TOKYO INSTRUMENTS, INC.

3D Raman Confocal Microscope

Nanofinder®30

Best in the World Specifications

Awards

Nanotech 2004 Grand Prize
"Evaluation and measurement section".
16th New Technology and New Product prize
"Excellent Small and Medium-size Enterprises".

High sensitivity (4th order of Si Raman within only 1 min exposure)

Fast Raman imaging, Low excitation power

High spatial resolution (130nm@364nm, 200nm@488nm) , **50 nm with TERS technology**

High spectral resolution 0.5 cm^{-1}/0.1 cm^{-1} (Echelle grating technology/Curve Fitting software)

Laser scanning microscope option

Autofocus. Automatic switching between 3 excitation lasers.
Simultaneous Confocal Raman Image (material specific) and Confocal Laser Optical Image.

Near Field Apertureless TERS microscope option

Combined Confocal Raman & Scanning Probe Microscope. Spatial resolution to 50 nm.

Deconvolution software

Provides 1.5 times improvement in resolution.
Raman Confocal Imaging with spatial resolution of 100 nm or less.
Standard resolution λ/4.2, λ : excitation lasers (488 nm, 532 nm, 633 nm, 785 nm) .

Nanofinder® 30
3D Raman microscope
TOKYO INSTRUMENTS, INC.

High spatially resolved images, full spectroscopy data from every mapping point.

Nanofinder® 30

Nanofinder® 30 is a Raman Confocal spectroscopy device with high sensitivity and high spatial resolution. It can do 3D Raman imaging with lateral spatial resolution of 200 nm and axial resolution of 500 nm. (→ 3D Confocal Raman Microscope)

Moreover, combined with Scanning Probe Microscope (SPM), it can perform simultaneously measured Raman and Topography Imaging. With Tip Enhanced Raman Scattering (TERS) technology it can obtain lateral resolution of 50 nm or less. (→TERS Aperture Less Near Field Raman Microscope)

With UV excitation, it is ideal for Si device stress distribution measurement.

Applications:

Semiconductor inspection, solid and liquid crystals, polymers, thin films, lightguides, glass, drug test, nanosized particles.

Stressed samples (Si, ceramics, compound semiconductors, etc.); Nanobiotechnology; CNT (Carbon nanotubes), etc.

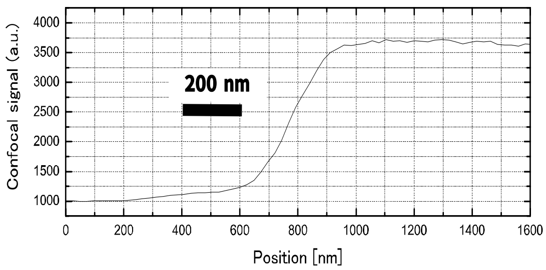
3D Confocal Raman system features

●High spatial resolution

Nanofinder® 30 is a Confocal Raman system, designed to obtain **maximum** spatial resolution. When using a 488 nm laser and an air objective lens lateral resolution of 250 nm is possible.

With UV excitation of 364 nm and an immersion lens lateral resolution can be as low as **130 nm**.

Raman signal step response with lateral resolution of ～250 nm.



Excitation：488 nm, objective lens：100xN.A.0.9.
Sample: sharp Si/SiO_2 border.

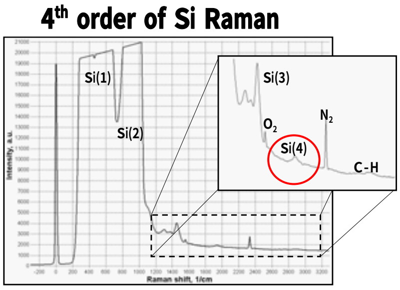
●High sensitivity, high speed 3D image measurement

With the *Nanofinder® 30* fourth order of Si Raman signal can be detected within one minute exposure (see figure below).

2D･3D images can be acquired rapidly.

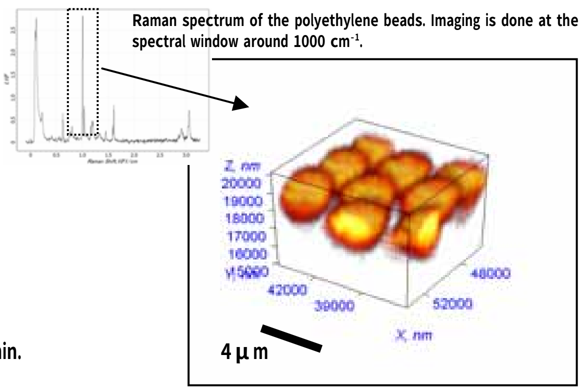
In addition, nondestructive low laser excitation power (sub μW～mW) can be applied.

4th order of Si Raman



Measurement condition:
Excitation laser：488 nm、power on the sample 5 mW、accumulation 1 min.

High sensitivity and 3D high-speed Raman imaging



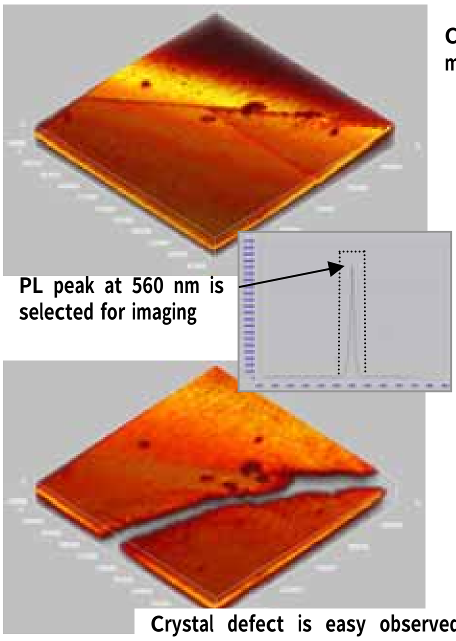
3D Raman image of polyethylene beads.

High spatially resolved images, full spectroscopy data from every mapping point.

●Simultaneous optical and spectral image

The Confocal Laser Microscope option provides the acquisition of 2 images after a single scan: a confocal laser microscope image (using laser light, reflected from sample) and a confocal spectral image (using Raman or luminescence spectra, scattered by the sample).

ZnTe. Crystal defect image.



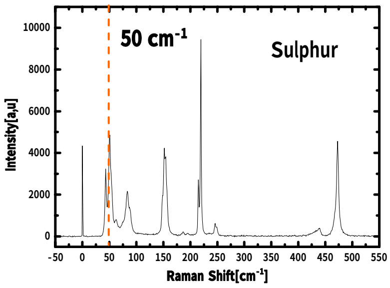
Confocal laser microscopic image

PL peak at 560 nm is selected for imaging

Crystal defect is easy observed with 3D spectral imaging

●Raman Spectroscopy nearby to excitation laser line

Raman signals below 100 cm^{-1} are easily detectable.



●3 excitation laser wavelengths

Up to 3 different excitation lasers can be installed in one system. The excitation laser wavelength is changed automatically with a single computer click.

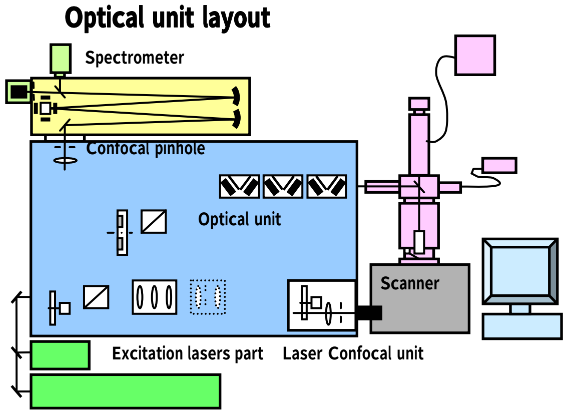
●Flexible system design

A zoom beam expander allows the excitation laser beams to have optimal diameters for any microscope objective lens.

Smooth motorized control of the confocal pinhole size allows optimization for highest spatial resolution or highest sensitivity.

Waveplates and Glan prisms are used for polarization measurements.

Optical unit layout



●High throughput 52cm imaging spectrometer

Motorized turret with 4 gratings. Dielectric coating for spectrometer mirrors for high throughput. 2 exit ports for CCD and PMT (APD, Streak-camera).

NEW ! A new Echelle grating option.

This option allows extremely high spectral resolution of 0.5 cm^{-1} (per 1.5 CCD pixel).

●Automating

Different system configurations (for different lasers or microscopic objective lenses, enc.) are saved in computer memory and changed by a single keyboard click.

Motorized control for laser power, beam diameter, polarization orientation, pinhole size, grating and central wavelength selection, detector, shutters etc.

●AFM option. TERS option

With a specially designed AFM head optical access to the probe apex with high NA microscopic objective lenses is possible (0.7 from the top, 0.42 from side and 1.4 from bottom) → **TERS Aperture Less Near Field Raman Microscope**.

High spatially resolved images, full spectroscopy data from every mapping point.

●Advanced software

The *Nanofinder® 30* software has an intuitive user-friendly interface and includes universal tools for advanced spectroscopy measurements with multiple calibration and curve fitting functions, Fluorescence Life Time Imaging functionality, 1-,2-,3-D mapping facilities with full spectral or fluorescence decay information saving. The mapping program can control an AFM to obtain Raman and topography images simultaneously. Multiple filters, functions and database options are available for post data and image processing and analysis.

Software structure

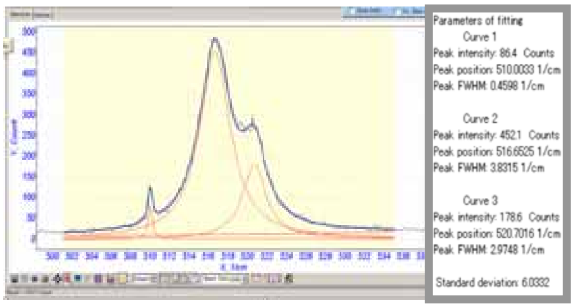
Operation system: Windows XP
Hardware control, spectral and mapping data acquisition
Real time display and data processing
Imaging of variety spectral functions, image analysis

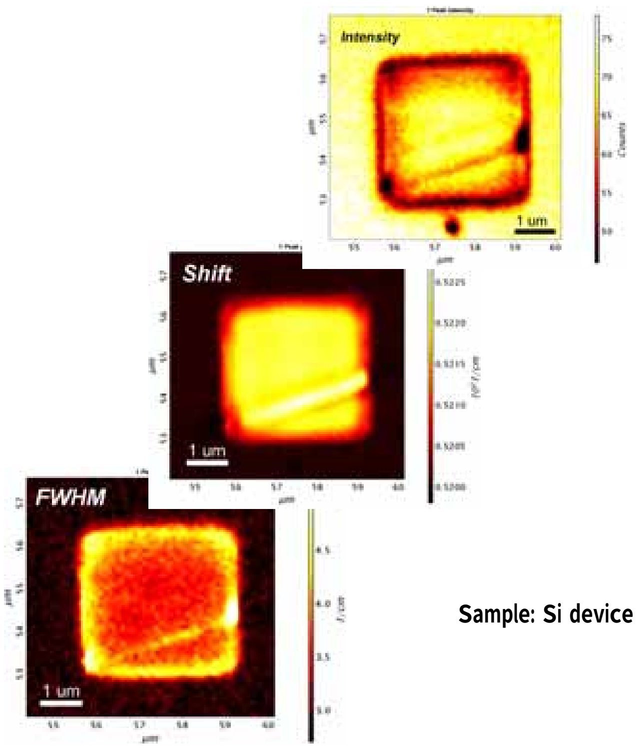
Software options

Spectral line fitting	Data Base
Deconvolution	Custom-designed

Spectral line fitting software

Spectral features can be fitted with up to 3 peaks of Lorentzian and Gaussian lineshape. All these 3 peaks can be used for construction of Raman Intensity, Shift, and half bandwidth (FWHM) images.

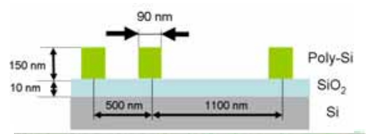




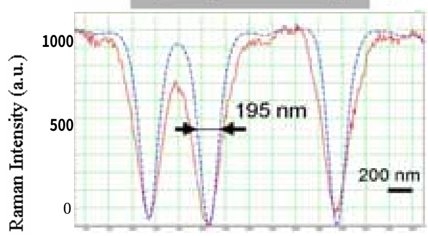
Sample: Si device

Deconvolution software function for spatially improved imaging

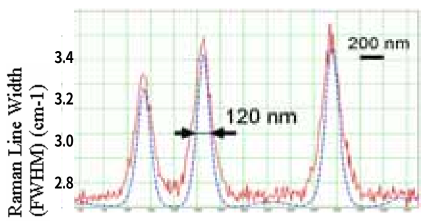
In the example shown on the right the application of a deconvolution function has improved the imaging of fine details from 295 to 195 nm (Raman intensity image) and from 160 nm to 120 nm (Raman line FWHM image).
In general, the deconvolution function application leads to about **1.5 times** of spatial resolution improvement.



Si device sample structure



Raman line at 520 cm^{-1} intensity cross-section



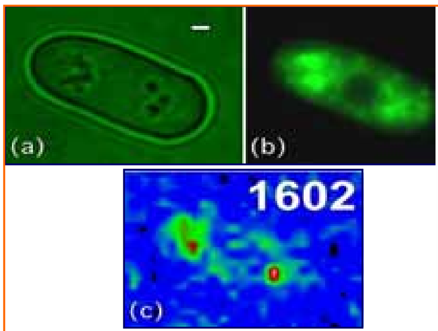
Raman line half bandwidth (FWHM) cross-section

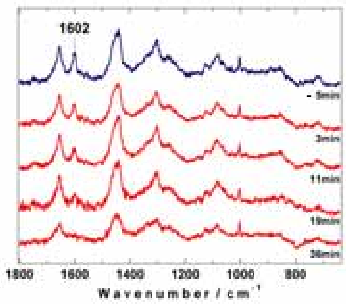
Red solid line - row data,
Blue dashed line - after the deconvolution function application.

Nanofinder® 30 3D Raman microscope TOKYO INSTRUMENTS, INC.

High spatially resolved images, full spectroscopy data from every mapping point.

●Applications Examples





Yeast cell. Microscopic image (a), fluorescence GFP image (b). Raman image (c) shows the distribution of highly metabolic- active mitochondria.

Raman peak at 1602 cm^{-1} shows degradation in metabolic activity due to suppression of respiration by KCN.

Raman band at 1602 cm^{-1} is called the "*Raman spectroscopic signature of life*"

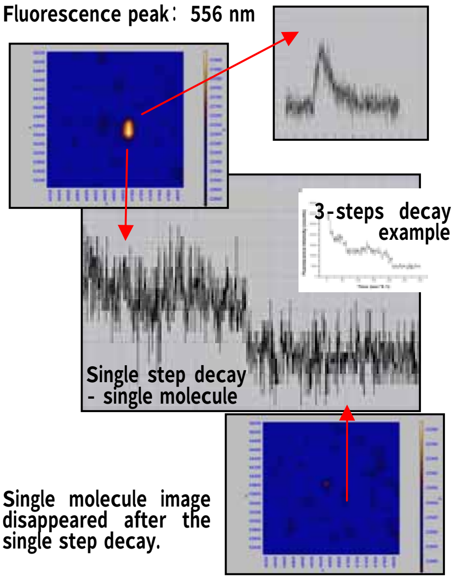
Data courtesy of Prof. Hiro-o Hamaguchi, The University of Tokyo.

Single molecule detection

Fluorescent image

Fluorescence spectrum
20 sec. accumulation

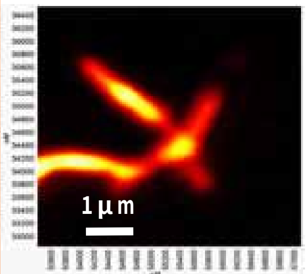
Excitation laser: 532 nm
Power: 200 nW
Fluorescence peak: 556 nm



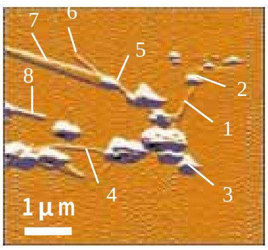
Single molecule image disappeared after the single step decay.

Simultaneous AFM topography and Raman image.

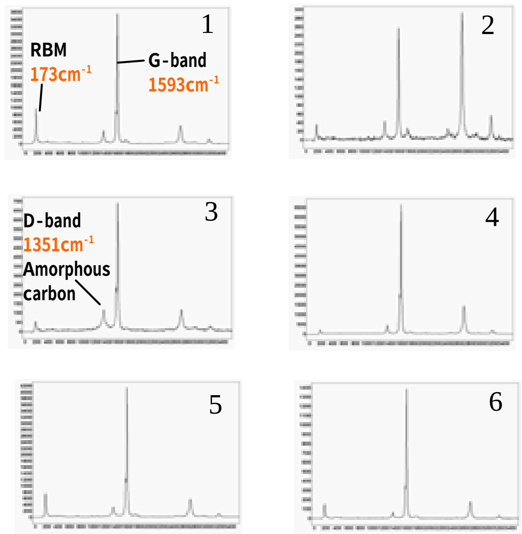
Single-walled Carbon Nanotubes (SWCNT)

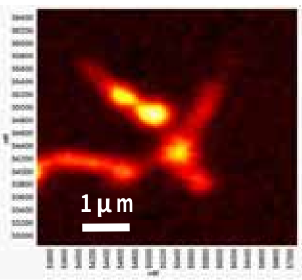


Raman image at 1593 cm^{-1} (G-band)

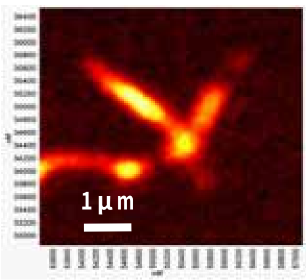


AFM topography image





Raman image at 1351cm^{-1} (D-band)



Raman image at 173 cm^{-1} (RBM)

Raman spectra measurement conditions :
- Excitation laser: 488 nm, Power: 1.5 mW
- Objective lens: 100xOil, N.A.1.3

Raman spectra from points 1-6, shown in AFM topography image. Points 1-6 show Raman spectra typical for semiconducting type SWCNT. Points 7, 8 do not show Raman spectra with 488 excitation laser wavelength. They revealed metallic type SWCNT Raman spectra when the excitation was done with 633 nm laser wavelength.

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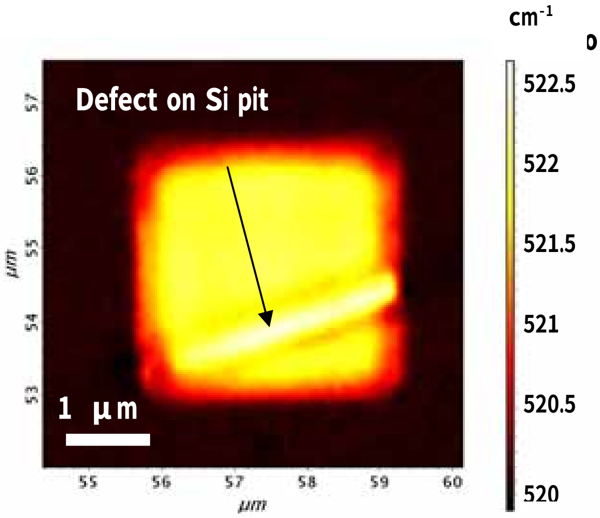
3D Raman microscope
TOKYO INSTRUMENTS, INC.

High spatially resolved images,
full spectroscopy data from every mapping point.

UV system for strained Si measurements



Si stress distribution image
Area : 5.5 × 5.5 μm, Laser power : 0.4 mW
Mapping step : 100 nm (55×55 points)
Exposure : 0.1 sec/point, Total measurement time : 5min.

●Stress measurement of Si device

Local stress on the surface of a Si device can be evaluated by analyzing the shift of the Si Raman peak. For this measurement *Nanofinder®30 UV* model was developed. The UV model combines both: high spatial and spectral resolution.

●Echelle grating feature

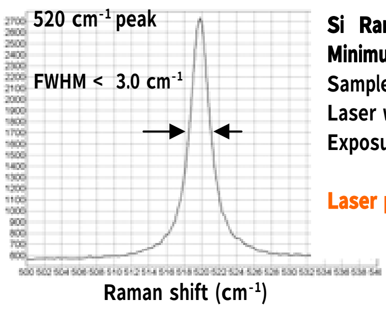
To obtain high spectral resolution (0.5 cm^{-1}) and high throughput (30 %) the 52 cm focal length spectrometer was designed to adopt an Echelle grating. To get the same spectral resolution with standard spectrometer it is necessary to use a much larger device (1.3 m focal length).

●Si stress measurement resolution

With 52 cm spectrometer, equipped with an Echelle grating it is possible to measure:
Strain of 0.05 % <0.5 cm^{-1} @364 nm (hardware resolution)
Strain of 0.01 % <0.1 cm^{-1} (spectral line fitting software).

●Non-destructive analysis

Using resonance excitation a low laser power is sufficient to acquire Raman spectra with narrow bandwidth (no sample heating) and good S/N ratio.



Si Raman peak at 520 cm^{-1}
Minimum distortion of data.
Sample: monocrystalline Si
Laser wavelength: 364 nm
Exposure: 1 sec

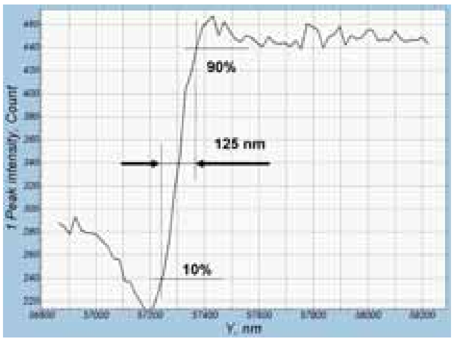
Laser power: 0.4 mW

●Ar ion excitation laser at 364 nm line

With the 364 nm excitation wavelength the penetration depth inside Si wafer is only 4 nm: an extremely thin surface layer can be measured. Confocal optics and optics inside spectrometer are optimized for UV excitation. Optimized optics for UV-VIS excitation is also available.

●Highest spatial resolution

With UV excitation wavelength and optimized confocal optics lateral resolution of 130 nm (as shown in the figure below) is possible.



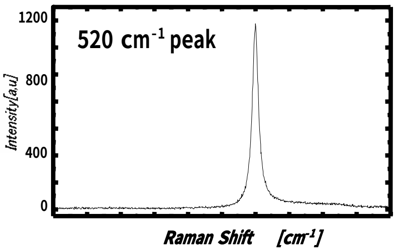
Step response in lateral direction of < 130 nm
Step response = distance, when signal increased from 10% to 90% from maximum value.
Excitation laser wavelength 364 nm, objective lens 100xImmersion, N.A.1.2

High spatially resolved images, full spectroscopy data from every mapping point.

● Sample data ～ high spectral resolution Raman shift measurement ～

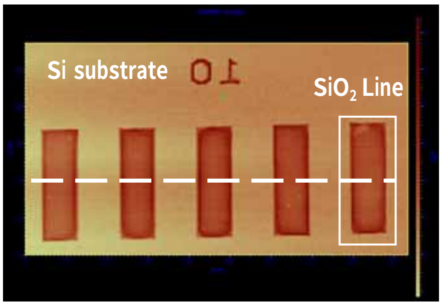
SiO_2/Si Raman spectrum and Raman image

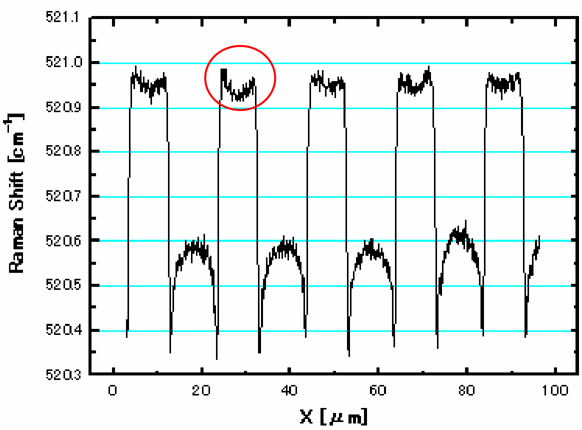
Raman spectrum of silicon (Si)



Measurement condition
・Laser wavelength：532 nm
・Grating：75 G/mm (Echelle)

Raman image at 520 cm^{-1}

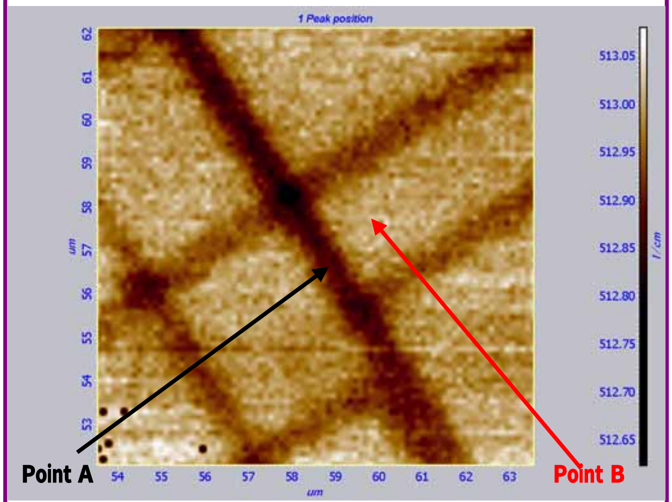




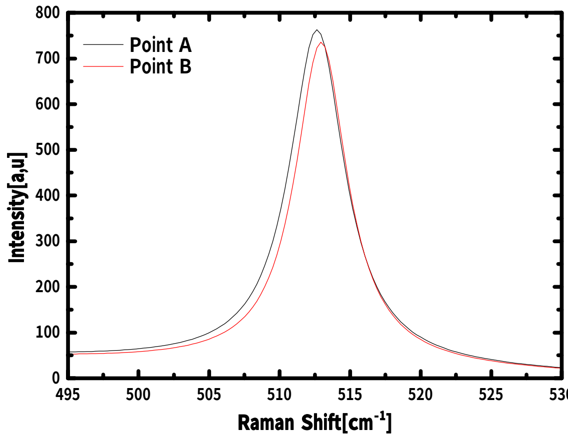
520 cm^{-1} Si Raman fine peak shift cross-section
(Corresponds to the Si stress distribution.)
Cross-section done along the white dashed line.

Cross-section shows 0.45 cm^{-1} Si Raman peak shift between pure Si surface and SiO_2 coated surface.
Noise level is about 0.03 cm^{-1}.

SiGe layer grown on Si substrate. Cross-hatch pattern of SiGe film strain obtained with Raman shift function.



※ Raman shift between the darkest "A" and the brightest "B" spots of the image is 0.4 cm^{-1} only.



Raman spectrum at points "A" and "B".

Combination of Echelle grating (hardware) and spectral line fitting (software) provides the unique ability for high quality fine Raman shift (sample strain) imaging.

Measurement conditions:

Laser wavelength	:364 nm
Objective lens	:100x, N.A.0.95
Grating	:75 G/mm (Echelle)
Laser power	: 1.5 mW
Measurement time	: 2 hour

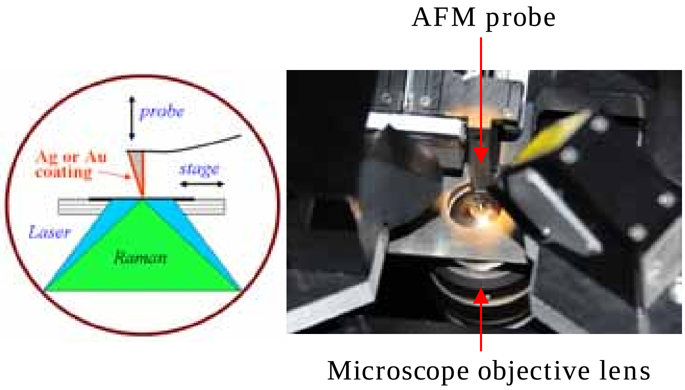
**High spatially resolved images,
full spectroscopy data from every mapping point.**

TERS (Tip Enhanced Raman Spectroscopy) Capability

●Combined Confocal Raman/AFM system

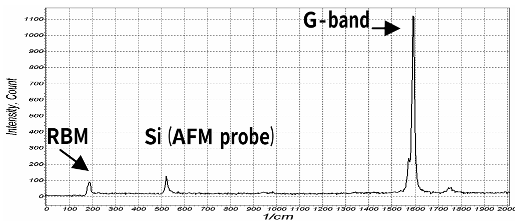
Confocal Raman and AFM topography images are available simultaneously from the same sample area.

The AFM head is specially designed for TERS application - high NA objective lens for simultaneous operation: NA=1.4 for bottom illumination, 0.7 for top illumination, 0.42 for side illumination geometries.



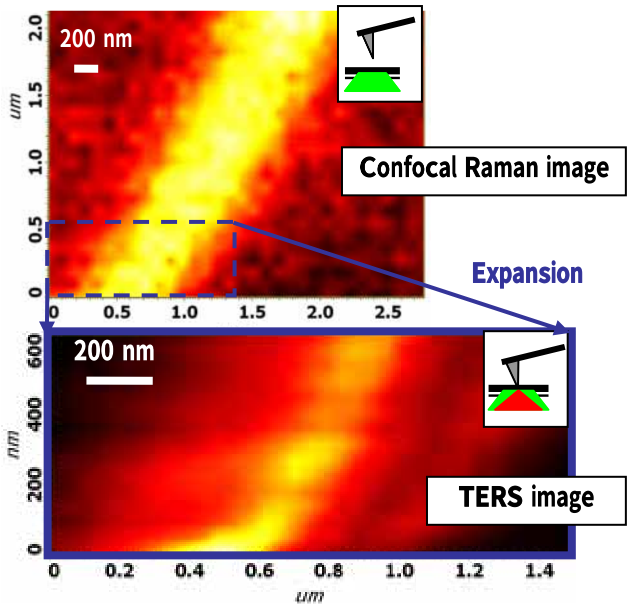
●TERS imaging

The spatial resolution of the scanned image can be improved with using TERS technology, as shown in right.



Confocal Raman spectrum of Carbon nanotube with Si tip approached.

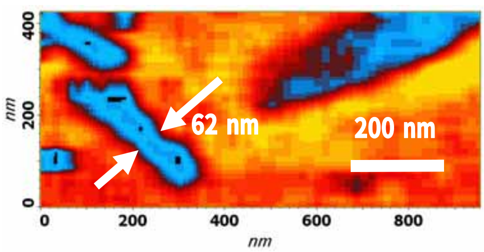
**Carbon nanotubes (CNT)
Raman image at G-band (1593 cm^{-1})**



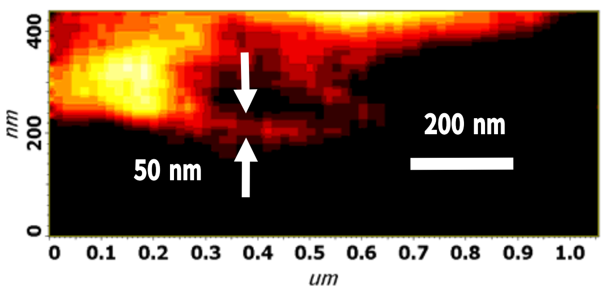
●Raman imaging below diffraction limit

Resolution of 50 nm is achievable with using TERS technology.

Sample: Carbon nanotubes (CNT)



Silver particles distribution on CNT layer. Raman image at CNT G-band line (1593 cm^{-1}).



Raman image of CNT row material (bundles mixture)

- Laser wavelength: 488 nm,
- Laser power: 2 mW,
- Measurement time: 10 min.

Scale bar (200 nm) shows minimum resolution level for confocal imaging.

High spatially resolved images, full spectroscopy data from every mapping point.

Specifications

●3D Raman confocal micro-spectroscopy system

・General performance

Spatial resolution(Typical):

Laser Wavelength λ (nm)	Objective Numerical Aperture N.A.	XY in-plane lateral resolution (nm)	Z axial resolution (nm)
364	1.4 (Oil immersion)	130	330
488	1.4 (Oil immersion)	200	500
488	0.9	250	520
532	0.9	275	560
633	0.9	320	660
785	0.9	390	800

Sensitivity: detects 4th order of Si Raman peak within 1 min exposure. (With 488 nm/5 mW)

Spectral range: 50 cm^{-1}～5000 cm^{-1} (varies with excitation laser wavelength)

Spectral resolution: up to 0.5 cm^{-1}/per 1.5 CCD pixel (with Echelle grating option)

PC control: Full automation

・Microscope

Upright or Inverted type

CCD for sample monitoring

・Optical unit (selection)

VIS-NIR or UV-VIS-NIR type

Polarization control option

・Imaging spectrometer

Focal length : 52 cm

Changeable gratings : 4 pc. Echelle grating option.

Slit width : 0～1.5 mm (motorized)

Exit ports : 2 (for CCD and PMT or APD)

Reciprocal dispersion : 1.529 nm/mm (at 600 nm with grating 1200 lines/mm)

・Piezo-stage scanner

X・Y : 100 μm (200 μm optional)

Z : 30 μm (100 μm optional)

Positional reproducibility: <30 nm (closed loop)

Max load: 2 kg

・Galvanic mirror scanner (option)

X・Y : 100 μm (with 100X objective lens)

250 μm (with 40X objective lens)

・Step motor scanner/positioner option

・Detector (2 detectors can be installed simultaneously)

Thermoelectrically cooled CCD: 1024×128 pixels (pixel size: 26 μm)

Cooling down to -100°C

UV, VIS, NIR type selection

APD (Avalanche Photo Diode)

Photon Counting mode

Fiber delivery system

Dark Counts/sec < 100

PMT (photomultiplier)

Photon Counting mode

Direct coupling or fiber delivery (for cooling version)

Dark Counts/sec < 100 (UV and VIS-NIR)

Optional: EMCCD, InGaAs linear diode array, Streak-camera, MCP-PMT.

・Excitation laser (3 lasers can be installed simultaneously)

Spatial mode TEM00

Laser wavelengths.

Main:

363.8 nm, 488 nm, 532 nm, 632.8 nm, 785 nm

Optional:

325, 405, 473, 514 nm.

・Software:

Nanofinder 30 standard software: mapping control, data acquisition and saving

Raman or fluorescence spectra display

Various spectrometer calibration functions

2D・3D imaging, arbitrary cross-section

Full system automatical control: Shutters, Laser wavelength, power, beam diameter adjustment, polarization orientation in excitation/detection channels, confocal pinhole size, grating and central wavelength selection, exit port of spectrometer, adjustment of signal on the confocal pinhole, etc.

Spectra and image processing

Spectral line fitting option

Deconvolution option

・Options:

- LCM (Laser Confocal Microscope)
- AFM (Atomic Force Microscope)
- FLIM (Fluorescence Lifetime Imaging Microscope)
- Cryostat, Temperature controlled stage
- Top laser input for inverted microscope

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