NCNR Facts and Figures

- ≈ 240 operating days/year
- ≈ 99% reactor reliability
- 28 experimental beam instruments/experiments
- ≈ 2000 research participants/year
- ≈ 300 publications/year
  ≈ 15% in very high impact journals
Neutron Properties

Isotopes have different scattering powers.

H : 1 proton
1 electron

D : 1 proton
1 neutron
1 electron

Incoherent scatterer
- Does not ‘see’ neighbor atoms

Coherent scatterer
- ‘Sees’ neighbor atoms

SPECTROSCOPY: “interesting” portions of the sample are hydrogenated and the “uninteresting” portions are deuterated.

Neutron magnetic moment interacts with spins.
Facility Layout
Facility Layout
Instrument Suites
Testing/Physics stuff
Absorption/Imaging
Absorption/Imaging

- Thermal Neutron Capture Prompt-Gamma Activation Analysis (PGAA)
- Cold Neutron Prompt-Gamma Activation Analysis (PGAA)

- Cold Neutron Depth Profiling (NDP)

- Neutron Imaging
Absorption/Imaging

- Thermal Neutron Capture Prompt-Gamma Activation Analysis (PGAA)
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- Neutron Imaging
## Absorption/Imaging

### Expected Sensitivity

<table>
<thead>
<tr>
<th>Range (µg)</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01 - 0.1</td>
<td>B, Cd, Sm, Gd</td>
</tr>
<tr>
<td>0.1 - 1</td>
<td>Eu, Hg</td>
</tr>
<tr>
<td>0.1 - 10</td>
<td>H, Cl, In, Nd</td>
</tr>
<tr>
<td>10 - 100</td>
<td>Na, S, K, Sc, Ti, V, Cr, Mn, Co, Ni, Cu, Ge, As, Se, Br, Mo, Ag, Te, I, Au</td>
</tr>
<tr>
<td>100 - 1,000</td>
<td>Mg, Al, Si, P, Ca, Fe, Zn, Ga, Rb, Sr, Y, Zr, Nb, Sb, Ba, La</td>
</tr>
<tr>
<td>1,000 - 10,000</td>
<td>C, N, F, Sn, Pb</td>
</tr>
</tbody>
</table>
Standard Reference Material 2387, $761
Standard Reference Material 3532, $711

Calcium-Containing Solid Oral Dosage
Dietary Supplement Health and Education Act (DSHEA)

Table 1. Certified Mass Fraction Values for Elements in SRM 3532

<table>
<thead>
<tr>
<th>Element</th>
<th>Mass Fraction (mg/kg)</th>
<th>Coverage Factor, k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium (Cd)</td>
<td>0.097 ± 0.001</td>
<td>2.0</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>175 ± 300</td>
<td>2.0</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>280.7 ± 7.6</td>
<td>2.0</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>11800 ± 200</td>
<td>2.0</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>532 ± 18</td>
<td>2.0</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>2110 ± 40</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Absorption/Imaging

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- Neutron Imaging
Absorption/Imaging

- B in Semiconductors - various
- Li in Nuclear Waste Glasses
- N in Specialty Glasses & Metal CRMs
- Li in Niobate Crystals
- Li in Lithium Ion Batteries
- Na in Steel Coupons
- O in Titanium oxides

* Data and images courtesy of Greg Downing
Absorption/Imaging

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Absorption/Imaging

* Data and images courtesy of David Jacobson
Small-Angle Neutron Scatt....(SANS)
Mesoporous Organohydrogels

- Oil-in-water nanoemulsions
  - silicone oil (PDMS) droplets [polydimethylsiloxane, (PDMS)]
  - aqueous continuous phase [18% D₂O]
  - functionalized hydrophilic polymer [poly(ethylene glycol) diacrylate (PEGDA)]
  - surfactant (SDS)

* Data and images courtesy Paul Butler et al.
Mesoporous Organohydrogels

Mesoporous Organohydrogels

After Photocrosslinking

Reflectometers
Reflectometers

- NG-7 Horizontal Sample Reflectometer allows reflectivity measurements of free surfaces, liquid/vapor interfaces, as well as polymer coatings.

- NG-D Polarized Beam Reflectometer (PBR) for measuring reflectivities as low as $10^{-8}$ to determine subsurface structure.

- NG-D MAGIK off-specular reflectometer for studies of thin-film samples with in-plane structure.
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Reflectometers

- NG-7 Horizontal Sample Reflectometer allows reflectivity measurements of free surfaces, liquid/vapor interfaces, as well as polymer coatings.

* Data and images courtesy Sushil Satija
Reflectometers

Replace organic toxic solvents by CO$_2$ as a “green” solvent for polymer processing. (~74 bar @ room temperature)
Supercritical fluid: anomalous behavior in sound velocity, thermal conductivity, partial molar volume.

Schematic view of high pressure cell for NR experiments

![High Pressure Cell Diagram]

NR curves for deuterated SBR

\[ D = \frac{2}{q} \]

D: film thickness

\[ q_z = \frac{4 \sin \theta}{\lambda} \]

\( q_z \): wavelength

Reflectometers

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(Koga et al. Macromolecules, 2003)
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Reflectometers
complex oxide interfaces

Oxide A
strongly correlated
electron systems

Oxide B

Oxide A
Interface
Oxide B
due to strain, charge transfer, etc.,
new properties can emerge at the
interface between A & B!

ferromagnetism, superconductivity, ...
[CaMnO₃ / CaRuO₃]ₜ

antiferromagnetic insulator

paramagnetic metal

spin-dependent oscillations & 1st order Bragg peak

small samples limit Q-range

consistent with 1 unit cell interfacial ferromagnetism controllable with E-field

* Data and images courtesy of Brian Kirby
Dengue envelope protein

- in collaboration with Mike Kent, Bulent Akgun, Sandia National Laboratories
- main objective: insertion depth of the protein into the bilayer

* Data and images courtesy of Frank Heinrich
Diffractometers
Diffractometers

- BT-8 Stress-strain engineering diffractometer

- BT-1 High resolution powder diffractometer
Neutron Stress Measurements

**Elastic** changes of lattice spacings in grains provide strain information.

Penetration of neutrons (≈ cm) provides non-destructive depth information.

\[ \lambda = 2d_{hkl} \sin \theta \]

* Data and images courtesy of Thomas Gnäupel-Herold
Sample and Equipment

- **EOSINT M 280 laser sintering machine** (400 watt Yb laser, 0.1..0.5 mm focus, 7 m/s scan speed)
- **GP1 powder** (15.5% Cr, 4.5% Ni, 3.5% Cu, 0.4%Mn, 0.3% Nb, 0.5% Si, Fe bal.), is equivalent to 17-4 stainless steel,
- **17-4: \( Y_{\text{min}} \approx 724...1172 \) MPa (depends on heat treatment)

* Data and images courtesy of Thomas Gnäupel-Herold
Stresses

* Data and images courtesy of Thomas Gnäupel-Herold
Stresses in “blade” structures

* Data and images courtesy of Thomas Gnäupel-Herold
Diffractometers

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Industrial gas separations

- $\text{H}_2/\text{CH}_4/\text{CO}/\text{CO}_2$
- $\text{O}_2/\text{N}_2$
- Olefin/paraffin

Contains:
- $\text{CH}_4$
- $\text{C}_2\text{H}_6$
- $\text{C}_3\text{H}_8$
- $\text{C}_4\text{H}_{10}$
- etc....
Diffractometers

Bloch et al., Science 2012, 335, 1606
Diffractometers

The first crystallographically characterized magnesium and zinc carbonyl compounds
The first high-spin manganese(II), iron(II), cobalt(II), and nickel(II) carbonyl species

JACS Spotlight “Molecular Boxes Act like Little Carbon Monoxide Hotels"
Diffractometers

JACS Spotlight “Molecular Boxes Act like Little Carbon Monoxide Hotels"
Spectrometers
Summer School on the Fundamentals of Neutron Scattering

NIST Center for Neutron Research
National Institute of Standards and Technology
Gaithersburg, MD 20899

June 8-12, 2015

The twenty first annual Center for High Resolution Neutron Scattering (CHRNS) "Summer School on Methods and Applications of Neutron Spectroscopy" will be held June 8-12, 2015 at the NIST Center for Neutron Research (NCNR). This year’s summer school is devoted to methods and applications of neutron spectroscopy.

The course is targeted at those with little or no previous experience with neutron inelastic scattering methods. The combination of introductory lectures and training in scattering techniques will provide participants with a unique opportunity to become familiar with neutron scattering methods and their application to current research topics.

Attendance for the summer school is limited to 35 students and to people affiliated with US universities and US industry.

The Summer School is sponsored by the NCNR and by the National Science Foundation under the Center for High Resolution Neutron Scattering (CHRNS) cooperative agreement DMR-0944772. Support for graduate students, postdoctoral fellows and junior faculty may be requested on the summer school application form.