Current Status of 40m SANS Instrument and SANS-related Research at HANARO

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HANARO Reactor

High-flux Advanced Neutron Application Reactor

Multi-purpose Research Reactor
Reactor Structure and Characteristics

Features

- **Type**: Open-tank-in-pool
- **Power**: 30 MW
- **Coolant**: Light Water
- **Reflector**: Heavy water
- **Fuel Materials enriched**: U$_3$Si, 19.75%
- **Absorber**: Hafnium
- **Reactor Building Confinement**
- **Max Thermal Flux**: $5 \times 10^{14}$ n/cm$^2$s
- **Typical flux at port nose**: $2 \times 10^{14}$ n/cm$^2$s
- **7 horizontal ports** & 36 vertical holes
- **Vertical hole for cold neutron source**
- **Operation Cycle**: 28 days@6 weeks
- **Operation Days**: 224 days/year
- **Stop operation**: 2014. 07~ current
- **Restart operation**: 2016. 09
Reactor Hall

NR Port
- Neutron Radiography Facility (NRF), 1997 Upgrade

ST4 Port
- Triple Axis Spectrometer (TAS), under construction

ST3 Port
- Bio-Diffractometer with Camera (Bio-C), 2012
- Bio-Diffractometer (Bio-D), 2011

ST2 Port
- Four Circle Diffractometer (FCD), 1999 Upgrade '05-'06

IR Port
- Ex-Core Neutron Irradiation Facility (ENF), 2005

ST1 Port
- Prompt Gamma Neutron Activation Analysis (PGAA), 2003
- Residual Stress Instrument (RSI), 2003 Upgrade

CN Port
- Cold Neutron Guide, 2009
- Formally SANS located

High Resolution Powder Diff. (HRPD), 1998
History of SANS Instrument at HANARO

- July 1997 : Development of 9m SANS Instrument at reactor hall started
- Sep. 2001 : 9m SANS instrument was opened to outside users
- July 2003 : Cold Neutron Research Facility (CNRF) Project was launched
  → Upgrade and relocation of 9m SANS instrument and development of new 40m SANS instrument were included in the project
- May 2007 : Period of CNRF project changed from 5 yrs to 7 yrs
- Sep. 2007 : Development of KIST-USANS started
- April 2010 : The CNRF project was finished
- Nov. 2010 : 18M/40M SANS instruments were opened to outside users
- Nov. 2012 : Inauguration Ceremony of KIST-USANS was held
- Jul. 2014 : stop operating (earthquake-proof...)

Specifications

• Total Instrument Length: 40 m
• Sample to Detector Distance: 1.1-19.8 m
• Max. Detector offset: 50 cm
• Wavelength: 4 – 20 Å
• Accessible Q-range: 0.0007 - 1.0 Å⁻¹ (with Focusing Lenses)
• Neutron Flux at Sample: 2.5 *10⁷ n/sec cm²
• Neutron Velocity Selector: Astrium
• Detector: Ordela 21000N (1*1 m²)
• Neutron Transmission Polarizer & RF Flipper

Information
http://hanaro4u.kaeri.re.kr
Email: useroffice@kaeri.re.kr
40M SANS Instrument

History

- April. 2008:
  1st fabrication was ordered (Detector Vessel)

- Sep. 2009:
  1st cold N-beam arrived

- Nov. 2009:
  Major hardware was finished

- Feb. 2010:
  First SANS data was obtained

- Nov. 2010
  Open to users

Dr. Tae-Hwan Kim
Dr. Young-Soo Han
Dr. Eunhye Kim
Mr. Ki-Jeong Park
18M SANS Instrument

Dr. Eunjoo Shin

<table>
<thead>
<tr>
<th>Dr. Eun-Joo Shin</th>
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<tbody>
<tr>
<td>Dr. Baek-Seok Seong</td>
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<tr>
<td>Dr. Tae-Kyu Shin</td>
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<td>Mr. Seong-Soo Kim</td>
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</tbody>
</table>

- June 2008 : Old 9m SANS was dismantled
- Sep. 2008 : Upgrade plan has changed (12m -> 18m)
- Dec. 2008 : 1st fabrication ordered (Collimator box)
- Nov. 2010 : Open to users
## Main Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>40M SANS</th>
<th>18M SANS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Instrument Length (m)</td>
<td>40</td>
<td>18</td>
</tr>
<tr>
<td>Detector Dimensions (cm²)</td>
<td>100 x 100</td>
<td>64 x 64</td>
</tr>
<tr>
<td>Detector Resolution (cm²)</td>
<td></td>
<td>0.5 x 0.5</td>
</tr>
<tr>
<td>Detector supplier</td>
<td>ORDELA, 21000N</td>
<td>ORDELA, 2660N</td>
</tr>
<tr>
<td>Velocity selector supplier</td>
<td></td>
<td>ASTRIUM</td>
</tr>
<tr>
<td>Source to sample distance (m)</td>
<td>2 - 20 (steps : 2m)</td>
<td>3 - 9 (steps : 2m)</td>
</tr>
<tr>
<td>Sample to detector distance (m)</td>
<td>1.1 – 19.8</td>
<td>1.3 – 9</td>
</tr>
<tr>
<td>Max. detector offset (cm)</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Q-range (Å⁻¹) (with lenses)</td>
<td>0.001 – 1.0 (&gt;0.0007)</td>
<td>0.003 – 0.5</td>
</tr>
<tr>
<td>Neutron polarizer</td>
<td>YES</td>
<td>To be installed</td>
</tr>
<tr>
<td>Refractive Focusing Optics</td>
<td>YES</td>
<td>To be installed</td>
</tr>
</tbody>
</table>
Comparison of SANS Data

Old & New HANARO SANS Instruments

- Both are absolutely calibrated with Silica Standard samples

HANARO & NIST NG-7 SANS Instruments

- NIST data are absolutely calibrated with using direct beam method
MgF2 Focusing Lenses in HANARO SANS

Wavelength of 7.49 Å for lens, 6Å
SDD = 19.85m (with lens), 5m, 1.16m
Q range = 0.0007 – 0.7 Å⁻¹

Up to 0.0007 Å⁻¹
High Resolution Detector Installation (40M SANS)

Ni base ODS alloy

$Q_{\text{min}} = 0.0004 \text{ Å}^{-1}$
- Both the large PSD and the high resolution detector can be automatically controlled by the ICP
- Real time display of $I$ vs $Q$ (right figure) can be realized during measurement
- Data reduction program can treat the data obtained from both the large PSD and the high resolution detector
Sample Environments in 18M/40M SANS

- **Temperature Control**
  - Heating/Cooling (-10C ~ 80C)
  - Heating (~300C)
  - Furnace (~600C)
  - 4K CCR

- **Magnetic Field**
  - Horizontal Field Electromagnet (1.5T)

- **Humidity Chamber**
  - 5% < R. H. < 90%

- **Pressure cell**
  - ~ 3 kbar & Heating

- **Rotating Sample Stage**
Accessible Q range of SANS Instrument at HANARO

- USANS (KIST)
  - $D \sim 5 \, \mu m$
  - $D \sim 300 \, \text{nm}$

- 40M SANS
  - $D \sim 40 \, \text{nm}$

- 18M SANS
  - $D \sim 15 \, \text{nm}$

- Old 9M SANS

Accessible Q range

$2 \times 10^{-5} < Q < 1.0 \, \text{Å}^{-1}$
User Statistics

- **Beam Time Distribution by User**
  - 40M SANS
    - Domestic User, 39%
    - Foreign User, 22%
    - NRF Program User, 13%
    - Internal User, 21%
    - Maintenance, 5%
  - 18M SANS
    - Domestic User, 60%
    - Foreign User, 7%
    - NRF Program User, 6%
    - Internal User, 10%
    - Maintenance, 17%

- **Beam Time Distribution by Topics**
  - Soft Matter, 66%
  - Material Science, 14%
  - Magnetism, 10%
  - Basic Science, 8%
  - Biology, 2%
Soft Matter _ polymers in bulk

- SANS Intensity of the Block copolymer and ionic liquid mixtures with contrast matching method

- Neutron Scattering Length Density

<table>
<thead>
<tr>
<th>component</th>
<th>SLD ($10^6 \text{Å}^{-2}$)</th>
</tr>
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<tbody>
<tr>
<td>PS</td>
<td>1.41</td>
</tr>
<tr>
<td>dPS</td>
<td>6.40</td>
</tr>
<tr>
<td>PVP</td>
<td>1.96</td>
</tr>
<tr>
<td>Ionic liquid</td>
<td>~3.0</td>
</tr>
</tbody>
</table>

$I(q^*) \propto (b_{s,eff} - b_{v,eff})^2$
Soft Matter polymers in solution

- SANS Intensity of the P85-5mS complex at varying 5mS concentration

- Fitting Parameters

  - Sphere Core Radius
  - Sphere Shell Thickness
  - Cylinder Core Radius
  - Cylinder Shell Thickness
  - Cylinder Length
  - Vesicle Core Radius
  - Vesicle Shell Thickness

- Model Fitting:
  - Debye Model (0%)
  - Spherical and Cylindrical Core-Shell Model (0.05 ~ 0.15%)
  - Vesicle Model with Gaussian Distributed Shell (0.15 ~ 0.2%)
Evaluation of the effects of cosmetics on the restoration of skin barrier

Nanostructures of cream with SANS and SAXS

Observation of rearrangement of lipid bilayer by small angle scattering
Closing Remarks

1. HANARO Neutron Research Facility is National Facility and Open to Users Worldwide.


3. HANARO is Ready to Share Experiences with All in Every Area of Science.