Raman Microscopy with High Spatial Resolution for Semiconductor Applications

Sol instruments Ltd., 58-10 Nezavisimosti ave.,
Minsk, Belarus

sales@solinstruments.com
SOL instruments Ltd. (SOLAR TII) was founded in 1994.

SOL instruments Ltd. is an innovation-focused manufacturer of technologically advanced instruments for

- Analysis
- Spectroscopy
- Lasers

SOL instruments Ltd. continually expands its presence on the world market of high-end products. The products are currently exported to over 30 countries.

www.solinstruments.com
3D Raman Microscopy System Confotec® NR500

www.solinstruments.com
Features

- 3D Raman Confocal Measurements
- Laser Reflection Measurements (1000x1000 pixels per 3 sec)
- Fully automated control
- Completely motorized laser change (up to 3 / 5 lasers)
- High spatial resolution (lateral: up to 200 nm; axial: up to 500 nm)
- High spectral resolution (up to 0.006 nm)
- Wide spectral range
- High temporal and temperature stability

www.solinstruments.com
Applications

Advantage of Raman Spectroscopy

- Qualitative and Structural material analysis
- No special requirements for sample preparations
- Nondestructive, non contact method
- Very small sample can be measured
- Depth analysis

Application field

- Pharmaceutical
- Material science
- Bioscience
- Geological
- Heritage and Art
- Organic and Polymer chemistry
- Forensic science, etc.

www.solinstruments.com
Confocal Raman Microscopy. Principles.

A pinhole blocks the scattered light which is coming from the out-of-focus points.
Confotec® NR500 Optical Setup
High sensitivity for Raman spectra detection

Raman spectrum of Si wafer.

Si (4) peak is clearly detected.

Si (1) and Si (2) are in deep saturation.

Accumulation time - 60 seconds.

488 nm laser, 5 mW power

www.solinstruments.com
High speed Raman imaging with Confotec®
Many lasers can be installed.

The next equation can be applied to the Si stress monitoring:

\[
\sigma (\text{MPa}) = -435 \cdot (\omega - \omega_0) \text{ (cm}^{-1}\text{),}
\]

where \(\sigma\) is the stress value, \(\omega_0 = 520.5 \text{ cm} \text{ }^{-1}\) is the peak position of the stress-free state, \(\omega\) is the Si peak position at the stressed state.

The sample consists 1, 1.5, 2 and 4 µm wide Si stripes separated by 4 µm shallow trenches.
Structured Si sample. Optical image (100x)
PolySi

Intensity distribution (Si peak)
Scan area: 50 x 50 x 7 µm
Points: 100 x 100 x 10
Time per point: 0.1 sec

www.solinstruments.com
Si peak position
Scan area: 50 x 50 x 7 um
Points: 100 x 100 x 10
Time per point: 0.1 sec
Self-assembled Ge dots grown on Si substrates are attracting attention because they have a potential to be simply integrated with the existing Si-based technology. The electronic properties of the Ge dots depend on many parameters, including shape, size and distribution of strain.

Raman scattering spectroscopy is absolutely necessary method for the characterization of QDs.

Raman spectroscopy allows to obtain information on the composition, strain in the structures, distribution of dots on the surfaces.
AFM Topography
Ge QD on a Silicon Substrate

Forming of three-dimensional Ge islands on Si substrate is illustrated below.

Growing of Ge dots on Si substrate (schematic diagram)
Optical image, 100x objective

Rayleigh scattering, 21x21um, 488 nm

www.solinstruments.com
Samples exhibit two strong bands at 504.9 cm\(^{-1}\) and 521 cm\(^{-1}\), and many weak features. Ge--Ge, Si--Ge and Si--Si optical modes can be found at around 290, 405 and 432 cm\(^{-1}\), respectively.
Удельная деформация в структуре:

\[ \omega_{\text{SiGe}} = 400.5 + 14.2x - 575\varepsilon \quad \text{405.08 cm}^{-1} \]
\[ \omega_{\text{GeGe}} = 282.5 + 16x - 385\varepsilon \quad \text{289.3 cm}^{-1} \]

\( \varepsilon \) — Удельная деформация в структуре

\( x \) — содержание Ge
SiC analysis

SiC has become important in the semiconductor industry because of its properties:

• High thermal conductivity
• High electric field breakdown strength
• High maximum current density
### Raman Scattering of Different SiC Polytypes

<table>
<thead>
<tr>
<th>Polytype</th>
<th>FTA : cm(^{-1})</th>
<th>FTO : cm(^{-1})</th>
<th>FLA : cm(^{-1})</th>
<th>FLO : cm(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>3C</td>
<td>(T_d^2)</td>
<td>-</td>
<td>796 ((F_2))</td>
<td>972 ((F_2))</td>
</tr>
<tr>
<td>2H</td>
<td>(C_{6v}^4)</td>
<td>264 ((E_2))</td>
<td>799 ((E_1))</td>
<td>968 ((A_1))</td>
</tr>
<tr>
<td>4H</td>
<td>(C_{6v}^4)</td>
<td>196, 204 ((E_2)) 266 ((E_1)) 796 ((E_1)) 776 ((E_2)) 610 ((A_1)) 968 ((A_1)) 838 ((A_1))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6H</td>
<td>(C_{6v}^4)</td>
<td>145, 150 ((E_2)) 236, 241 ((E_1)) 266 ((E_1)) 797 ((E_1)) 789 ((E_2)) 767 ((E_2)) 504, 514 ((A_1)) 965 ((A_1)) 889 ((A_1))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*FTA - Folded Transversal Acoustical mode, FTO - Folded Transversal Optical mode, FLA – Folded Longitudinal Acoustical mode, FLO – Folded Longitudinal Optical mode*
Silicon Carbide (4H-SiC)

www.solinstruments.com
# SOL instruments® Spectographs

<table>
<thead>
<tr>
<th>Series</th>
<th>MS200 monochromator-spectrograph</th>
<th>MS350 monochromator-spectrograph</th>
<th>MS520 monochromator-spectrograph</th>
<th>MS750 monochromator-spectrograph</th>
<th>MSDD1000 monochromator-spectrograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo of device:</td>
<td><img src="image" alt="MS200" /></td>
<td><img src="image" alt="MS350" /></td>
<td><img src="image" alt="MS520" /></td>
<td><img src="image" alt="MS750" /></td>
<td><img src="image" alt="MSDD1000" /></td>
</tr>
<tr>
<td>Ports</td>
<td>1 input, 2 output</td>
<td>1 input, 2 output</td>
<td>1 input, 2 output</td>
<td>1 input, 2 output</td>
<td>2 input, 2 output</td>
</tr>
<tr>
<td>Wavelength range:</td>
<td>185 nm – 60 μm</td>
<td>185 nm – 60 μm</td>
<td>185 nm – 60 μm</td>
<td>185 nm – 60 μm</td>
<td>185 nm – 60 μm</td>
</tr>
<tr>
<td>F/number (entrance):</td>
<td>1/3.6</td>
<td>1/3.8</td>
<td>1/5.4</td>
<td>1/8.9</td>
<td>1/5.9</td>
</tr>
<tr>
<td>Focal length (output):</td>
<td>200 mm</td>
<td>350 mm</td>
<td>520 mm</td>
<td>750 mm</td>
<td>1000 mm (2 x 500)</td>
</tr>
<tr>
<td>Size of diffraction gratings:</td>
<td>40 x 40 x 6 mm</td>
<td>70 x 70 x 10 mm</td>
<td>80 x 70 x 10 mm</td>
<td>80 x 70 x 10 mm</td>
<td>80 x 70 x 10 mm</td>
</tr>
<tr>
<td>Stray light (20nm from laser line 632.8nm):</td>
<td>$3 \times 10^{-5}$</td>
<td>$1 \times 10^{-5}$</td>
<td>$1 \times 10^{-6}$</td>
<td>$5.5 \times 10^{-7}$</td>
<td>$1 \times 10^{-8}$</td>
</tr>
</tbody>
</table>
### SOL instruments® Spectral Cameras

<table>
<thead>
<tr>
<th>Model</th>
<th>HS 103H</th>
<th>HS 101H (HR), HS 101H</th>
<th>HLS 190IR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCD area image sensor</td>
<td>CCD area image sensor</td>
<td>Linear InGaAs detector</td>
</tr>
<tr>
<td>Photo of the device</td>
<td><img src="image" alt="HS 103H" /></td>
<td><img src="image" alt="HS 101H" /></td>
<td><img src="image" alt="HLS 190IR" /></td>
</tr>
<tr>
<td>Spectral sensitivity</td>
<td><img src="image" alt="HS 103H" /></td>
<td><img src="image" alt="HS 101H" /></td>
<td><img src="image" alt="HLS 190IR" /></td>
</tr>
<tr>
<td>Technical characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wavelength range</td>
<td>from 200 to 1100 nm</td>
<td>from 200 to 1100 nm</td>
<td>from 0.9 to 2.55 μm</td>
</tr>
<tr>
<td>Max. readout speed</td>
<td>up to 500 kHz</td>
<td>up to 500 kHz</td>
<td>up to 415 kHz</td>
</tr>
<tr>
<td>Sensor type</td>
<td>CCD Back-Thinned</td>
<td>CCD Back-Thinned or Front-Illuminated</td>
<td>linear InGaAs</td>
</tr>
<tr>
<td>Number of pixels</td>
<td>2048 x 54</td>
<td>from 2048 x 122 to 2048 x 606</td>
<td>256 or 512</td>
</tr>
<tr>
<td>Pixel size (H x V)</td>
<td>14 x 14 μm</td>
<td>12 x 12 μm</td>
<td>from 25 x 250 μm to 50 x 500 μm</td>
</tr>
<tr>
<td>Nominal value of the</td>
<td>10 mm</td>
<td>10 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>Distance from a forward</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>plane of the sensor up to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>photosensitive field of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure time</td>
<td>from 10 ps to 7.5 h</td>
<td>from 10 ps to 7.5 h</td>
<td>from 1 ps to 7.5 h</td>
</tr>
<tr>
<td>Analog-digital converter</td>
<td>16 bit</td>
<td>16 bit</td>
<td>16 bit</td>
</tr>
<tr>
<td>(ADC) of the cameras</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thank you very much for your attention!