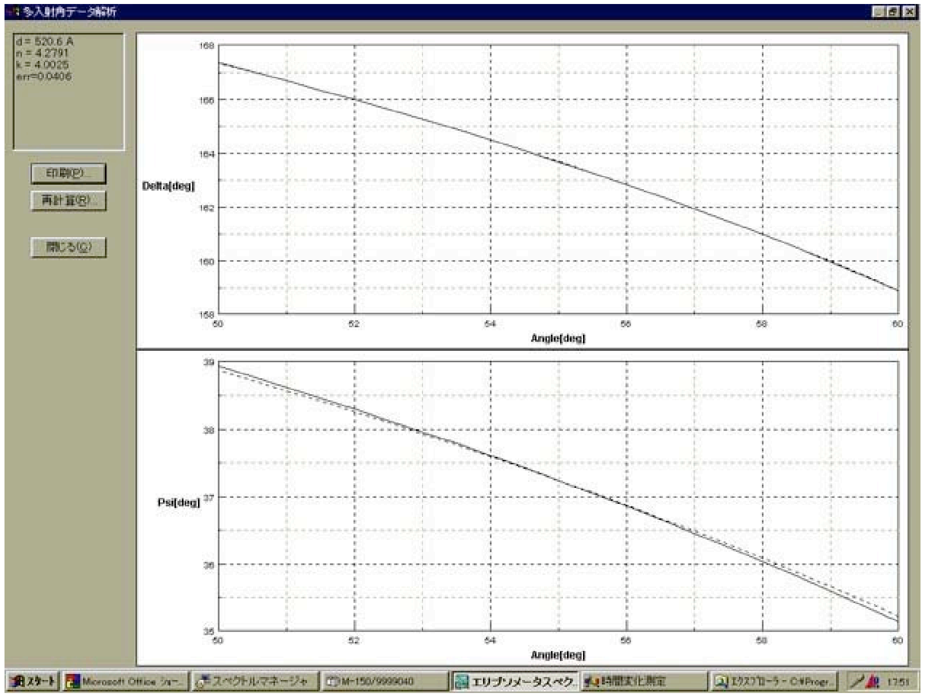


Dichroism & Birefringence



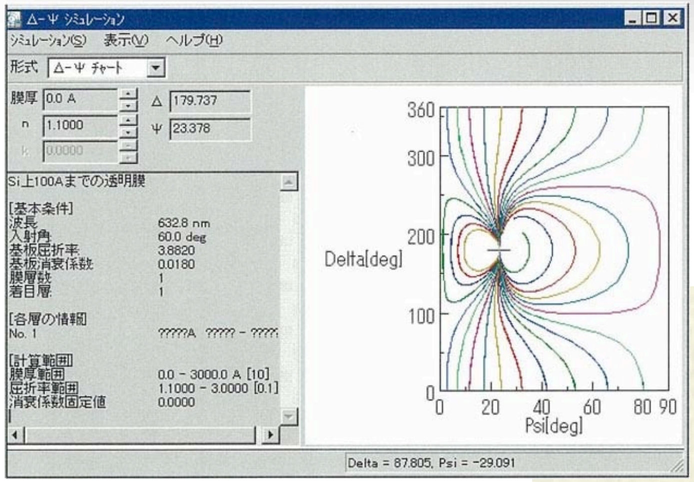
MW-302 Multiple Incidence Angle Measurement

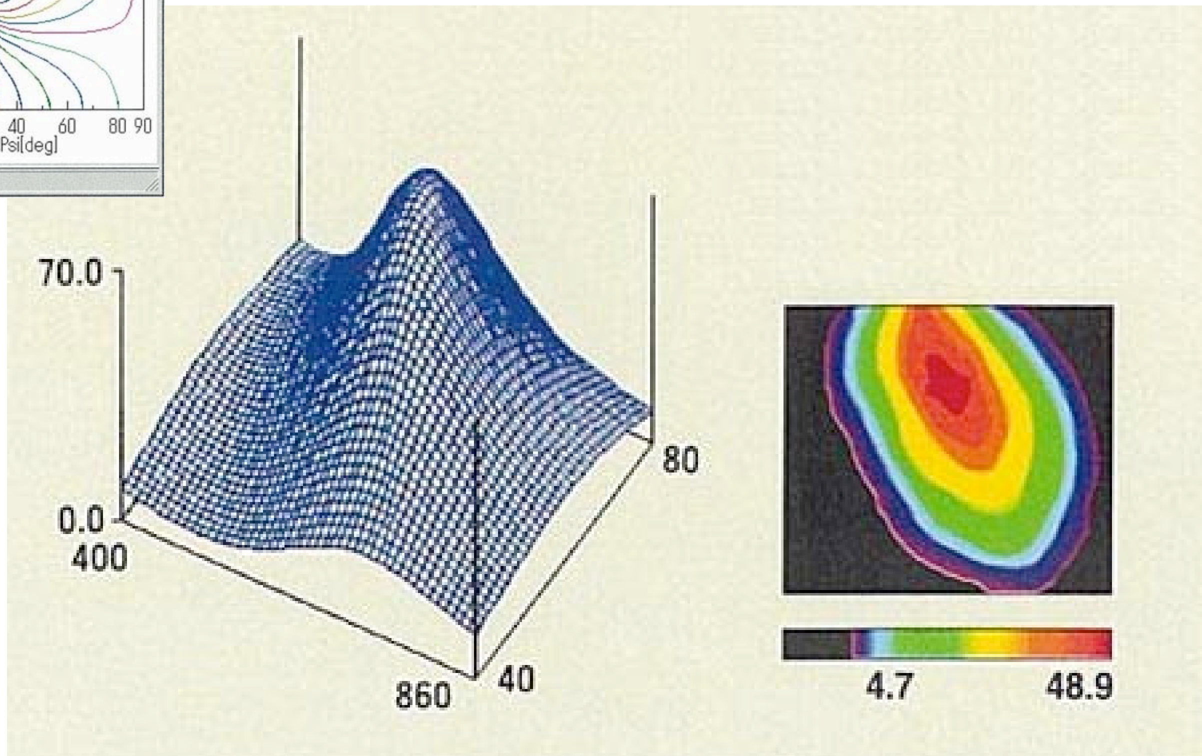
Conventional measurement using a single wavelength and single incidence angle can only find two parameters (for instances, n and d) at one time. This makes analysis difficult when k is not 0, even in a single layer. Our ellipsometers, however, offer you the power to measure multiple incidence angles to find parameters n, k, and d for film from the Δ, Ψ and w incidence angle dependency in this kind of absorption film. The figure to the right shows a measurement example for $Ge_2Sb_2Te_5$.   After measuring in the incidence angle range between 60 and 50 degrees in 0.5 degree steps at a wavelength of 800 nm, the findings indicate a film thickness of 520.6 Å, refractive index of 4.2791, and extinction coefficient of 4.0025.



MW-304 Δ–Ψ Sensitivity Simulation

By postulating n, k, and d for the sample to be measured, and then parametizing the incidence angle and measurement wavelength and simulating changes in measurement accuracy, it is possible to calculate the optimum wavelength and optimum incidence angle and check the appropriateness of the film thickness measurement conditions.

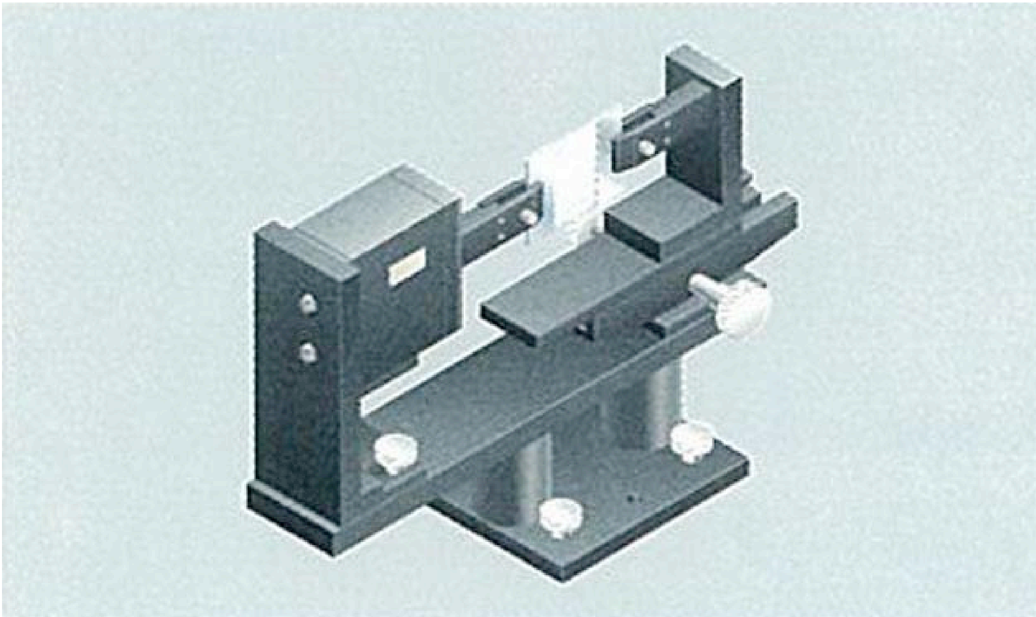




Optional sample stage

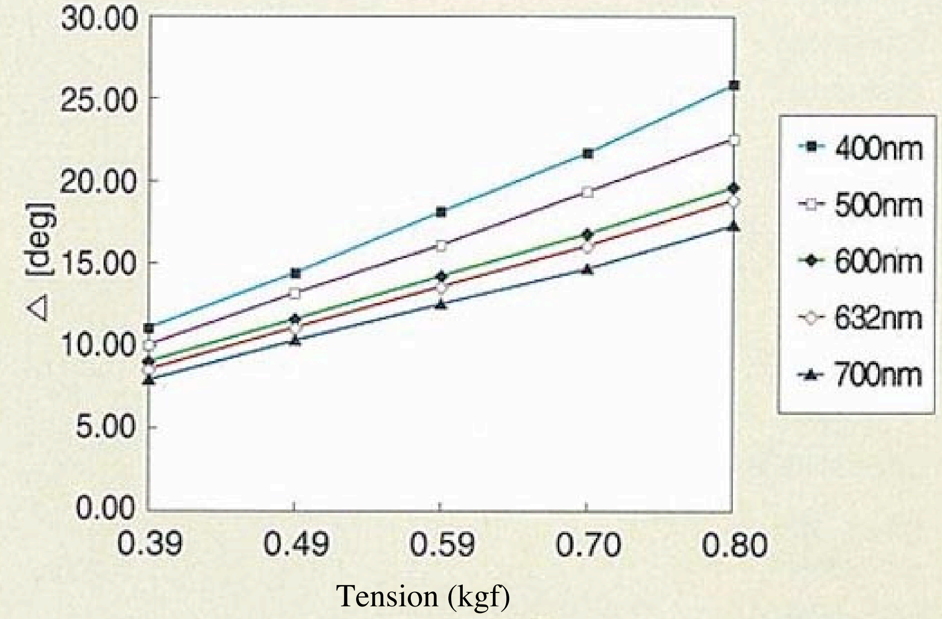
PES-105 Photoelastic measurement stage

Sample size:
50 mm x 60 mm film sample

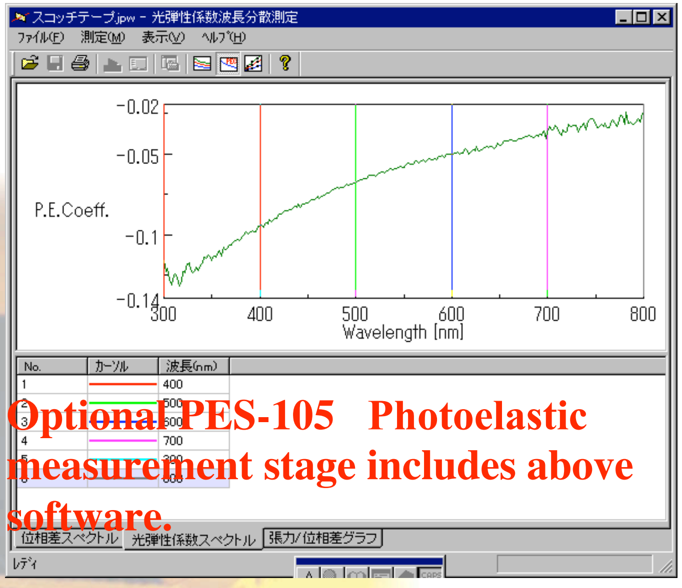


Photoelastic Constant Measurement

Setting up the M-200 series at an incidence angle of 90˚ allows you to use the unit as a transmission ellipsometer, making possible photoelastic constant measurement. Applying tension to a film sample evens out the axis of orientation of the macromolecules forming the film, and the amount of retardation varies in proportion to the strength applied. By measuring the strength applied and the amount of retardation, it is possible to find the photoelastic constant from the relationship between those two values. Measurement uses a transmission stage for photoelastic measurement and a photoelastic constant measurement program.



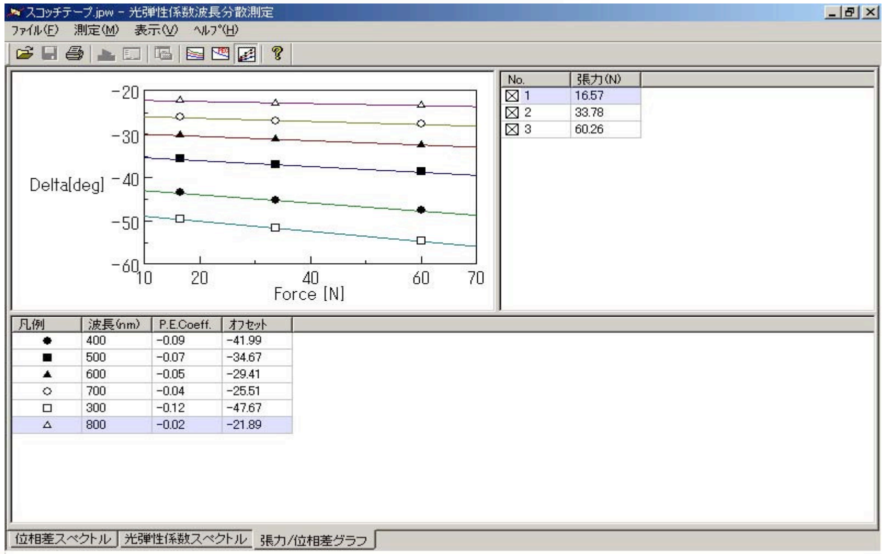
	Wavelength (nm)				
Tension (kgf)	400	500	600	632	700
0.39	10.89	9.96	8.87	8.56	7.96
0.49	14.36	13.05	11.56	11.13	10.28
0.59	17.99	16.07	14.10	13.55	12.48
0.70	21.70	19.16	16.70	16.02	14.71
0.80	25.66	22.45	19.51	18.70	17.14
Δ/Tension (kgf)	35.62	30.03	25.50	24.32	22.01
Photoelastic constant	40.35E-13	42.53E-13	43.33E-13	43.53E-13	43.63E-13



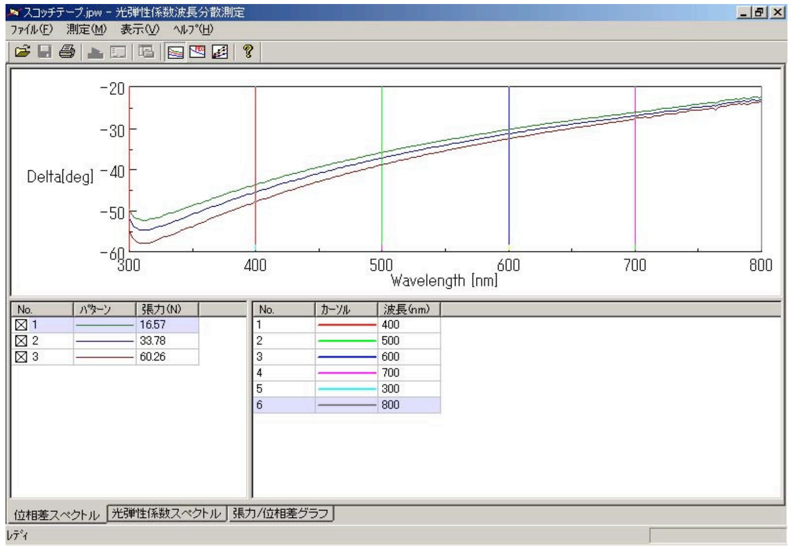
Optional PES-105 Photoelastic measurement stage includes above software.

Photoelastic Constant Measurement (Option)

Phase difference vs tensile force



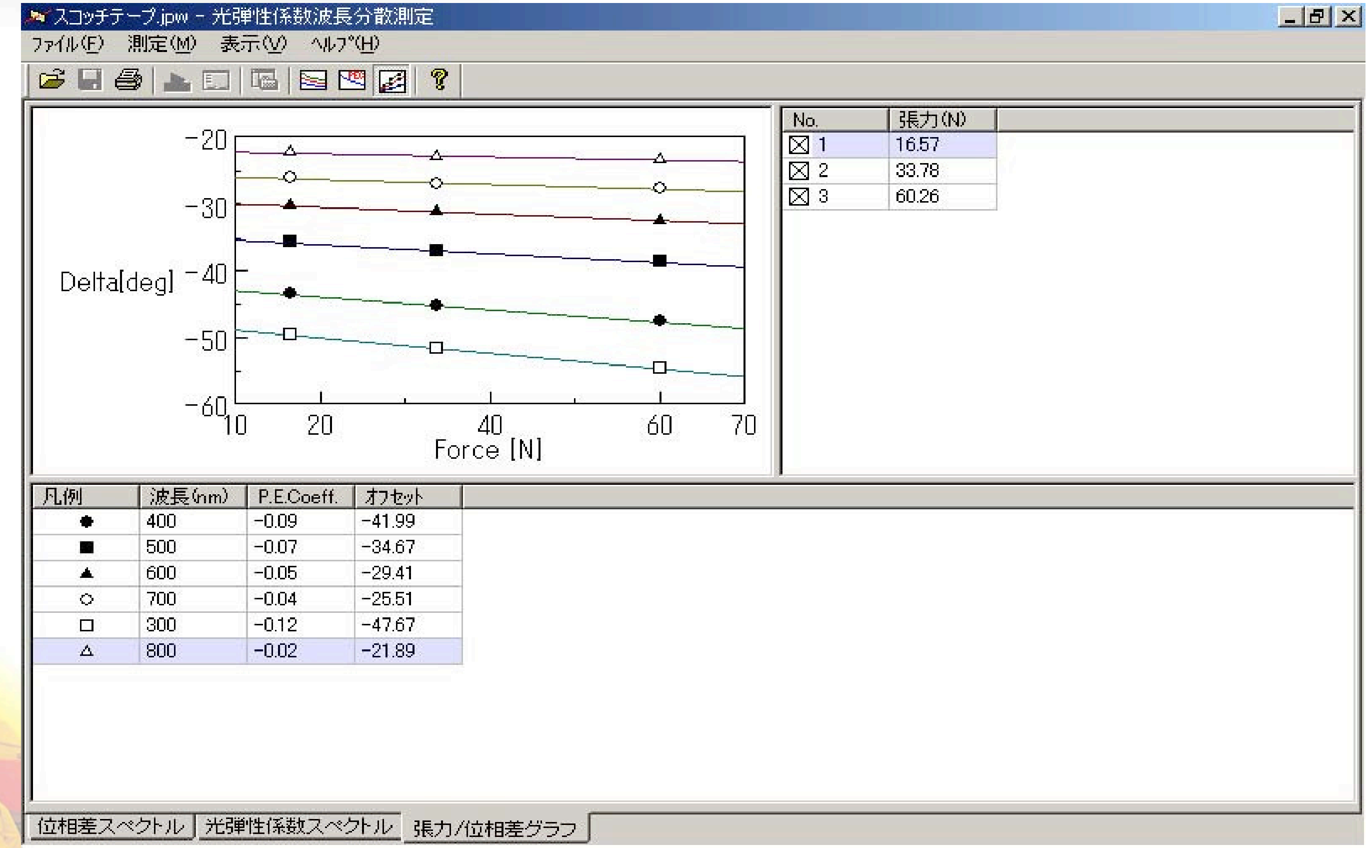
Phase difference spectra



Optional PES-105 Photoelastic measurement stage includes above software.

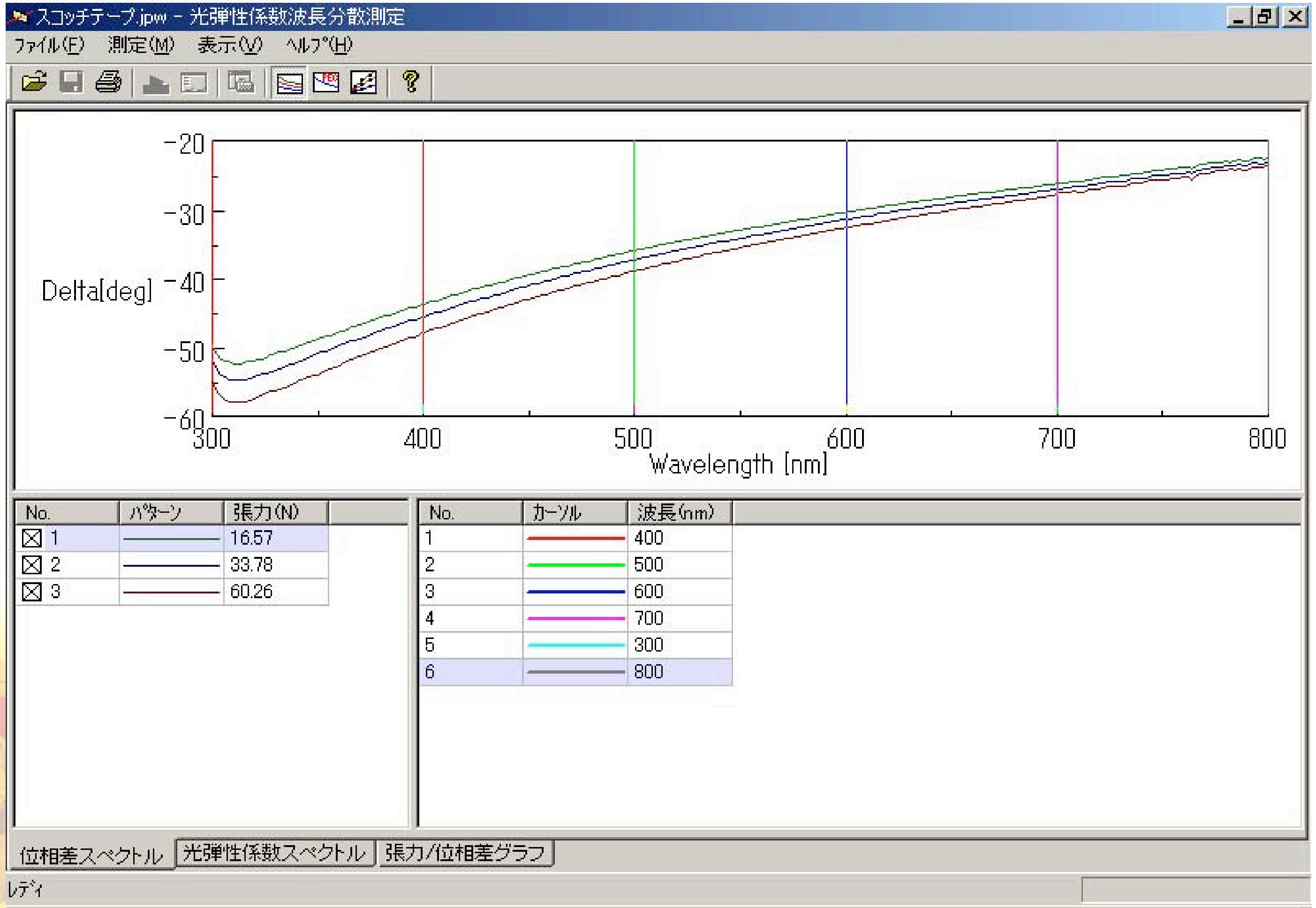
Photoelasticity of films (1)

Phase difference vs tensile force



Photoelasticity of films (2)

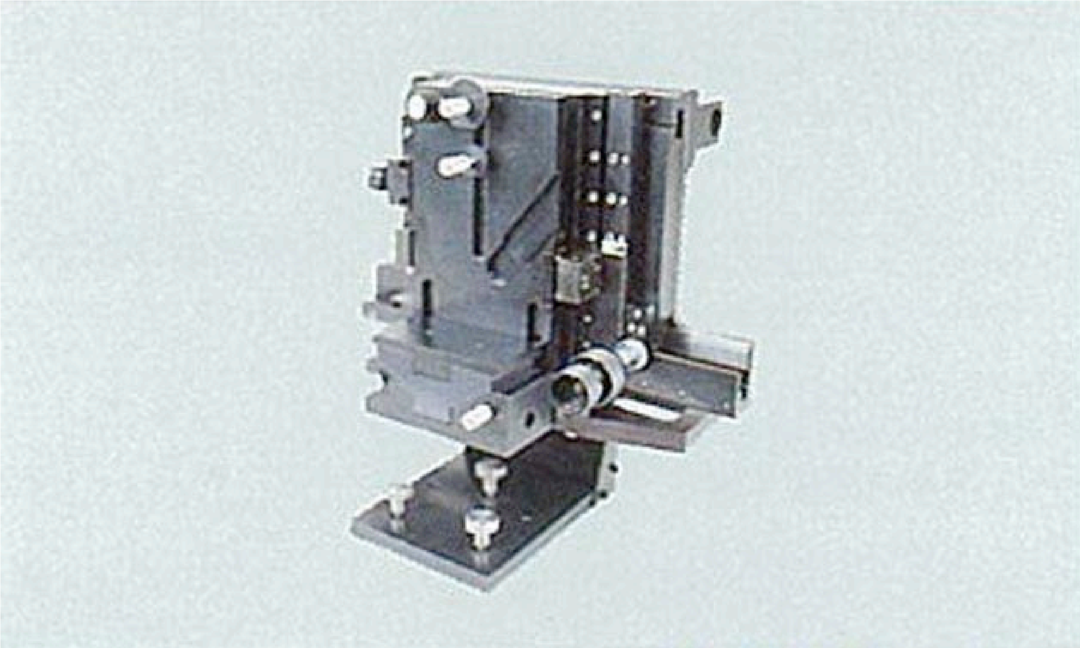
Phase difference spectra



Optional sample stage

MXY-101 Manual X-Y stage

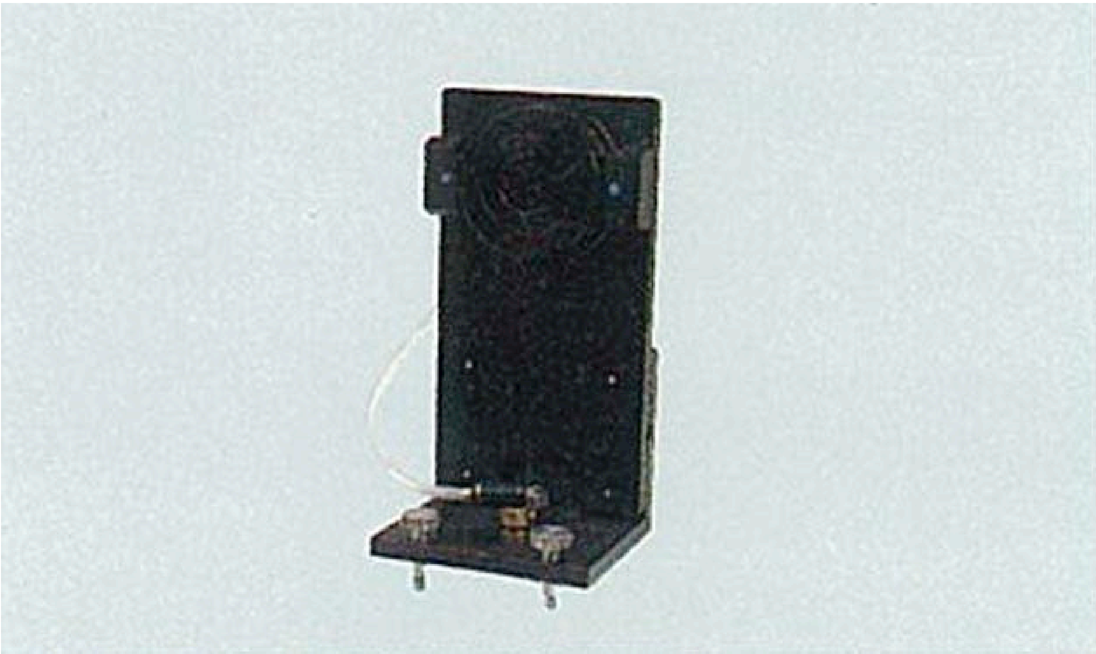
Sample size: 20 to 100 mm round or rectangular sample
Minute movement distance: ± 50 mm horizontally and 50 mm vertically
Sample thickness: Max. 10 mm
Holding method: Held upright by sample holder fixture



Optional sample stage

VCS-103 Absorption stage

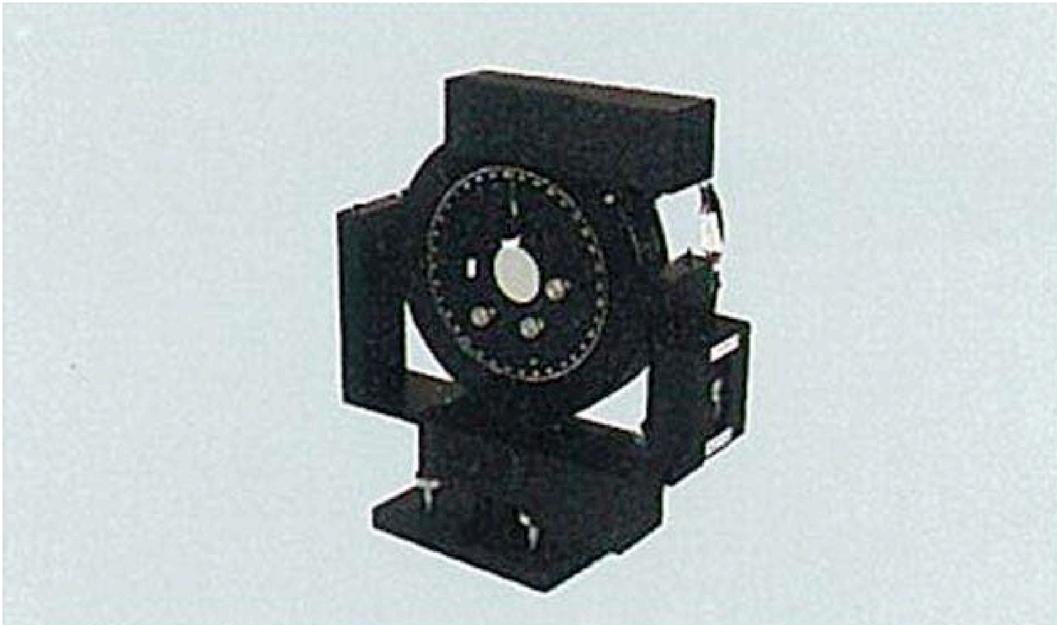
Sample size: 10 mm x 10 mm to 2-inch round or rectangular sample
Sample thickness: Max. 10 mm
Holding method: Held upright by vacuum suction



Optional sample stage

ADR-102 Anisotropy measurement stage

Sample size:
40 mm x 40 mm to 50 mm x 60 mm film sample
100 mm x 100 mm t=1 to 5 mm Luquid crystal cell



Time-Resolved Measurement of Liquid Crystal

ELC-300 Spectroellipsometer for liquid crystal time-resolved measuremet

Time-Resolved Measurement of Liquid Crystal

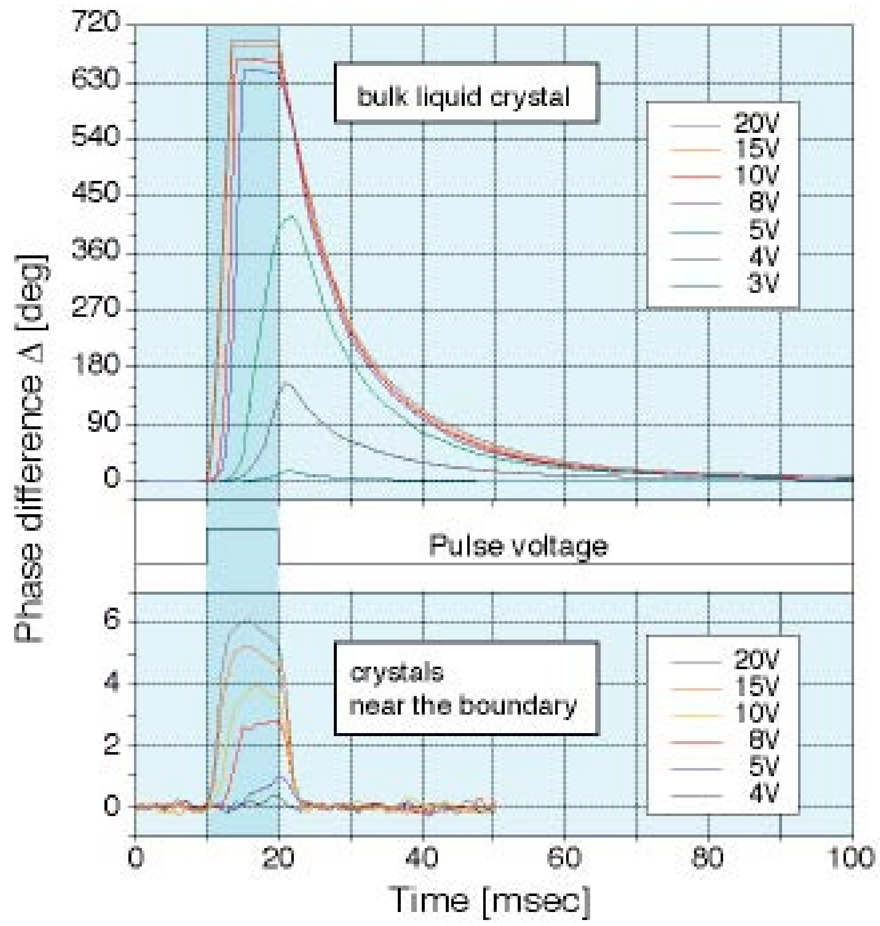
Generally, the behavior of liquid crystal molecules in the vicinity orientying layer is different from the behavior of bulk liquid crystal. It is said to be influenced by an anchoring effect that works between the orientation film and liquid crystal molecules. Measuring the electric field response of the liquid crystals is indispensable to understanding that orientation mechanism.

The M-200 series enables time-resolved analysis of liquid crystal using the high-speed data acquisition of its PEM dual lock-in system.

The figure to the right shows an example of the dynamic electric field response of nematic liquid crystal bulk and crystals near the boundary. The measurement used a 5CB liquid crystal cell (orientation: parallel: cell thickness: 8.17μm) doped with 6wt% p-dimethylaminoazobenzene. First the bulk liquid crystal's electric field response in a transmission configuration is measured at a wavelength (698 nm) where the dye is transparent, and then the electric field response of the liquid crystal near the boundary is measured in a reflective configuration (dye-doped reflection method*) at the DAB absorption peak wavelength (419 nm). If you compare the time-resolved measurement results for the bulk liquid crystal and liquid crystal near the boundary as shown in the figure, you will see that their electric field responses are quite different.

* The dye-doped reflection method makes it possible to suppress the light reflected from a liquid crystal cell's back surface and then measure the electric field response of the liquid crystal near the anchoring interface by doping dye in the liquid crystal cell and then applying the reflection ellipsometry at the absorption wavelength. [1-3]

1)Tadokoro, Fukazawa, and Toriumi. Preliminary Draft of the 22nd Panel Discussions on Liquid Crystals, 1AO6 (1996).
2)Ono, Akabane, Kimura, Tadokoro, Akao, and Toriumi. Preliminary Draft of the 44th Spring Term Applied Physics Society, 30a-SNL-11 (1997).
3)Tadokoro, Akao, Kimura, Akabane, Ono, and Toriumi. Preliminary Draft of the 44th Spring Term Applied Physics Society, 30a-SNL-12 (1997).



Dynamic electric field response of nematic liquid crystal bulk and crystals near the boundary

Stages are available for a very wide range of samples. Contact us for more information and discuss your own sample requirements