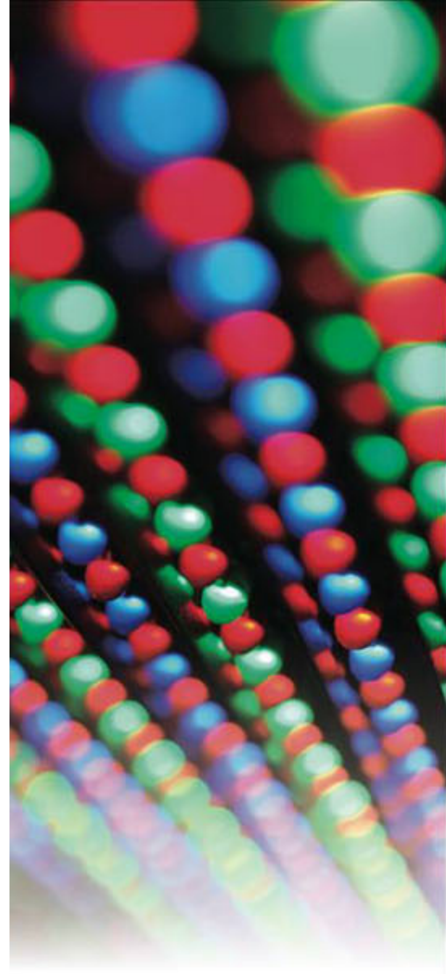
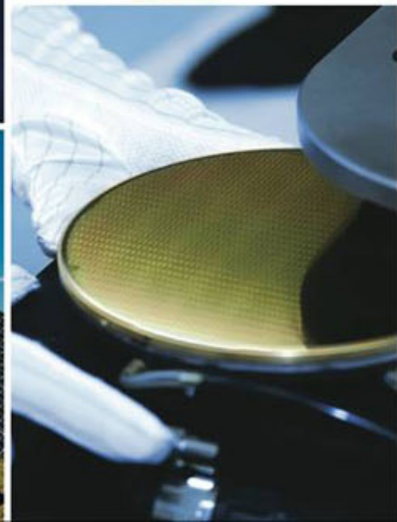


Applications and Solutions

For Research and Development in Material and Semiconductor field



Materials research applications / Materials evaluation applications

JASCO offers a wide variety of instruments and applications for materials research and analysis.

Full vacuum UV — UV/Vis

Transmission / Reflection Measurement

Full Vacuum UV spectrometer

V-1000

* Evaluation of VUV Transmittance materials
* High energy band gap measurements
* Evaluation of VUV reflection elements

Electric field absorption measurement spectrometer

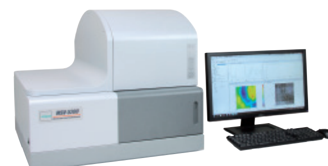
EMV-100

* Evaluation of organic EL materials
* Evaluation of photo sensitive layer
* Evaluation of Stark effect

UV/Vis/NIR Spectrophotometer

V-600 Series

* Band gap measurements
* Transmission/Reflection measurement of glass
* Film thickness and refractive index measurements
* Haze measurements



UV/Vis/NIR microscope system

MSV-5000

* Film thickness measurements of microscopic samples
* Color analysis of a microscopic area

Emission / Scattering Measurement

Full vacuum UV fluorescence emission measurements

FLV-1000

* VUV excitation for fluorescence measurements
* Evaluation of PDP fluorescent materials

Spectrofluorometer

FP-8000 series

* Evaluation of white LED fluorescent materials
* Evaluation of luminescence from organic EL compounds
* Color rendering evaluation of illumination sources

Laser Raman spectrophotometer

NRS-5000 / 7000 series

* Evaluation of Si stress
* Evaluation of crystallization
* Diameter estimation of Carbon nanotubes
* Evaluation of Carbon materials

Near Field microscope system

NFS series

* Band gap measurements of a microscopic area by near field luminescence
* Lattice defect measurements of a microscopic area by near field luminescence

Polarization Measurement

Full vacuum UV Double refraction monitor

BRV-100

* VUV double refraction monitoring

Spectroellipsometer

M-220 **M-550**

* Electro- optical constant measurement
* Film thickness and refractive index measurement
* Static and dynamic double refraction measurement

Polarization film evaluation system

V-7000 with VAP-7070

* Polarization film evaluation

Materials research applications / Materials evaluation applications

JASCO offers a wide variety of instruments and applications for materials research and analysis.

Near IR | Mid IR | Far IR

Reflection Measurement

Film thickness measurement system

UTS-2000

* Thickness measurement of Si wafer
* Thickness measurement of layer(s) on Si wafer
* Trench measurement

Transmission / Reflection Measurement

FTIR spectrometer

FT/IR-4000, 6000 series

* O_2/N_2 concentration measurement inside of Si wafer
* Hydrogen-terminated evaluation on Si wafers
* Quantitative/ Qualitative measurement of highly polymerized compounds
* Dynamic analysis of liquid crystal materials
* Reflectance of solar radiation on glass
* Gas phase analysis

IR microscope system

IRT-5000/7000 system

* Impurity identification
* IR imaging measurements

Near field IR microscope system

NFIR-200

* Identification of microscopic area
* IR imaging measurements of microscopic samples

Terahertz spectroscopy system

FARIS-1

* Conductivity evaluation of Si wafer
* Observation of lattice vibration of crystal

Emission / Scattering Measurement

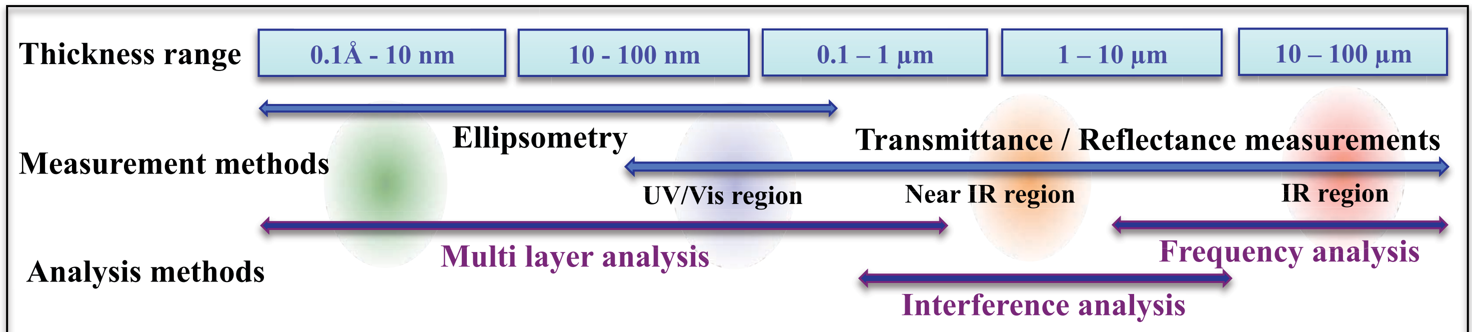
Near IR Spectrofluorometer

FP-8600NIR

* Chirality analysis of Carbon nanotubes

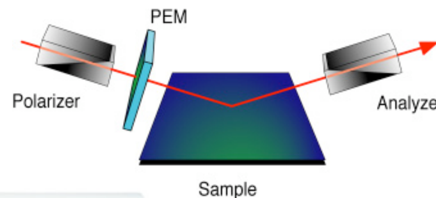
Film Thickness Measurement

Optical methods for thickness measurement are applicable to various research and development of materials such as novel coatings of dielectrics and semiconductor. The primary advantage of these methods is to provide non-destructive and non-contact measurement, as well as wide measurement range from sub nm to μm. JASCO can provide the most suitable method for measurement and analysis depending on thickness of film, number of multiple layers and substrate materials.



Ellipsometry with Multi-layer analysis : 0.1Å – several 100 nm

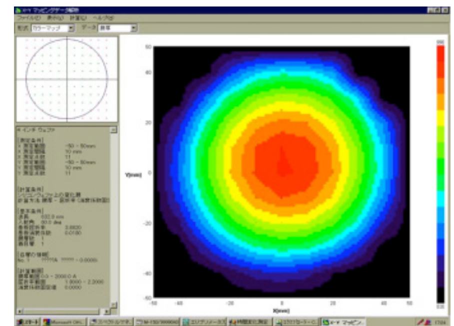
JASCO's ellipsometer employs a proprietary polarization modulation technique (a PEM dual lock-in system) utilizing a photoelastic modulator, instead of the rotational drive mechanism of conventional ellipsometers. The PEM dual lock-in system provides a stable measurement with additional capabilities including high speed data sampling and wavelength scanning.



Automated wavelength scanning
High-speed data sampling
High stability and reliability
High sensitive thin film analysis

M-220

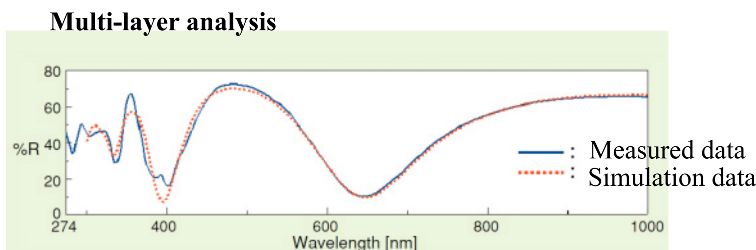
M-550



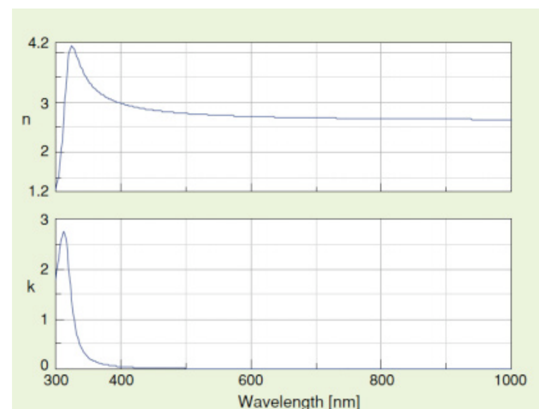
Transmittance / Reflectance measurement with Multi-layer analysis :10 – several 100 nm

Multi layer analysis of SiO_2/TiO_2 layers on Si substrate and optical constant of TiO_2 by calculation based on Tauc-Lorentz formula and reflective index table of SiO_2.

Multi-layer analysis



TiO_2 layer : 61.53 nm
SiO_2 layer : 221.27 nm

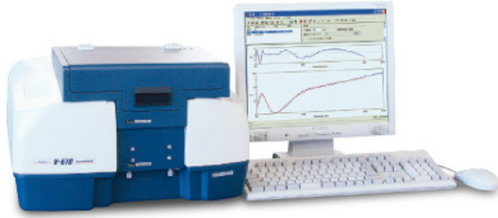


V-600 Automatic absolute reflectance measurement system

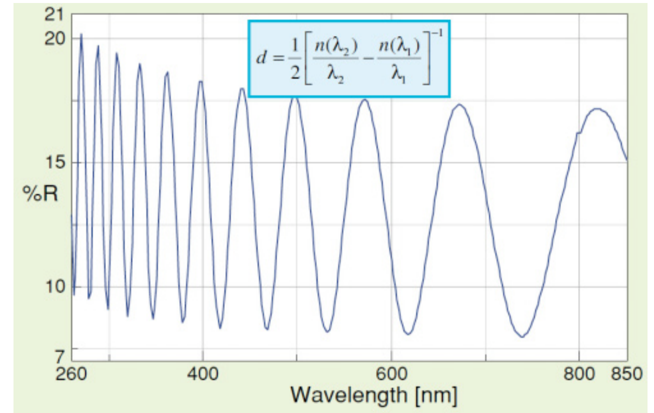
Reflectance spectrum of YAG layer on glass substrate

This method is well known as classical method for film thickness measurement by calculation based on wavelength of peak and valley, and interval between peaks of interference curve .

Visible region : Several hundred nm to several μm
Near IR region : Several μm to 100 μm
Mid IR region : Several 10 μm to several hundred μm

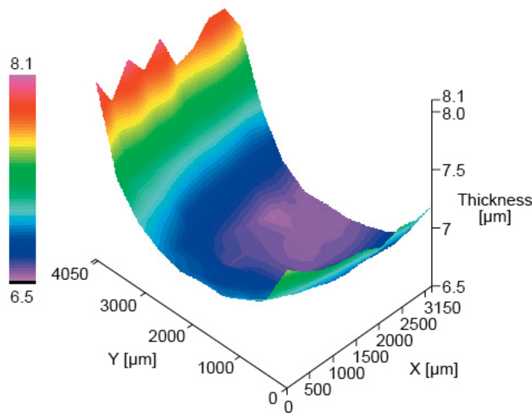


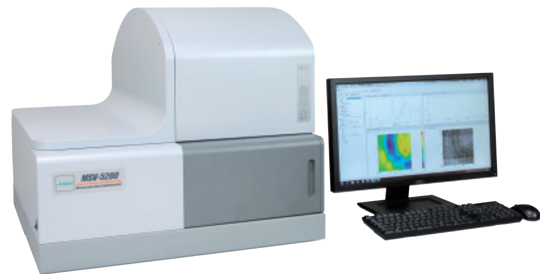
V-600 with SLM-738



Film thickness distribution of protective layer on semiconductor detector

UV/Vis microscope system has optional function of this film thickness distribution measurement using standard film thickness measurement and mapping measurement function in micro area.
The film thickness distribution of semiconductor detector protection layer was calculated from interference curve in NIR region.

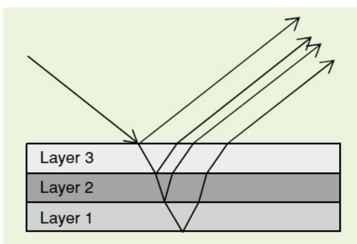


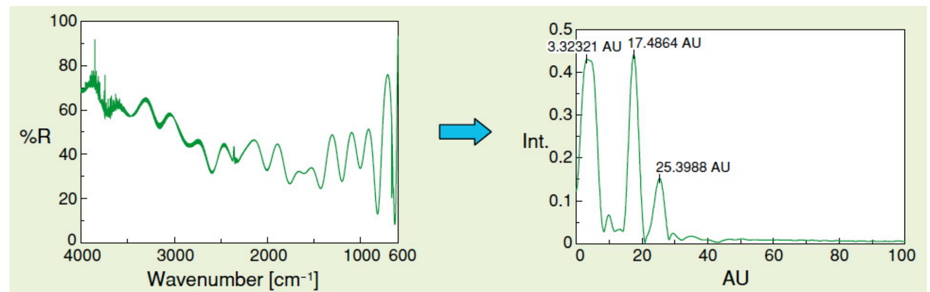


MSV-5000 UV/Vis/NIR microscope

Film thickness measurement of multi layer film by using frequency analysis method

Reflectance spectrum of multi layer film sample consists of complex overlaid multiple interference curves.
JASCO film thickness program can calculate thickness of each layer accurately by using frequency analysis of reflectance spectra.





UTS-2000

FT-IR Microscope system

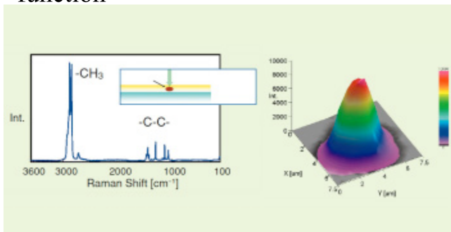
Impurity Analysis

Impurity analysis is one of the most important analyses for quality control and research in the materials science industry. The vibrational spectroscopy technique such as IR and Raman spectroscopy with subsequent analysis using a spectral library is critical for identification of the impurities in products or specific samples. JASCO has developed a wide range of instruments and accumulated a series of applications to meet these impurity analysis requirements.

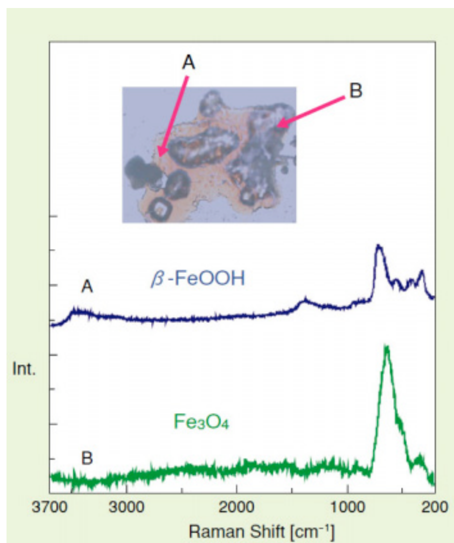
[Sample size] 1 µm 2 µm 5 µm

Raman microscope system

- Non destructive measurements
- Inorganic compound measurements in the low wavenumber region
- Measurement of complex impurities in a short time using high speed imaging function

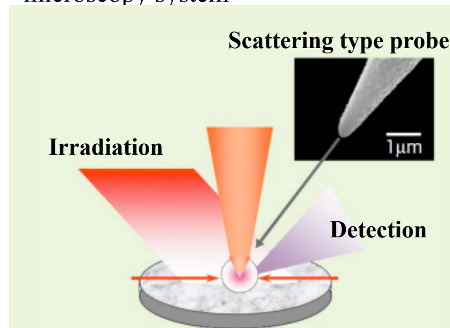


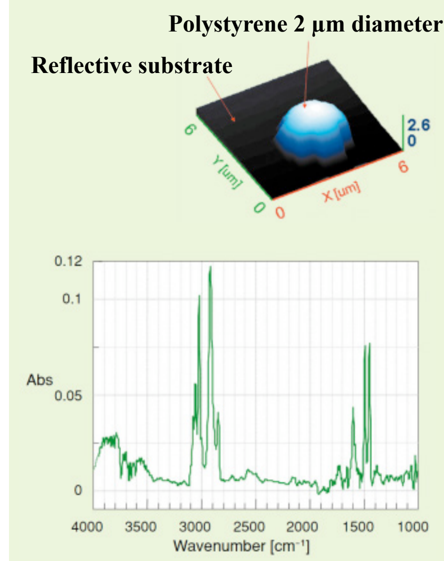
Two different rust portions on an iron sample were measured. The obtained spectra show Fe_3O_4 (B) and Iron Oxyhydroxide (A).



Near Field IR system

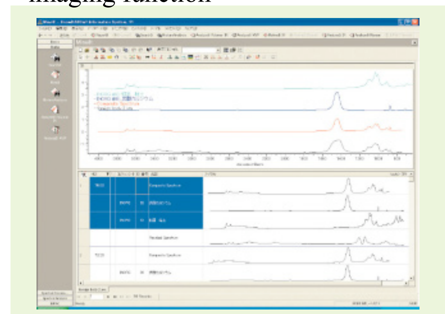
- Measurements with high spatial resolution beyond diffraction limit using Near Field scattering.
- Simultaneous spectra and topography measurements using a scanning probe microscopy system



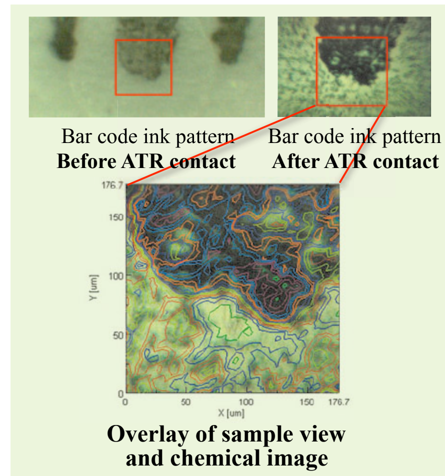


IR Microscope system

- Most extensive spectral database information
- Minimal sample preparation
- Measurement of complex impurities in a short time using high speed imaging function



Simultaneous sample observation and measurement area selection with Clear-View ATR objectives and IQ mapping capability.



Overlay of sample view and chemical image

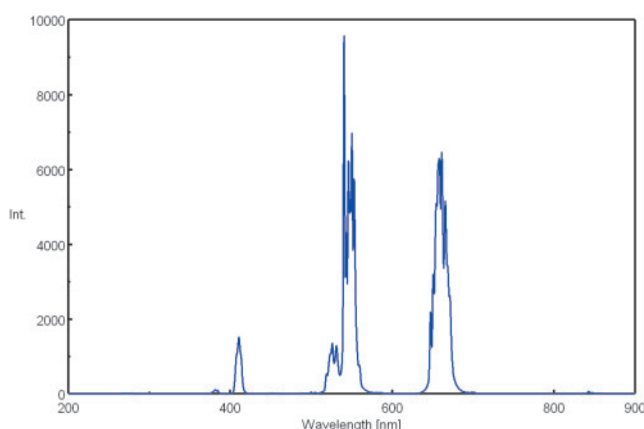
Solar cell material evaluation

JASCO has a wide range of applications for evaluation of cutting edge materials for solar cell.

Material	Application	Instrument
Crystalline silicon solar cell	Impurity analysis	FTIR
	Defect in Photoluminescence	PL
Silicon based thin film solar cell	Hydrogen bond condition	FTIR
	Crystallinity/Stress/crystallite size	Raman
CIGS solar cell	Transmittance and Reflectance characteristics of Transparent electrode, Buffer layer, Glass substrate	UV/Vis/NIR/IR
Dye Sensitized Solar Cell	Crystallization of Semiconductor thin layer electrode	Raman
	Absorption band of Dye sensitized element	UV/Vis/NIR/IR
	Structural analysis	FTIR, Raman

Upconversion Phosphors (UCP) system

Recently, upconversion technique as converting long wavelength light to short wavelength becomes popular in research and development of Solar cell materials. JASCO has developed dedicated evaluation system using FP-8000 with upconversion accessory including 980 nm NIR laser. As one of fluorescence measurement results, several peaks were observed in visible region with 980 nm excitation.

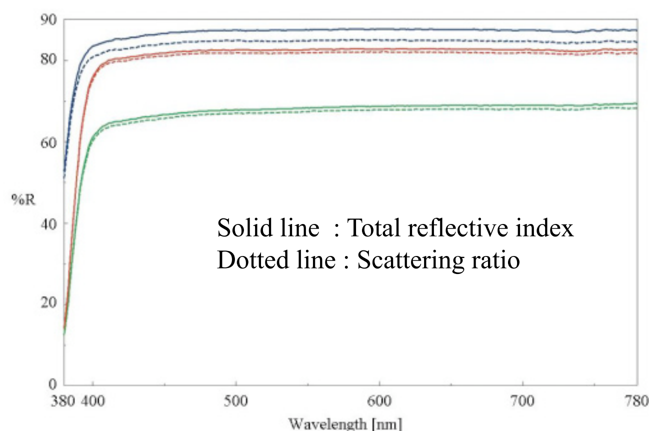


When 980 nm laser is radiated to upconversion Phosphor, green light appears as fluorescence.

Upconversion Phorphors system

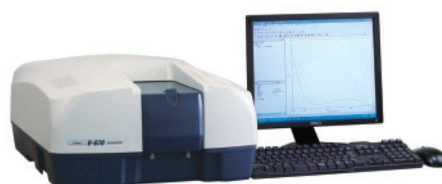
Haze measurement of textured structure

For improving the efficiency of Silicon based thin film solar cell, it is important to develop substrate material which has different textured structures for scattering the incident light. In order to evaluate the scattering property of materials, haze measurement by UV/VIS spectrophotometer for both reflection and transmission is usually utilized.



Spectra of reflection plates with 3 different textures.

Sample	Line	Tt (%)	T4 (%)	Td (%)	Haze (%)
Texture #1	Blue	87.4	84.7	84.7	97
Texture #2	Green	68.2	67.3	67.3	98.7
Texture #3	Red	82.5	81.8	81.8	99.1

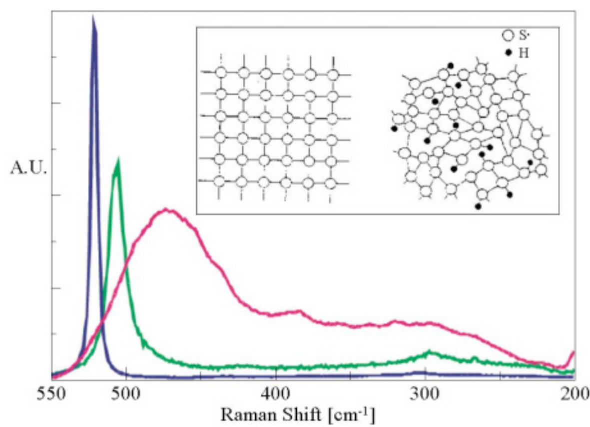


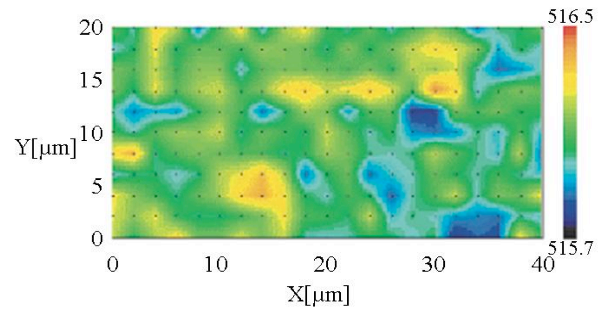
V-670 UV/Vis/NIR spectrometer

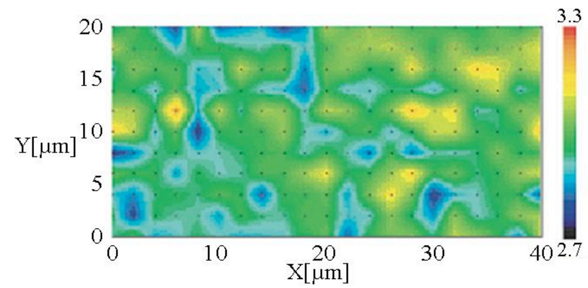
Evaluation of crystallinity of Si for Solar cell

Si peak shift due to crystallinity.

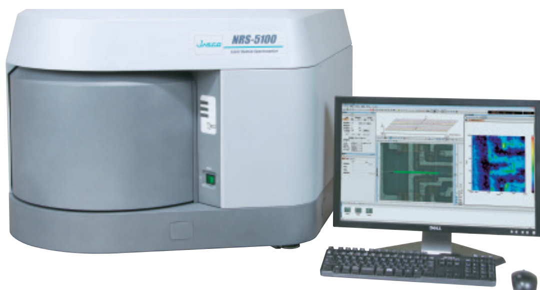
The peak of monocrystal Silicon spectrum shifts to lower wavenumber side as crystallinity of Silicon becomes less with peak shape broader. Distribution of crystallinity was evaluated by peak position and half width in XY mapping measurement of surface of Polycrystalline Silicon.







Crystallinity Image of polycrystalline Silicon on glass substrate



Laser Raman Spectrophotometer NRS-5100

Complex impurities on Silicon Wafer

Impurities on Silicon wafer were measured by high speed imaging and color coded image was created with peak height and PCA mapping analysis. Complex impurities including Protein, Cellulose and Calcium Carbonate were spatially separated and analyzed by using of high spatial resolution linear array detector and high speed imaging.

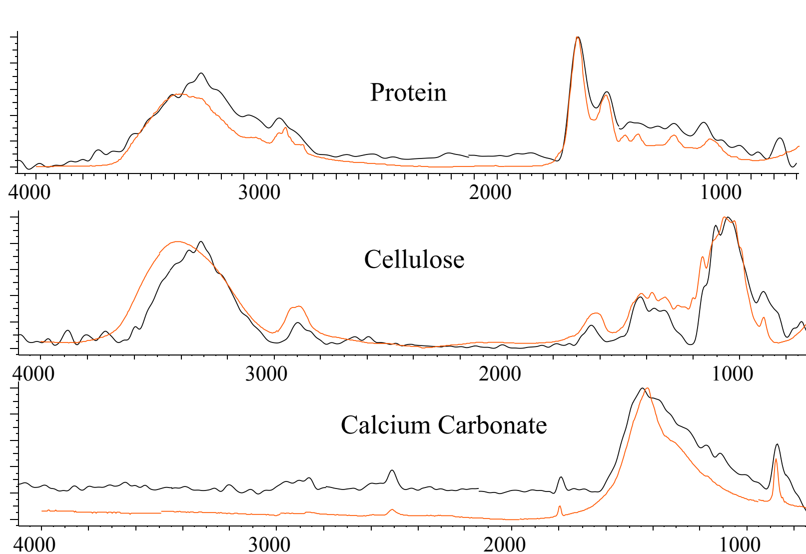
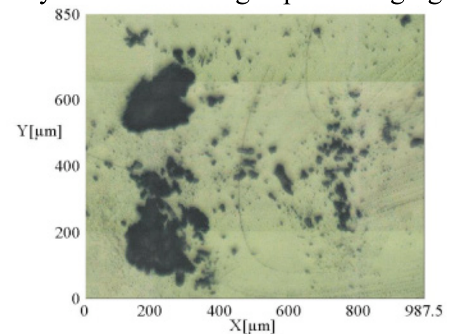
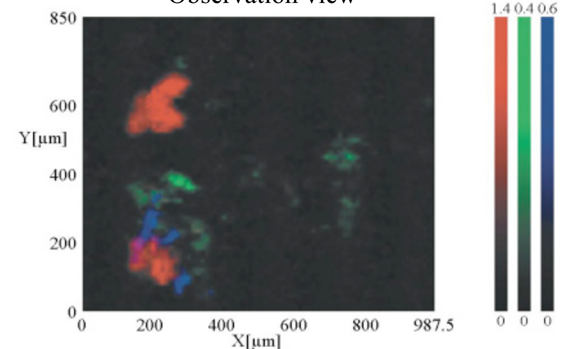


Fig. 1. Sadtler library search result of each component
Black: Measured spectrum / Red : Spectrum in Sadtler data base



Observation view

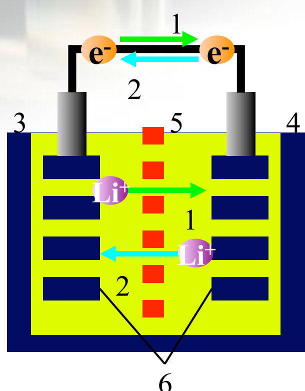


Imaging view

FT/IR-6100 + Microscope system IRT-7000

Lithium Ion battery

JASCO has a wide range of applications for evaluation of cutting edge materials for Lithium Ion battery.



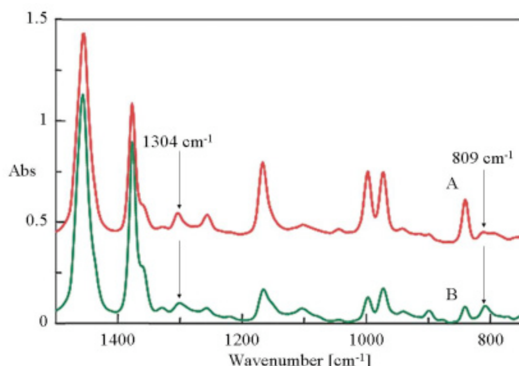
1 : Discharge
2 : Charge
3 : Anode
4 : Cathode
5 : Separator
6 : Binder

Material	Application	Instrument
Anode/Cathode	Crystallization, Deterioration analysis	Raman
Electrode/ Surface of electrolyte	Chemical composition analysis of electrode and surface of electrolyte	FTIR
Binder	Chemical composition analysis	FTIR
Separator	Chemical composition analysis	FTIR

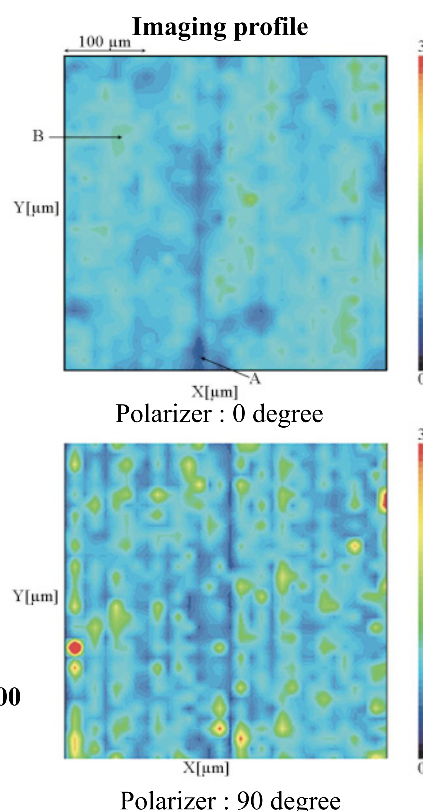
Separator – Orientation distribution analysis of Polypropylene

In general, polyolefin porous material such as polyethylene and polypropylene is used for separator of Lithium Ion battery. IR spectroscopy is widely used for evaluation of such materials in molecular size level.

Here the molecular orientation distribution of stretched polypropylene was evaluated by transmission method using JASCO microscope system IRT-7000 and polarizer. Ratio of peak at 809 cm^{-1} due to vertical vibration to peak at 1304 cm^{-1} due to horizontal vibration is utilized to show the orientation distribution in imaging profiles. By polarization imaging method using IRT-7000, orientation distribution of sample can be seen clearly.



FT/IR-6100 + Microscope system IRT-7000

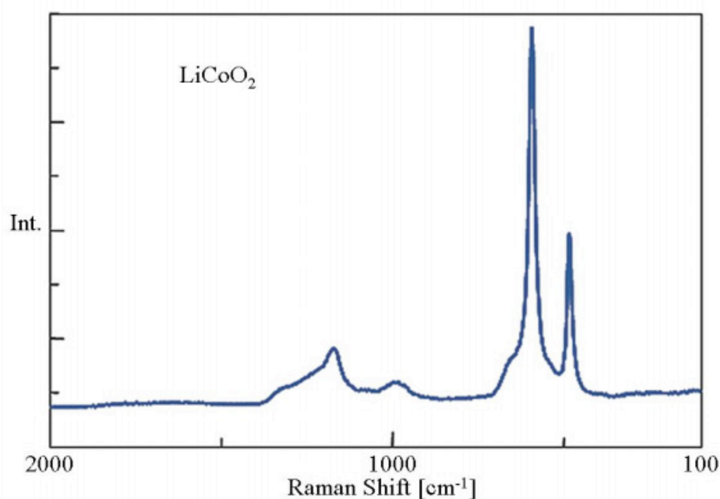


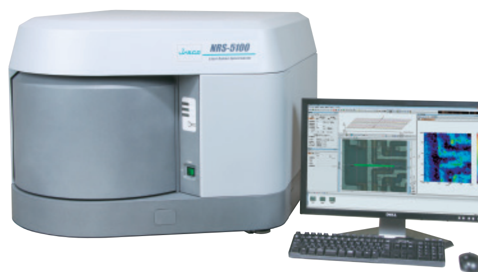
Polarizer : 0 degree

Polarizer : 90 degree

Cathode evaluation

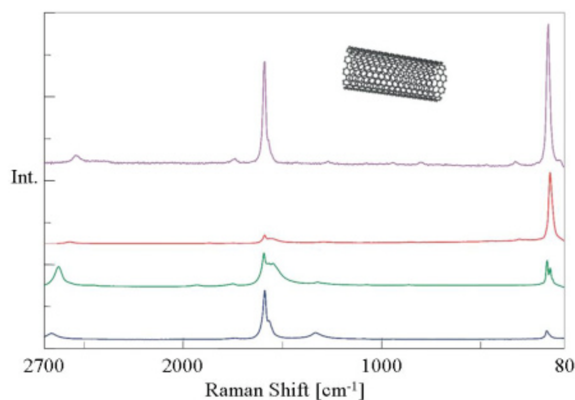
Transition metal oxide such as $LiCoO_2$ is used as material for cathode electrode.
Raman spectroscopy is an effective method for analysis of material deterioration.





Laser Raman Spectroscopy NRS-5100

Anode evaluation – Raman spectroscopy for Carbon nanotube (CNT) with different excitation

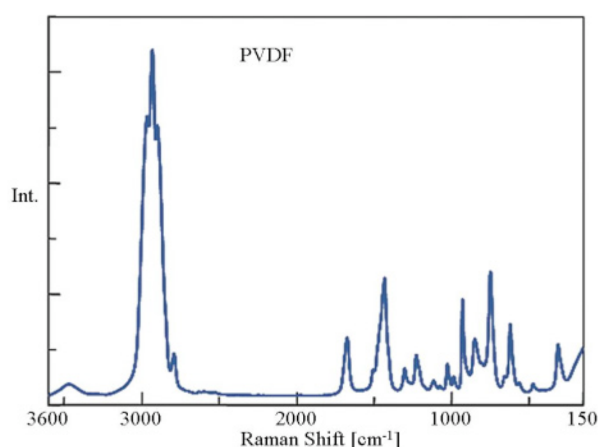


Raman spectrum of carbon nanotube depends on excitation wavelength due to its diameter and helicity.
It is possible to measure carbon nanotubes with different diameters selectively by changing excitation wavelength and to evaluate crystallinity by D-band.

JASCO NRS-5000/7000 series with multi laser mounting capability can provide optimum method for carbon nanotube evaluation.

Laser Raman Spectroscopy NRS-5100

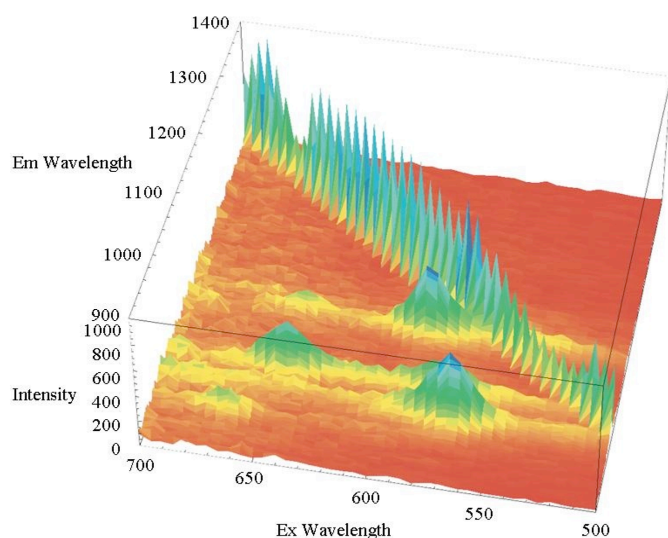
Binder evaluation



PVDF is one of the materials used for binder of Lithium ion battery. The material quality and distribution condition of the binder are closely related to lifetime and performance of battery. Raman imaging can analyze distribution condition of both active materials and binder.

Chirality analysis of Carbon nanotube

JASCO NIR Spectrofluorometer is the upgraded system based on FP-8600 with NIR Photomultiplier tube, which has wider measurement range up to 1700 nm.
This system can measure fluorescence spectra of materials which have fluorescence in NIR region such as rare earth materials and Carbon nanotube. The evaluation method by 3D fluorescence spectrum measurement using of excitation / fluorescence wavelength scanning function is very useful especially for carbon nanotube sample since its characteristics depends very much on tube diameter and chiral angle.

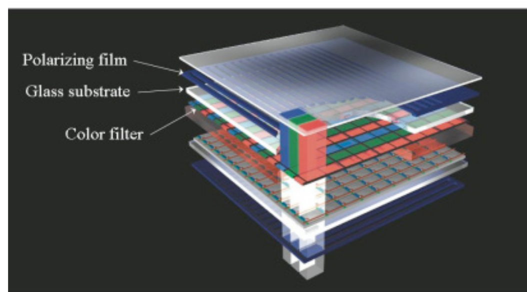


NIR 3D fluorescence spectrum of single layer carbon nanotube

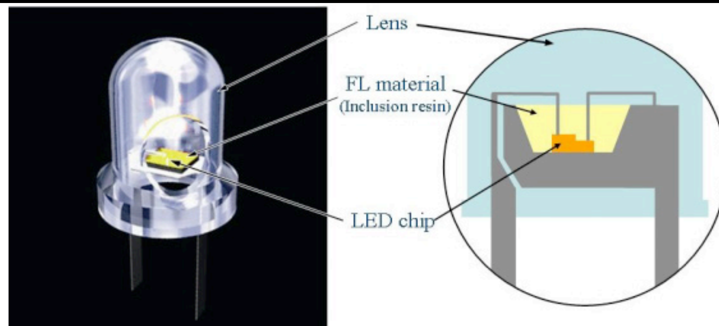
NIR Spectrofluorometer FP-8600NIR

Display / Illumination

Topics	Application	Instrument
Oriented film/Substrate	Impurity/abnormality analysis	FTIR microscope
	Contrast evaluation by polarization spectroscopy	UV/Vis
Color filter	Analysis of pigments and binder resin	FTIR microscope
	Color appraisal	UV/Vis, UV/Vis microscope
Organic EL/LED	Color analysis	Fluorescence
	Film thickness, optical constant	Ellipsometer
Energy conversion of emitting material	Quantum efficiency	Fluorescence



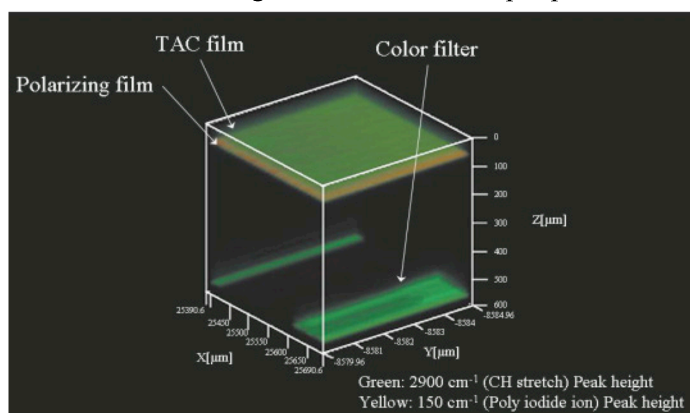
Graphic image of LCD panel



Graphic image of LED

3D imaging of LCD panel

Raman spectroscopy is optimum measurement method to obtain 3D imaging of samples with even complex structure such as LCD Panel. In this application, 3-D image indicates the structure of polarization film which is sandwiched by TAC films, thickness of glass substrate and depth position of color filter.

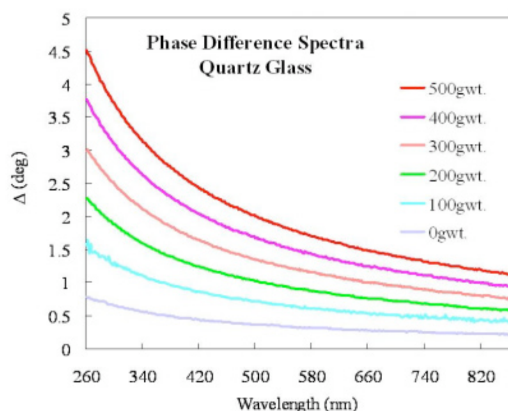


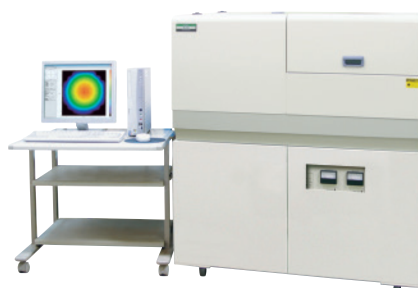
3D image of key band in each layer

Laser Raman Spectrophotometer NRS-7100

Photoelastic phase difference measurement

A feature such as the high measurement sensitivity of minute phase difference can be applied to high sensitive photoelastic measurement. Left side figure shows overlaid phase difference spectra when applying load at every 100 gram-weight on the circular synthetic quartz plate (20 mm diameter, 5 mm thickness). As conventionally used Senarmont Method has low sensitivity, it is impossible to detect photoelastic phase difference until large load using hydraulic pressure is applied, to the extent that glass is almost destroyed. On the other hand, PEM method can detect the photoelastic phase difference with good signal to noise ratio. The value of 3.48+/-0.02Br (nm/cm)/(kg/cm^2) was calculated at 546 nm, and this obtained value is in good agreement with the value in Heraeus Kulzer's catalogue.

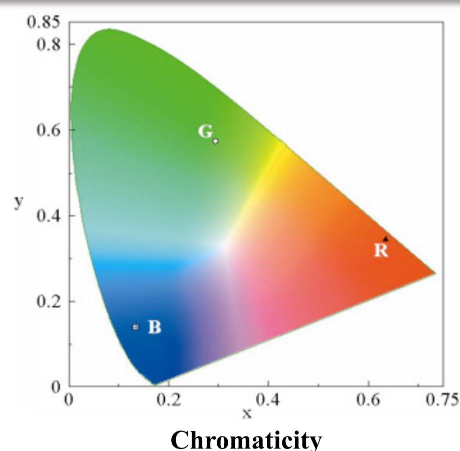




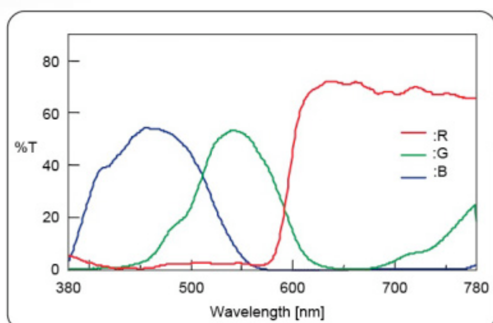
Ellipsometer M-220

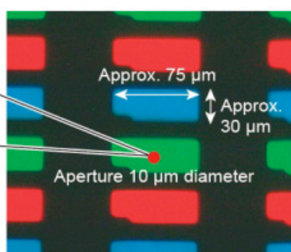
Transmittance measurement of color filter for LCD panel

JASCO MSV-5000 UV/Vis/NIR Microscope system allows wide range of applications in material research field such as evaluation of optical characteristics of functional crystal, band gap measurement and film thickness measurement of semiconductor materials and evaluation of transmission / reflection property of micro size devices.



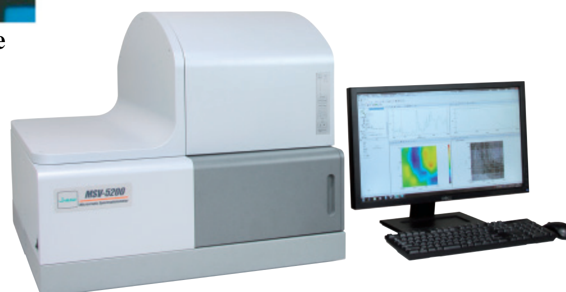
Chromaticity





Microscopic image

Transmittance spectra of color filters for LCD panel
A circular 10 µm aperture was applied for each subpixel of red, green and blue (R, G, B).



MSV-5200 Microscopic spectrophotometer

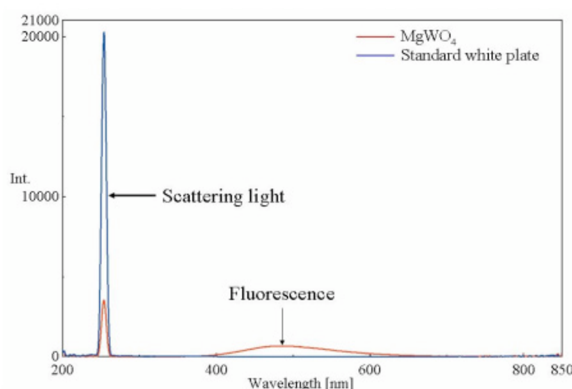
Measuring system for Fluorescence / Phosphorescence quantum yield

Quantum yield measurement is essential to evaluate fluorescent materials, such as organic EL or white LED used in illumination system. Three models of integrating sphere are available for FP-8000 series for measurement of total fluorescence of films, liquid and powder samples. Quantum yield can be calculated by analyzing obtained spectra using [quantum yield calculation] program.
Especially by using a model ILFC-847 100 mm diameter integrating sphere unit which can cool the sample by liquid nitrogen, measurement of phosphorescence quantum yield of material for organic EL can be done in addition to fluorescence quantum yield measurement.

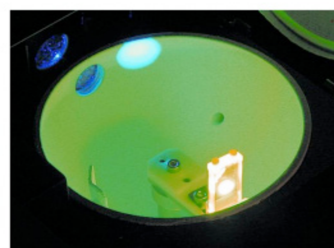
FP-8500 + ILF-835 + ESC-842

Fluorescence quantum yield measurement of magnesium tungstate

Magnesium tungstate used as blue-white fluorescent material in fluorescent lamp was sandwiched between two KBr plates and fluorescence spectrum was measured using FP-8500 with ILFC-847 / 100 mm diameter integrating sphere unit. Then quantum yield was calculated and internal quantum efficiency was determined to be 80.8 %, which is in good agreement with the published value of 81 % (J.IIIum. Engng.Inst.Jpn.Vol.83 No.2, 1999)

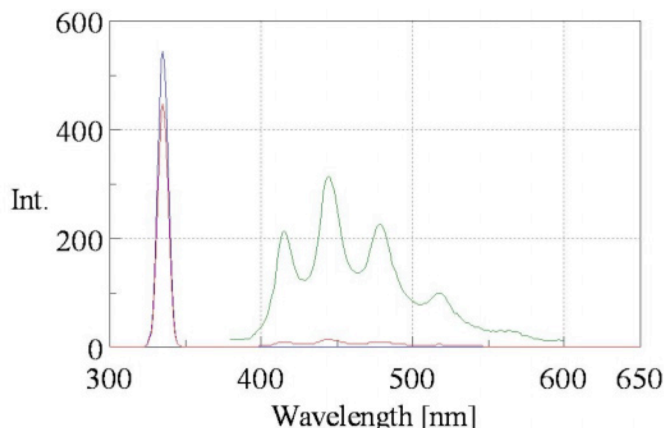


Fluorescence spectrum of $MgWO_4$ and a standard white plate

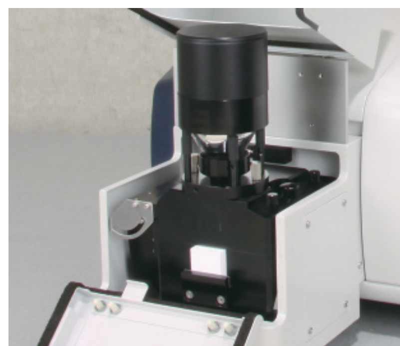

Inside of integrating sphere

Phosphorscence quantum yield measurement of benzophenone

Benzophenone was measured using FP-8500 with ILFC-847 / 100 mm diameter integrating sphere unit by cooling sample by liquid nitrogen and then phosphorescence quantum yield of bezophenone was determined to be 93 %.



Phosphorescence spectrum of benzophenone

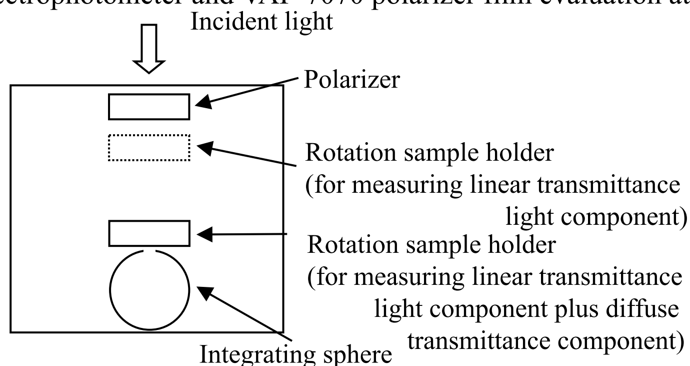


Integrating sphere with dewar

Polarization film evaluation

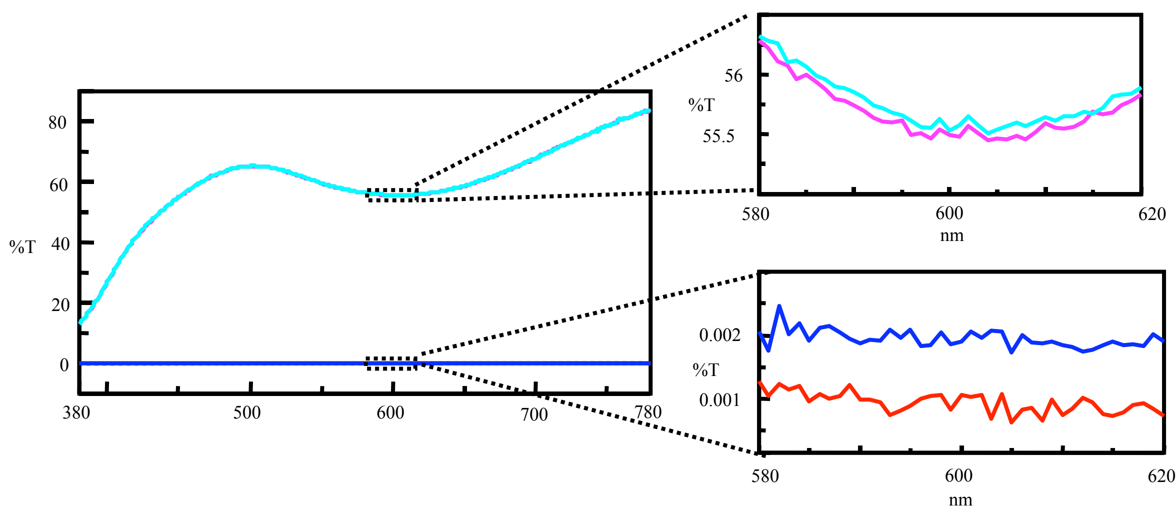
With innovation for higher quality of the above high technology products, much higher accuracy have been required for quality control of the polarizer to evaluate optical characteristic or color design. Liquid crystal display industry is especially proceeding to achieve higher quality of display, and it is now getting very important to evaluate shielding capability more precisely on condition that polarized prisms are in crossed-Nicol status.

In order to evaluate polarizer accurately, JASCO offers evaluation system consisting of V-7100 UV/VIS spectrophotometer and VAP-7070 polarizer film evaluation attachment.



Sample compartment diagram

JASCO V-7100 with VAP-7070 system



Transmittance spectra of polarizer for crossed-Nicol and parallel

- Spectrum of crossed Nicol when mounting sample just in front of the integrating sphere
- Spectrum of crossed Nicol when mounting sample having some distance from integrating sphere
- Spectrum of parallel when mounting sample just in front of the integrating sphere
- Spectrum of parallel when mounting sample having some distance from integrating sphere

Power semiconductor

SiC and GaN are power semiconductor materials which have big band gap characteristics and capability to control high current.

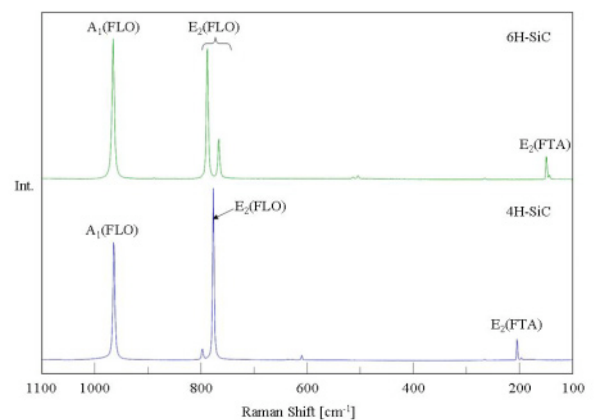
Application	Instrument
Chemical composition / condition	FTIR, Raman spectrophotometer
Band gap	UV/Vis spectrophotometer
Carrier concentration of SiC crystal	Raman spectrophotometer
Photo luminescence (PL) measurement of InGaN	Near Field System
Porous distribution, Film thickness, Density	FTIR, Ellipsometer

Evaluation of SiC crystal polymorphism

It is well known that SiC has more than 200 different types of polymorphism depending on atomic arrangement and each polymorphism has different physical property. Among such many types of polymorphism, there are the most valuable ones starting from 4H polymorphism which has the biggest band gap and also high mobility and the trials have been attempted to grow crystals selectively as one of hot topics and challenge in field.

Raman spectroscopy can evaluate and determine the type of polymorphism by analysis of peak patterns due to lattice vibration of crystals, appearing in low wavenumber region where the measurement is quite difficult by IR spectroscopy.

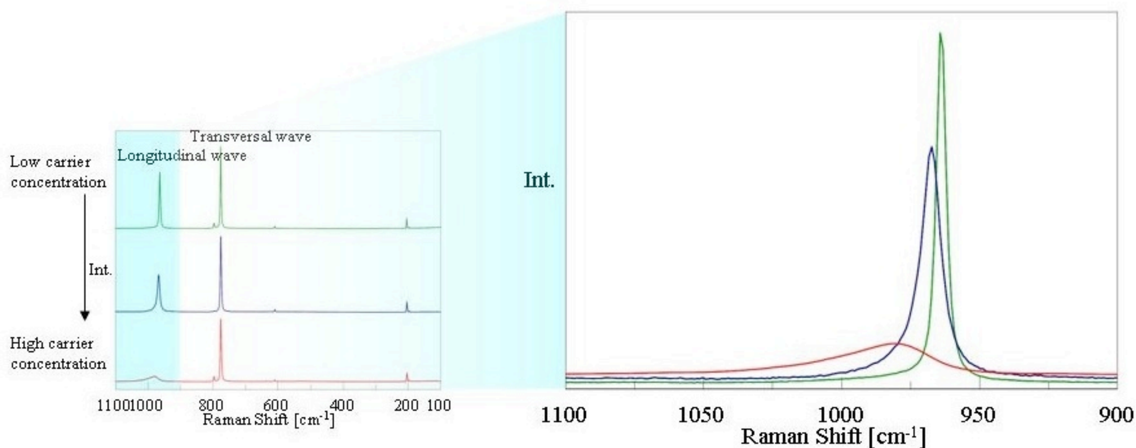
Laser Raman Spectrophotometer NRS-5100



Raman spectra of 6H-SiC and 4H-SiC

Evaluation of carrier density

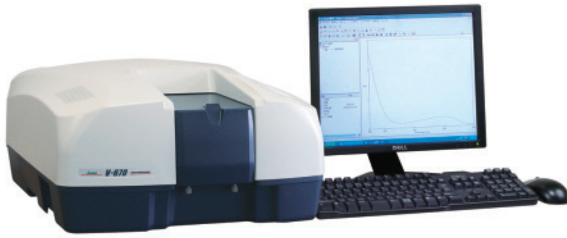
Collective oscillation of free electron which exists in n-type semiconductor as carrier is called as Plasmon, which is longitudinal wave similar to sound wave. This plasma oscillation is the same kind of wave as the longitudinal wave due to lattice vibration, LO phonon and therefore they interact with each other. It is known that the Raman peak due to such interaction shifts to higher wavenumber side with broadening peak shape when carrier concentration is increased and accordingly, the absolute carrier concentration is evaluated by the peak position. In this example, 3 kinds of 4H-SiC monocrystal were measured using JASCO NRS-5100 Raman Spectrophotometer. Raman spectroscopy makes it possible to evaluate sample in micron level spatial resolution which is difficult by the technique for Hall measurement, to analyze surface by imaging and also to evaluate depth profile with ease as non-destructive method.



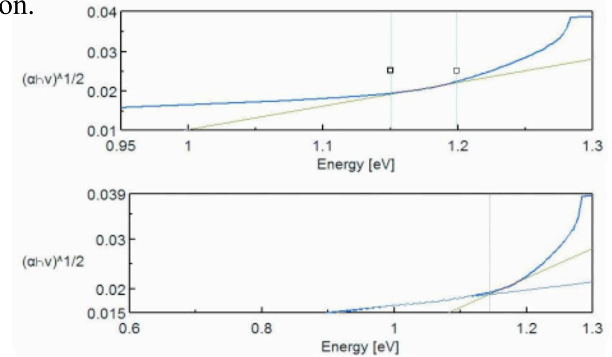
Raman spectra comparison about carrier density of 4H-SiC

Evaluation of band gap

Band gap generally refers to the energy difference between the top of the valence band and the bottom of the conduction band in insulators and semiconductors. In research and development of semiconductor materials, particularly power device, the evaluation of the band gap is considered as one of the most important factors for higher performances. This band gap can be obtained from transmission / reflection spectra in UV region. JASCO V-670 spectrophotometer is optimum system for this application.



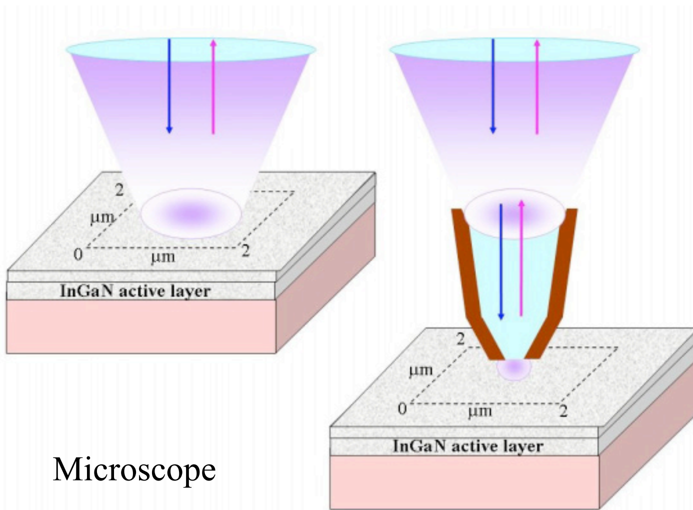
V-670 UV/Vis/NIR spectrometer



Calculation of band Gap

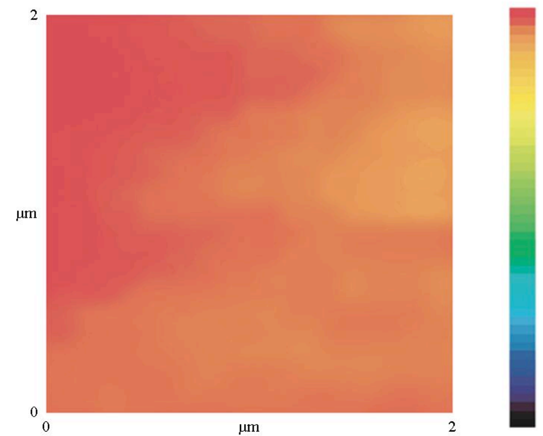
nm scale imaging of chemical composition distribution of GaN type semiconductor

Right figures show the Indium composition distribution on the InGaN by microscopic photoluminescence(upper) and near-field photoluminescence(lower) method respectively. As clearly seen, it is quite difficult to see the Indium composition distribution by the conventional FTIR microscope, but the Near Field microscope is essential for applications requiring 100 nm spatial resolution.

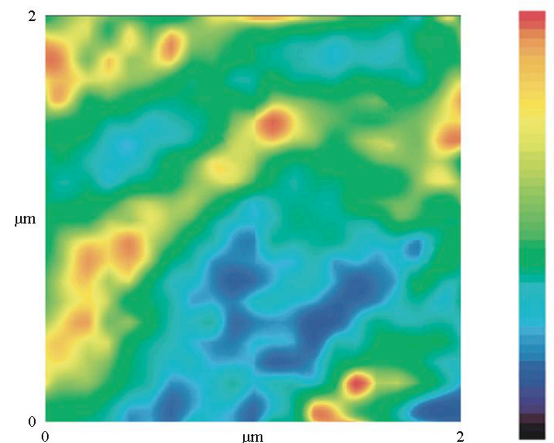


Microscope

Near-field



Microscopic PL



Near-field PL

Near-field spectrometer NFS-330

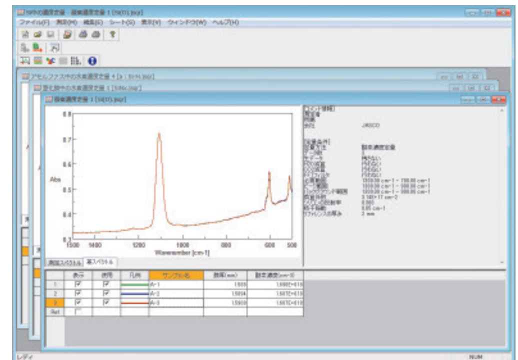
Other applications

Quantitative analysis of light element impurity in silicon

In order to evaluate the quality of wafer, it is important to analyze the concentration of oxygen and carbon in silicon material. For establishing the reliable analysis method, JASCO supplies FT/IR-6000 system with dedicated software to measure oxygen and carbon with ease and analyze quantitatively.

The system can also evaluate molecular bonding state of Si-H, Si-H_2 in amorphous silicon and Si-H and N-H in silicon nitride film.

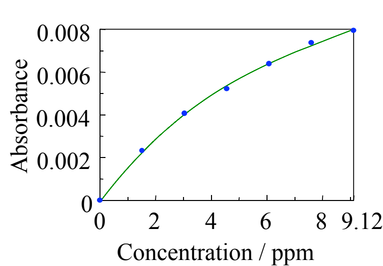
Fourier Transform Infrared Spectrometer FT/IR-6000

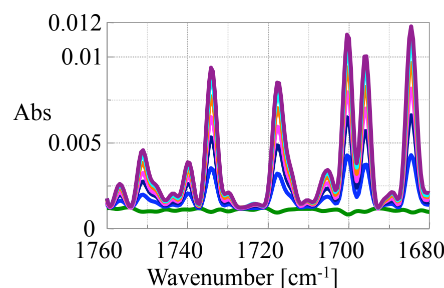


Quantitative analysis of O2 in Silicon

Gas analysis system in semiconductor field

In order to measure accurately low level gas concentration, it is essential to select long path gas cell and to remove influence from CO_2 and H_2O in air. JASCO supplies FT/IR-6300FV, full vacuum type with 12M gas cell as the most suitable system for high sensitive gas analysis.

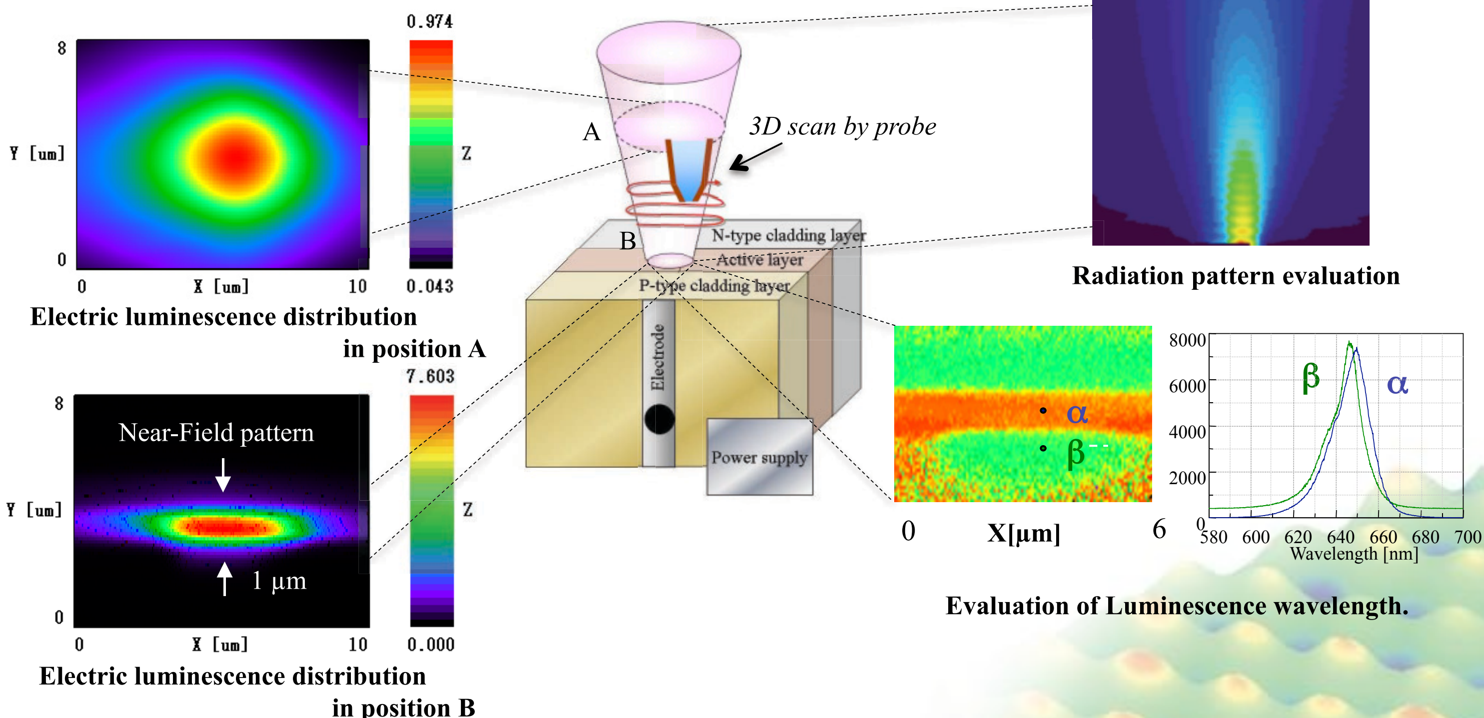




FT/IR-6300FV+12M gas cell

Optical characteristics evaluation of semiconductor laser

JASCO Near-field system can evaluate optical characteristics of semiconductor laser in nano scale. Generally, this evaluation method consists of radiation pattern analysis, electric luminescence distribution and wavelength of luminescence.



Electric luminescence distribution in position A

Electric luminescence distribution in position B

Radiation pattern evaluation

Evaluation of Luminescence wavelength.