Research Instrumentation
Electronic and Magnetic Properties at High Pressure

Dr. Andrew Cornelius
Department of Physics & Astronomy
Phone (702) 895-1727

Expertise:
• Experimental high pressure measurements
• Magnetism
• Superconductivity
Superconductivity

Quantum Design PPMS at UNLV
- Measurements from 0.3 K to 400 K
  - Heat capacity, electric and thermal transport, and AC/DC magnetization
- Pressure cells to measure electrical properties (clamp to 3 GPa and diamond anvil cell to >100 GPa)

Addition of high pressure synchrotron experiments (diffraction and X-ray absorption) allows mapping of complex superconducting phase diagrams
Correlated-Electron Systems

Modified periodic table

- Going from localized to delocalized electrons one often finds strong electron-electron correlations
- Correlated electron systems can yield interesting behavior: fluctuating valence, superconductivity, non-Fermi liquid, heavy fermion and many more

Increasing Localization

Empty Shell

<table>
<thead>
<tr>
<th>Partially Filled Shell</th>
<th>Full Shell</th>
</tr>
</thead>
<tbody>
<tr>
<td>4f La Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu</td>
<td>Yb³⁺ Ca Ce</td>
</tr>
<tr>
<td>5f Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr</td>
<td>Ce</td>
</tr>
<tr>
<td>3d Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn</td>
<td>Cu Zn</td>
</tr>
<tr>
<td>4d Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd</td>
<td>La Hf Ta W Re Os Ir Pt Au Hg</td>
</tr>
<tr>
<td>5d Ba La Hf Ta W Re Os Ir Pt Au Hg</td>
<td>Yb³⁺</td>
</tr>
</tbody>
</table>

f-electron delocalization

X-ray absorption

Heavy fermions
Heat Capacity

Fluctuating valence
X-ray fluorescence

Increasing Localization

X-ray fluorescence

Heat Capacity

f-electron delocalization
Design and Testing of Advanced Separation Processes using Additive Manufacturing

- Liquid-Liquid Extraction and Separation of Plutonium, Uranium, Minor Actinides, Lanthanides and Fission Products
- Twenty-seven 3D-printed acrylic centrifugal contactors (CC), fabricated at Argonne National Lab are available at UNLV
- Contactors can be 3D-printed in stainless steel or any alloy
- Solvent extraction separations can be tailored to a specific goal
- Example: Actinide Lanthanide SEParation process - ALSEP, designed and tested for DOE-NE
Microfluidic Systems for Rapid Radionuclide Separation and Detection

• Microfluidic device to combine aqueous and organic phases, rapidly mix, then separate phases, following by analysis
• Selective Extraction of radionuclides on a very small scale
• Can be implemented either as a bench-top setup or as a portable detector
• Potential applications: rapid Pu separation and detection from Uranium and FP for safeguards; ”dirty bomb” analysis
Surface and Interface Characterization of Materials for Energy Conversion

Dr. Clemens Heske
Professor
Department of Chemistry and Biochemistry
heske@unlv.nevada.edu

Expertise

• Electronic and Chemical Structure of Energy-Conversion Materials
• Surface and Interface Characterization
• Soft x-ray and Electron Spectroscopy
• Scanning Probe Microscopy
• Synchrotron Radiation
Surface and Interface Characterization

Gloveboxes
High dyn. range
XPS, UPS, IPES, Auger
Sample preparation
and distribution
Scanning Probe
Microscope

Photoelectron Spectroscopy
(PES, XPS, UPS)
UV-Visible
Absorption
Spectroscopy
(UV-Vis)
X-Ray Emission
Spectroscopy (XES)
X-ray Absorption
Spectroscopy (XAS)
Inverse Photo-
emission (IPES)
Auger Electron
Spectroscopy
(AES)

Conduction band
Valence band
Core level

SALSA: Solid And Liquid Spectroscopic Analysis
In-situ cell
Photoemission
X-ray Emission

Pump
From beamline
To XES/XAS spectrometer
From solar simulator
Window
UHV chamber
External reservoir

UNLV COLLEGE OF SCIENCES
Materials for Energy Conversion

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnO</td>
<td></td>
</tr>
<tr>
<td>CdS (20 nm)</td>
<td></td>
</tr>
<tr>
<td>Cu(In,Ga)(S,Se)₂ (2μm)</td>
<td></td>
</tr>
<tr>
<td>Mo (2μm)</td>
<td></td>
</tr>
<tr>
<td>Na-lime glass (2 mm)</td>
<td></td>
</tr>
</tbody>
</table>

η = 23.35%

Energy diagrams showing band structures and energy levels for different materials.

UNLV College of Sciences
Island – Quantum computing, quantum sensing

The Nanoscale Physics Group @ UNLV

Areas of Research

• Nanotechnology, device physics
• Photodetection and quantum sensing
• Quantum computing, topological qubits
• Non-equilibrium, driven systems
• Superconductivity, proximity effects
• Low dimensional materials

Island's Lab website
Quantum computing: Topological phases for fault-tolerant, universal quantum computing.

Industry-disruptive photodetectors: Ultra-sensitive phototransistors designed with 2D materials and heterostructures.

Transient phases of driven systems: Non-equilibrium response of pumped nanomaterials below the diffraction limit.


Island's Lab website
Island – Quantum computing, quantum sensing

Journal publications:

Spin-orbit-driven band inversion in bilayer graphene by van der Waals proximity effect

Enhanced superconductivity in atomically thin TaS2

Proximity-induced Shiba states in a molecular junction

T1S3 transistors with tailored morphology and electrical properties

Environmental instability of few-layer black phosphorus

Ultrahigh photoresponse of few-layer TiS3 nanoribbon transistors

Gate controlled photocurrent generation mechanisms in high-gain ln2Se3 phototransistors

Precise and reversible band gap tuning In single-layer MoSe2 by uniaxial strain

Island's Lab website
Economic Geology

Dr. Simon Jowitt
Department of Geoscience
simon.jowitt@unlv.edu

Expertise:
Geochemistry, mineral exploration, ore deposit geology, mineral economics, mineral exploration technique development, igneous petrology, environmental impact of mining
Geochemistry

- Understanding mineralizing systems
- Links between tectonic and magmatic events and mineral systems
- Development of mineral exploration tools

Links between Large Igneous Province plumbing systems and mineralization

Distribution of Orogenic Au deposits within West Africa

Model for the formation of PGE mineralization in the Bushveld Complex

Pre-Rietfontein Magma

Staging Chamber

Fractionation of Chamber

Chamber Overpressure

Expulsion of upper chamber to form rapidly-chilled basal magma

Expulsion of lower chamber to form sedimentary and ultramafic rocks

Chrome trapped in anomalous opx
Mineral economics

- Understanding global metal resources
- Assessing future demand and supply
- Materials for green technology and critical metals

Understanding global metal reserves and production
Critical metals

- Identification of potential sources of the critical metals
- Determining the processes that concentrate critical elements and development of associated exploration tools

Metal companionality; understanding how critical metal production is reliant on other metals

Be-bearing rare metal pegmatite, southern Nevada

Production and recycling of Nd
Environmental impact of mining

• Assessing environmental impacts
• Potential of wealth from waste; assessing mining waste metal production and CO₂ sequestration potential

Understanding arsenic mobility in mining and mineral processing environments

Assessing the environmental impact and critical metal potential of mineral processing waste and tailings

BSE and Synchrotron XFM mapping of CO₂ sequestration reactions
Other research areas

• GIS-based mineral prospectivity modeling in 2D and 3D space
• Machine learning approaches to exploration targeting
• Igneous petrology and the formation of Large Igneous Provinces
• Pegmatites and highly evolved rhyolites as sources of critical metals

• I run a well-equipped fluid inclusion lab that allows the determination of the composition and the temperature and pressure of trapping of hydrothermal fluids associated with mineral deposit formation. I also have a wide range of expertise in other analytical fields, including SIMS, ICP-MS, LA-ICP-MS, ICP-OES and XRF, stable and radiogenic isotopes, XRD, EPMA, SEM, and synchrotron beam analytical approaches.
Ubiquitin-mediated protein degradation

Dr. Gary Kleiger
Associate Professor
Department of Chemistry and Biochemistry
gary.kleiger@unlv.edu

Expertise
• Structural biology
• Proteomics
• Enzyme kinetics and biophysical assays
• Cell biology

Protein structure of Ubiquitin.
Uncovering how the enzymes that promote protein degradation function in human cells.

- **Kinetics** help us understand how enzymes select protein targets for modification with ubiquitin.
- **High-resolution mass-spectrometry** tells us how mutations in enzymes that lead to human disease affect the stabilities of key human cellular proteins.
- Small molecule inducers of protein degradation can be used to treat human disease. We study the mechanism of how they function both in test tubes and cells.
The Kleiger lab partners with both industry and academic labs to help discover treatments for human diseases such as cancer.

Mass-spec proteome exploration with Dr. Don Kirkpatrick at Genentech Inc.

How to utilize small molecules to induce the degradation of disease-causing proteins with Dr. Craig Crews (Yale and founder of Arvinas Inc.).

Cryo-EM and structural biology with Max Planck Institute of Biochemistry Director Dr. Brenda Schulman.
Novel chemistry and biology using highly ionizing radiation

Michael Pravica, Ph.D.  
Professor of Physics  
Department of Physics and Astronomy  
Phone: (702)895-1723  
Email: michael.Pravica@unlv.edu

Expertise:
Useful Hard X-ray photochemistry  
High pressure  
Spectroscopy  
Ion Beam Nuclear Transmutation Doping  
High quality synthesis of vaccines using tuned hard x-rays
Pravica Group Research

A. Photochemistry

B. Novel materials synthesis

C. New Physics/Chemistry

D. Device applications

Optical mixer

Wide bandgap semiconductor

Radiation-hardened sensors/direct energy conversion devices for EXTREME CONDITIONS or tuned solar materials

Useful hard x-ray photochemistry

X-ray >16 keV SrC_2O_4

Sr^{x+} C_2O_4^x

SrCO_3 + p-CO

Novel structures of known materials produced With hard x-rays and high pressure (e.g. CsO_2)
High Pressure Fluorine Chemistry

$2F_2 + O_2 \xrightarrow{hv} 2OF_2 \text{ @ 3 GPa}$

$XeF_2 \xrightarrow{hv} Xe + F_2$ (in situ x-ray fluorination)

$HgF_2 + F_2 \xrightarrow{hv} HgF_4$

Inner shell chemistry at high pressure

Molecular mixtures at high pressure

$x$-ray induced combustion

Using tuned hard x-rays to damage viruses to create high quality vaccines by targeting specific molecular groups/bonds that resonantly absorb x-ray energy leading to decomposition chemistry.
Electrochemistry and Spectroelectrochemistry in molten salts for the development of the molten salt nuclear reactor

- Fundamental redox and thermodynamic properties of nuclear fuel can be gained using electrochemistry and spectroelectrochemistry.

- Diamond electrodes are specifically amenable to use as the sensing material due to its robustness and tunable properties.
Detection of clinically- and environmentally-relevant analytes with electrochemical sensors

• The all-diamond microfiber electrodes are a supremely biocompatible electrode. With the advantageous properties of diamond electrodes, the suite of potential analytes is expanded.

• The conductive BDD core is covered along the shank with un-doped diamond, thereby making the device non-reactive.

• The batch-fabricated nature of these devices make them attractive compared to others.
Publication track record


Google Scholar: Google scholar webpage of Dr. Rusinek
Salamat Group – Collaboration with MSTS

Metrology – accurate mapping of P, V, T

High temperature modelling – understanding emissivity under extreme conditions
Warm dense matter – probed using EXAFS

- Development of a CO₂ laser heating
- Direct heating of non-metallic systems in a DAC
- First HTHP EXAFS measurements of insulators
- In situ and post heating measurements
- Determining absolute temperature from X-ray spectroscopy
Publications


Materials Compression & Strain

Dr. Oliver Tschauner
Research Professor
Department of Geoscience
Phone: 702-895-3137
Email: olivert@physics.unlv.edu

Expertise:
Dynamic compression
Crystal structure analysis
Minerology
Dynamic Compression

Shockwave Lab:

Compressed He gas, single-stage guns, vertical gun
- Velocimeter, impedance match calculation of sample shock pressure
- Recovery Experiments
- Advantage of advanced structural and chemical characterization at synchrotrons
Microscale analysis: Structure, Strain, HE materials

A. Microscale Structure
   analysis HPCAT

B. Dynamic compression
   strain mapping
   Laue XRD

C. HE materials
   EOS
   HPCAT, LLNL
Zhou Group– Precision measurements, quantum computation, and cold chemistry

- Explore new physics beyond the Standard model by precision measurements
- Develop a quantum transducer bridging ion trap and superconducting quantum computers
- Cold and ultracold ion-radical collisions
- Dual optical frequency comb high-resolution and ultrafast spectroscopy

https://www.physics.unlv.edu/~yanzhou/index.html
Quantum transducer bridging ion trap and superconducting quantum computers

Dual phase stabilized optical frequency combs
Revealing mechanisms of universe evolutions by studying cold ion-radical reactions

- Chain reactions
- Radiative association
- Tunneling resonances
- Collisional resonances

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Expected specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction arm length</td>
<td>30 cm</td>
</tr>
<tr>
<td>Ion beam velocity</td>
<td>0-1000 m/s</td>
</tr>
<tr>
<td>Collision energy range</td>
<td>&lt;0.1 meV to &gt;100 meV</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>&lt;0.1 meV</td>
</tr>
<tr>
<td>Effective reaction duration</td>
<td>1 s</td>
</tr>
<tr>
<td>Detection sensitivity</td>
<td>$1 \times 10^{-16}$ cm$^{-3}$s$^{-1}$</td>
</tr>
</tbody>
</table>