Natural Resources, Climate, and Clean Energy

Energy Resources & Infrastructure Research

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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

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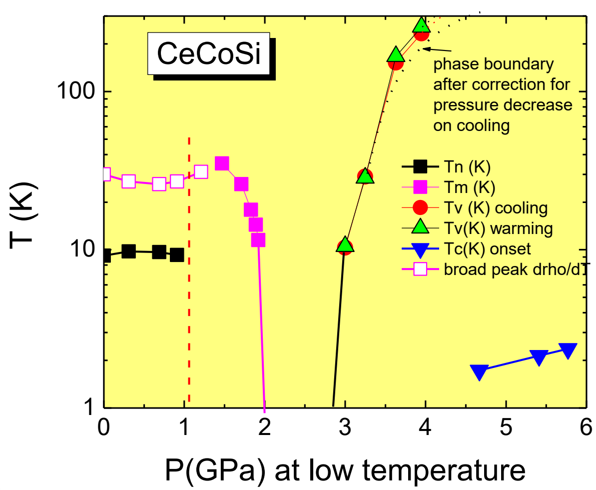
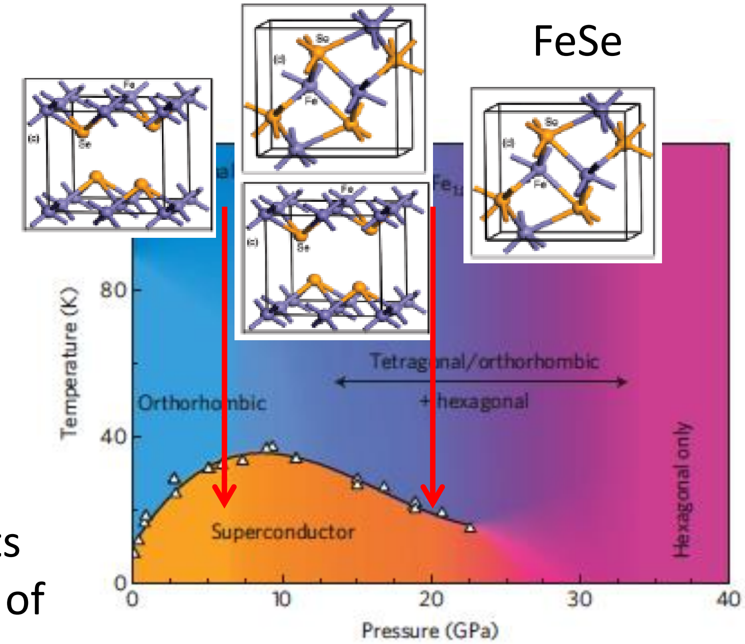
Superconductivity

Quantum Design PPMS at UNLV

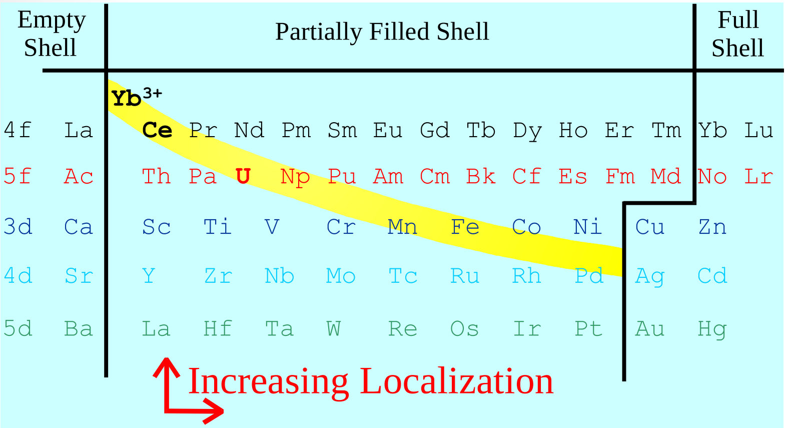
- Measurements from 0.3 K to 400 K
  - Heat capacity, electric and thermal transport, and AC/DC magnetization
- Pressure cells to measure electrical properties (clamp to 3 GPa and diamond anvil cell to >100 GPa)





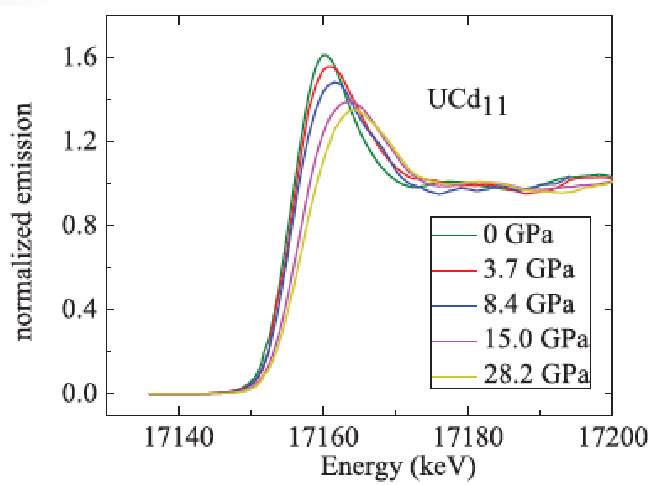
Addition of high pressure synchrotron experiments (diffraction and X-ray absorption) allows mapping of complex superconducting phase diagrams

Correlated-Electron Systems

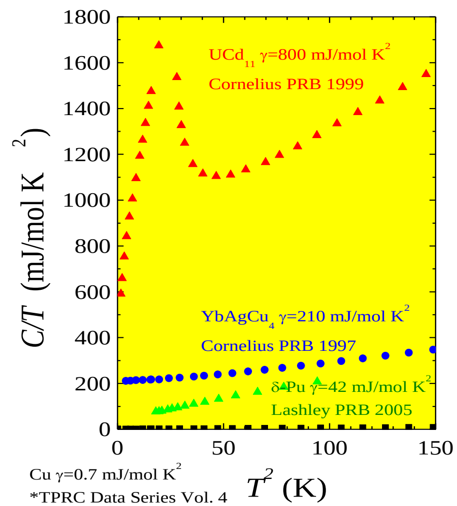


Modified periodic table

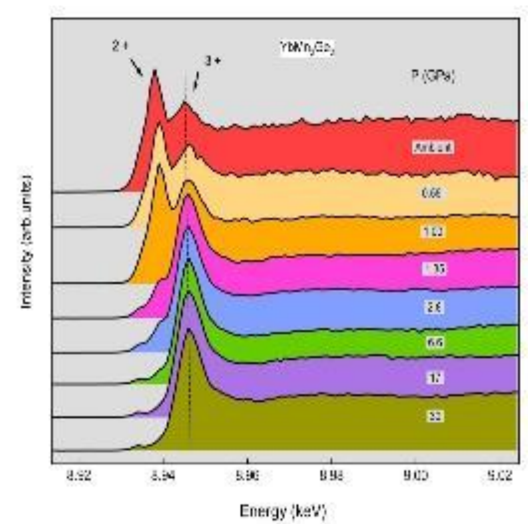
- Going from localized to delocalized electrons one often finds strong electron-electron correlations
- Correlated electron systems can yield interesting behavior: fluctuating valence, superconductivity, non-Fermi liquid, heavy fermion and many more



f-electron delocalization
X-ray absorption



Heavy fermions
Heat Capacity



Fluctuating valence
X-ray fluorescence

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

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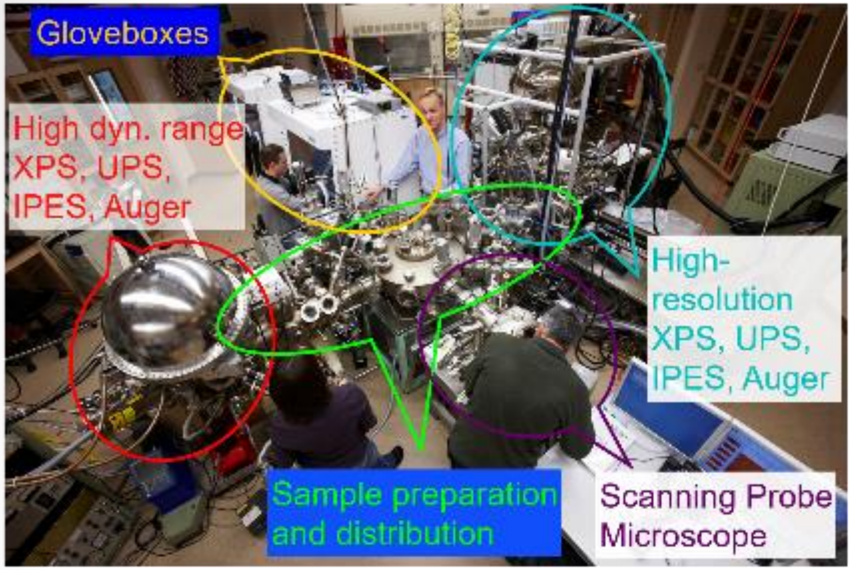
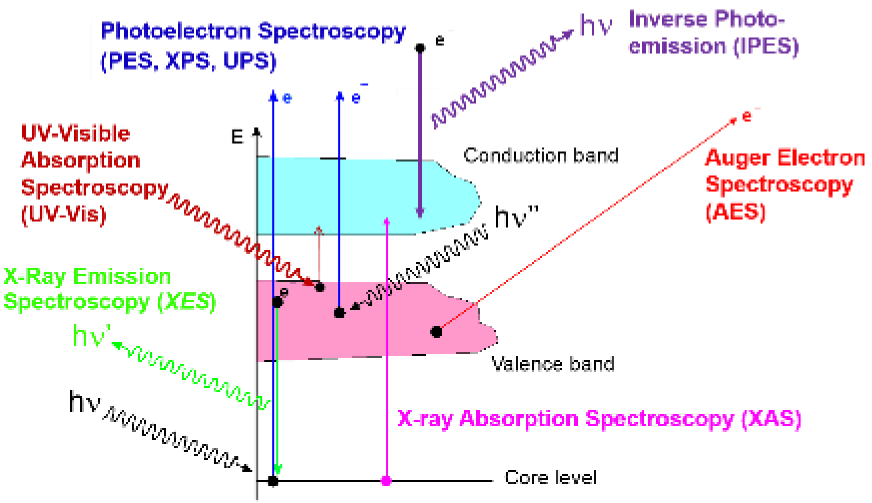
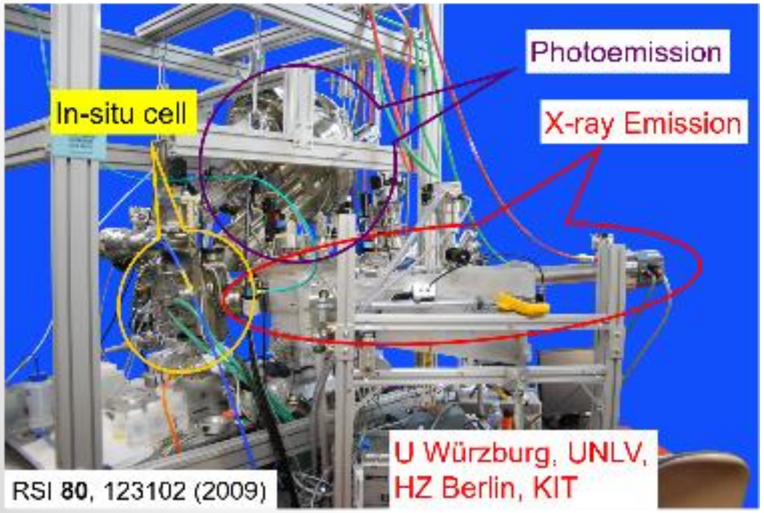
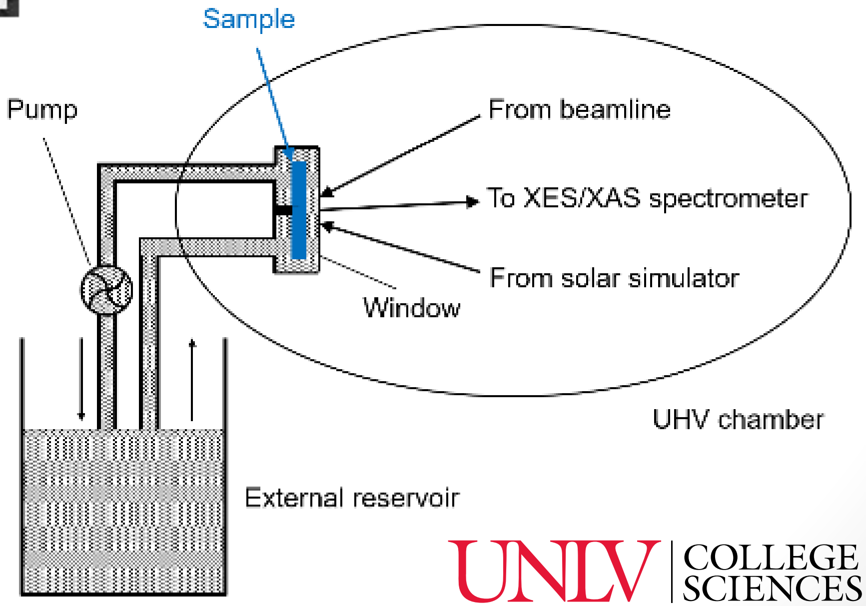
Surface and Interface Characterization





SALSA: Solid And Liquid Spectroscopic Analysis





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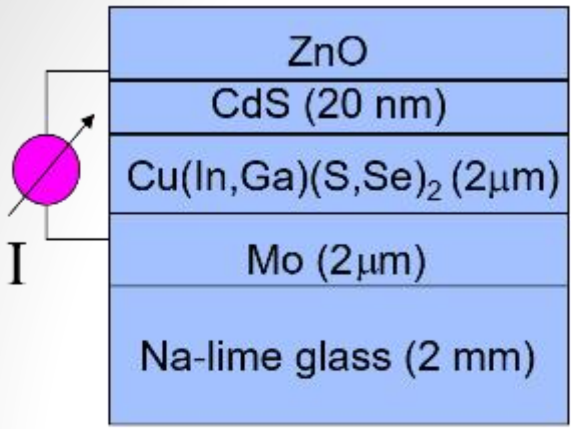
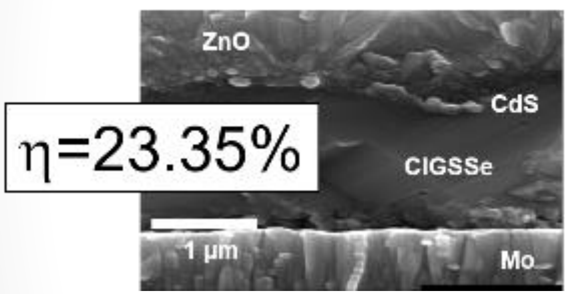
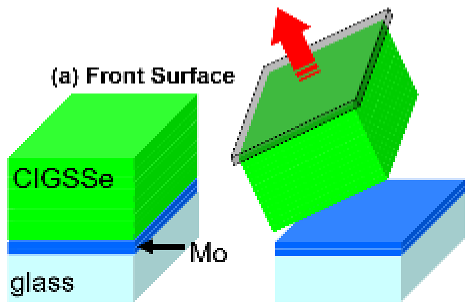
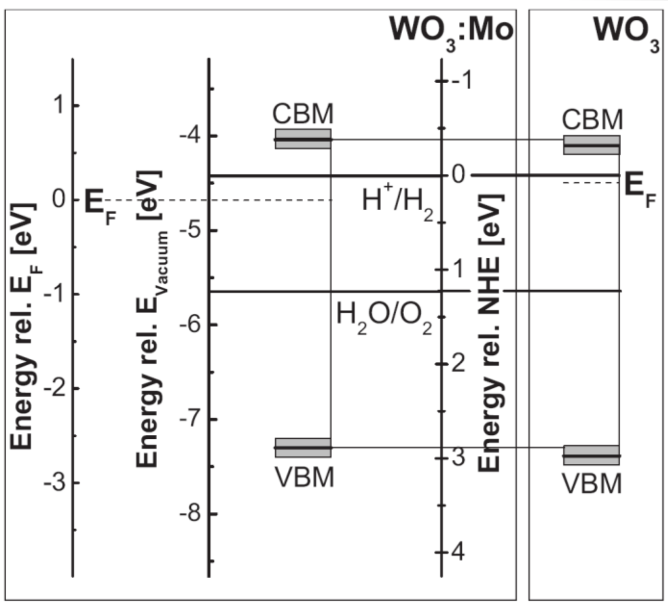
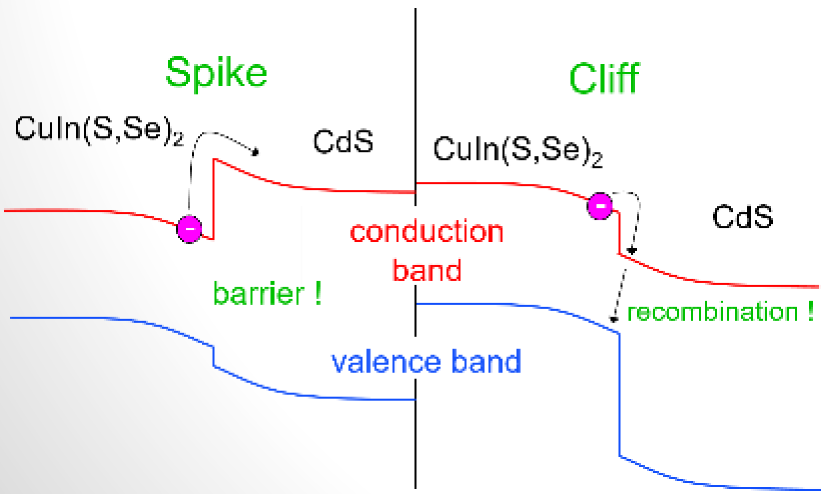
Materials for Energy Conversion

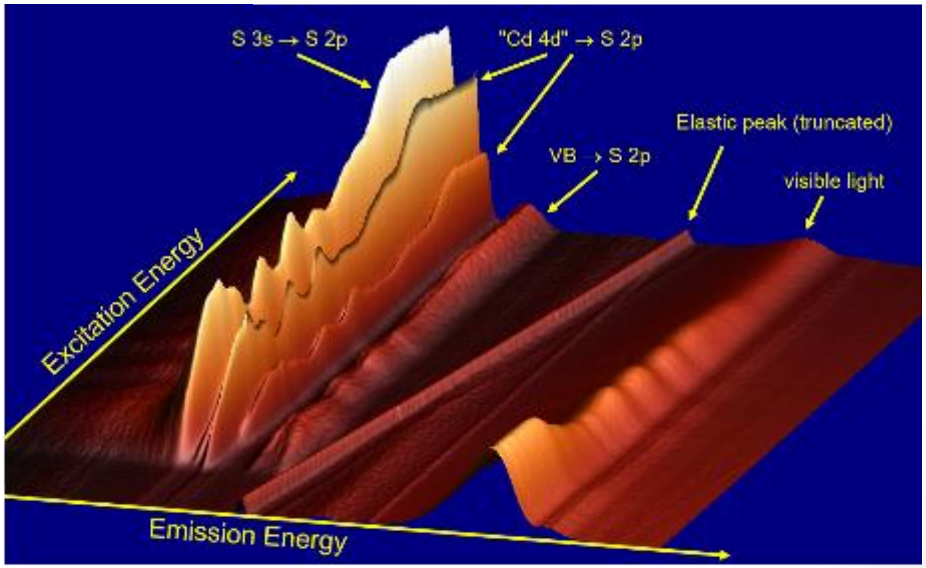












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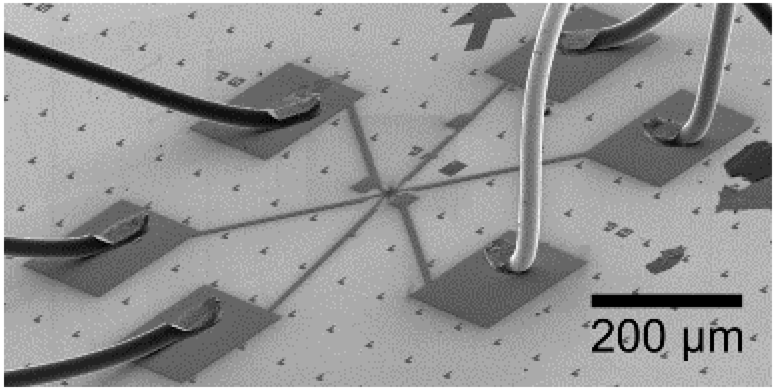
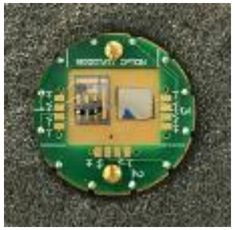
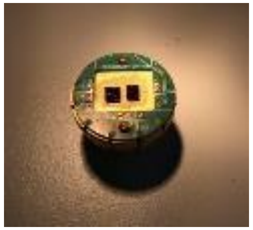
Island – Quantum computing, quantum sensing

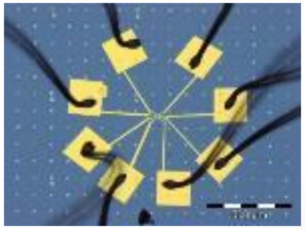
Areas of Research

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









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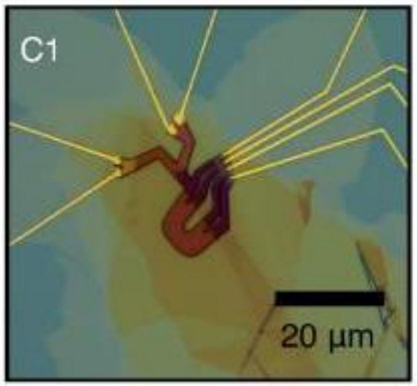
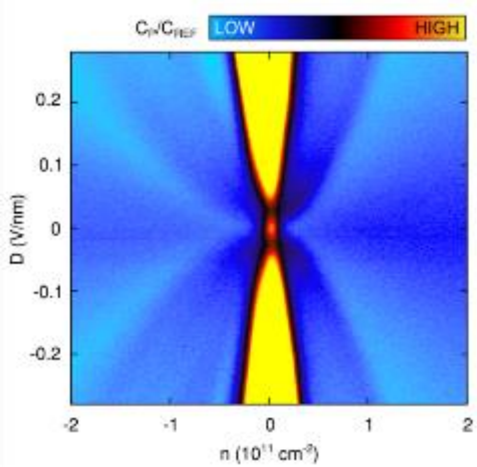
Island – Quantum computing, quantum sensing

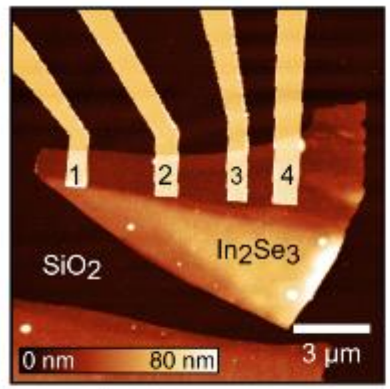
Quantum computing: Topological phases for fault-tolerant, universal quantum computing.

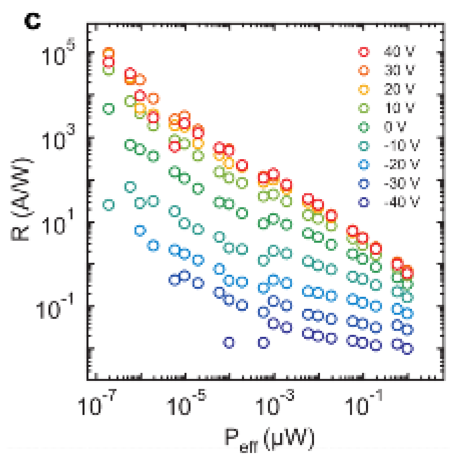




Island, J. O., et al. *Nature* **571** (2019): 85–89.

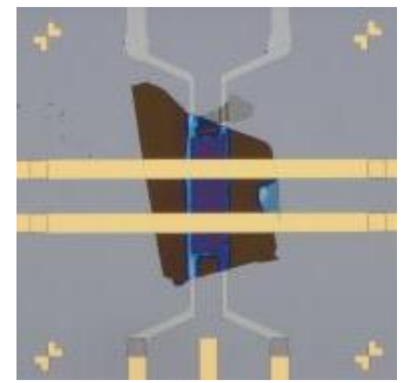
Industry-disruptive photodetectors: Ultra-sensitive phototransistors designed with 2D materials and heterostructures.

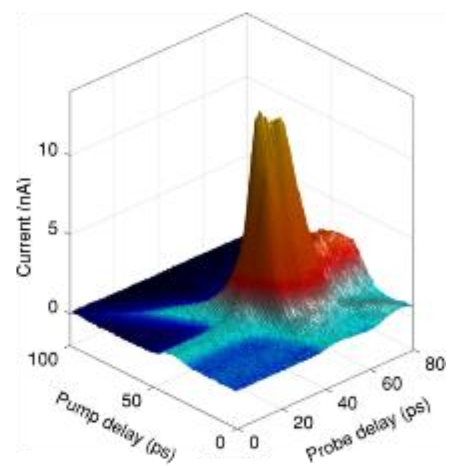




Island, J. O., et al. *Nano Letters* **15** (2015): 7853-7858.

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





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Island – Quantum computing, quantum sensing

Journal publications

Spin-orbit-driven band inversion in bilayer graphene by van der Waals proximity effect
J. O. Island, X. Cui, C. Lewandowski, J. Y. Khoo, E. M. Spanton, H. Zhou, D. Rhodes, J. C. Hone, T. Taniguchi, K. Watanabe, L. S. Levitov, M. P. Zaletel, A. F. Young, *Nature* **571**, 85-89 (2019). (arXiv)

54 5

Enhanced superconductivity in atomically thin TaS2
E. Navarro-Moratalla*, J. O. Island*, S. Manas-Valero, E. Pinilla-Cienfuegos, A. Castellanos- Gomez, J. Quereda, G. Rubio-Bollinger, L. Chirolli, J. A. Silva-Guilln, N. Agrat, G.A. Steele, F. Guinea, H.S.J. van der Zant, E. Coronado, *Nature Communications* **15**, 7853 (2016). (arXiv)

55 97

Proximity-induced Shiba states in a molecular junction
J. O. Island, R. Gaudenzi, J. de Bruijckere, E. Burzuri, C. Franco, M. Mas-Torrent, C. Rovira, J. Veciana, T. M. Klapwijk, R. Aguado, H. S .J. van der Zant, *Physical Review Letters* **118**, 117001 (2017). (arXiv)

2 15

TiS3 transistors with tailored morphology and electrical properties
J. O. Island, M. Barawi, R. Biele, A. Almazan, J.M. Clamagirand, J.R. Ares, C. Sanchez, H.S.J. van der Zant, J.V. Alvarez, R. D'Agosta, I. J. Ferrer, A. Castellanos-Gomez, *Advanced Materials* **27**, 2595 (2015). (arXiv)

1 77

Environmental instability of few-layer black phosphorus
J. O. Island, G.A. Steele, H.S.J. van der Zant, and A. Castellanos-Gomez, *2D Materials* **2**, 011002 (2015). (arXiv)

5 376

Ultrahigh photoresponse of few-layer TiS3 nanoribbon transistors
J. O. Island, M. Buscema, M. Barawi, J.M. Clamagirand, J.R. Ares, C. Sanchez, I.J. Ferrer, G.A. Steele, H.S.J van der Zant, and A. Castellanos-Gomez, *Advanced Optical Materials* **2**, 641 (2014). (arXiv)

1 88

Gate controlled photocurrent generation mechanisms in high-gain In2Se3 phototransistors
J. O. Island*, S.I. Blanter*, M. Buscema, H.S.J. van der Zant, and A. Castellanos-Gomez, *Nano Letters* **15**, 7853 (2015). (arXiv)

10 102

Precise and reversible band gap tuning in single-layer MoSe2 by uniaxial strain
J. O. Island, A. Kuc, E.H. Diependaal, H.S.J. van der Zant, T. Heine, and A. Castellanos- Gomez, *Nanoscale* **8**, 2589 (2016). (arXiv)

1 45

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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

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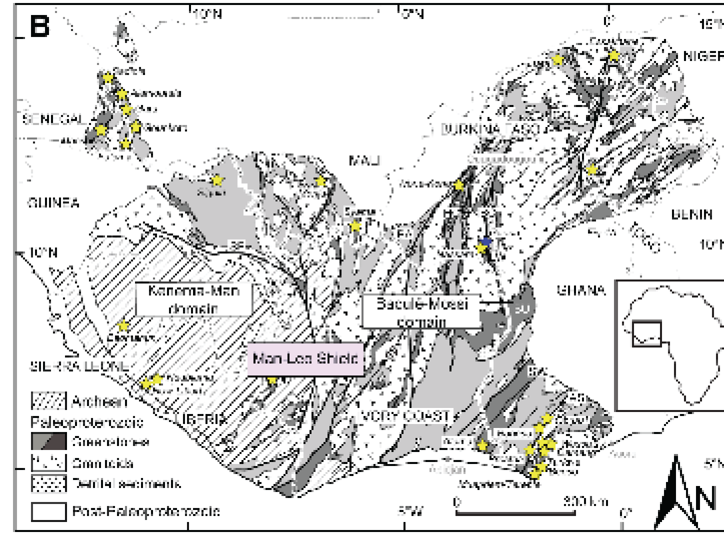
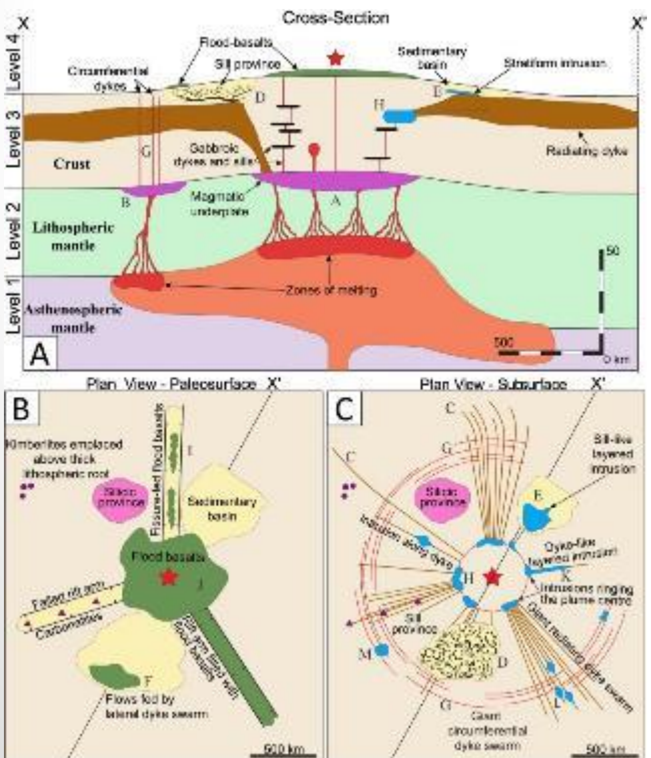
Geochemistry

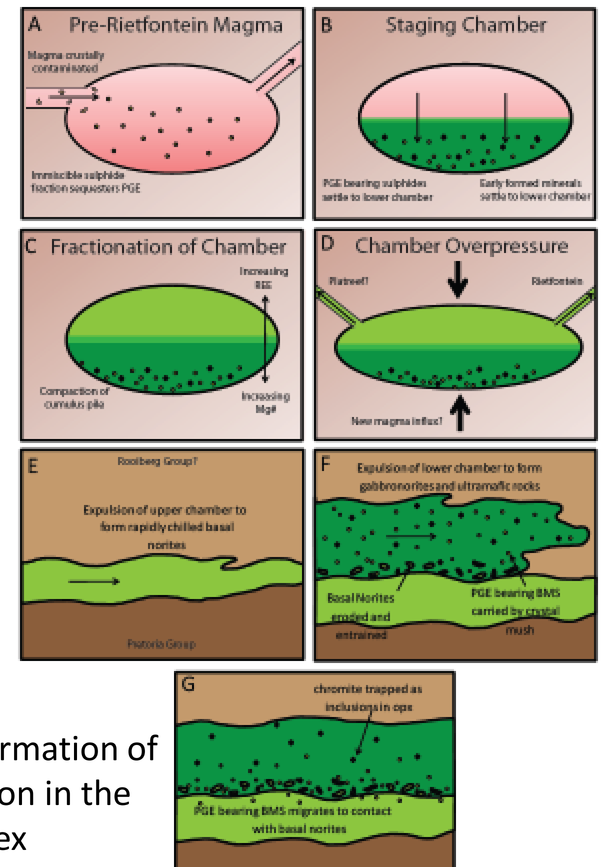
- Understanding mineralizing systems
- Links between tectonic and magmatic events and mineral systems
- Development of mineral exploration tools

Distribution of Orogenic Au deposits within West Africa





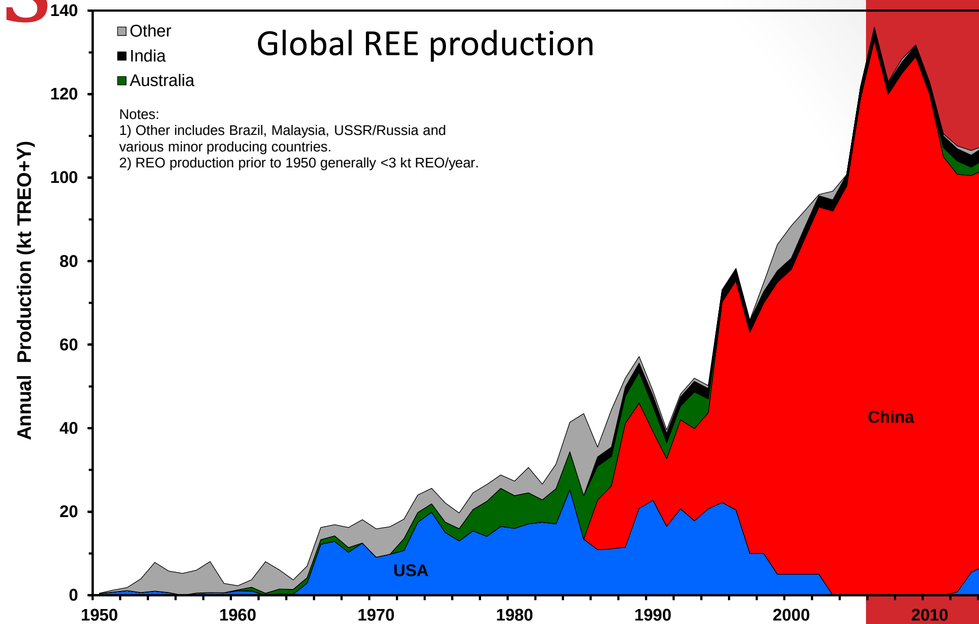
Links between Large Igneous Province plumbing systems and mineralization



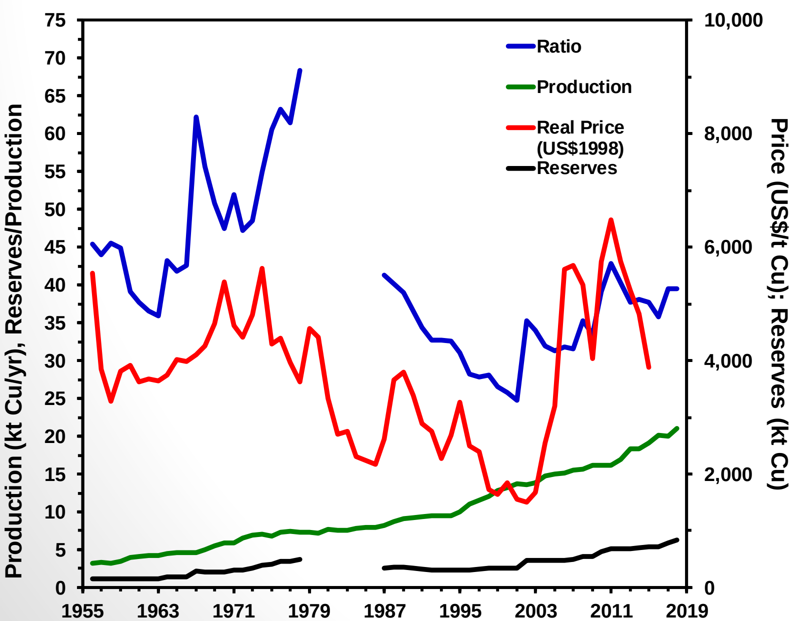
Model for the formation of PGE mineralization in the Bushveld Complex

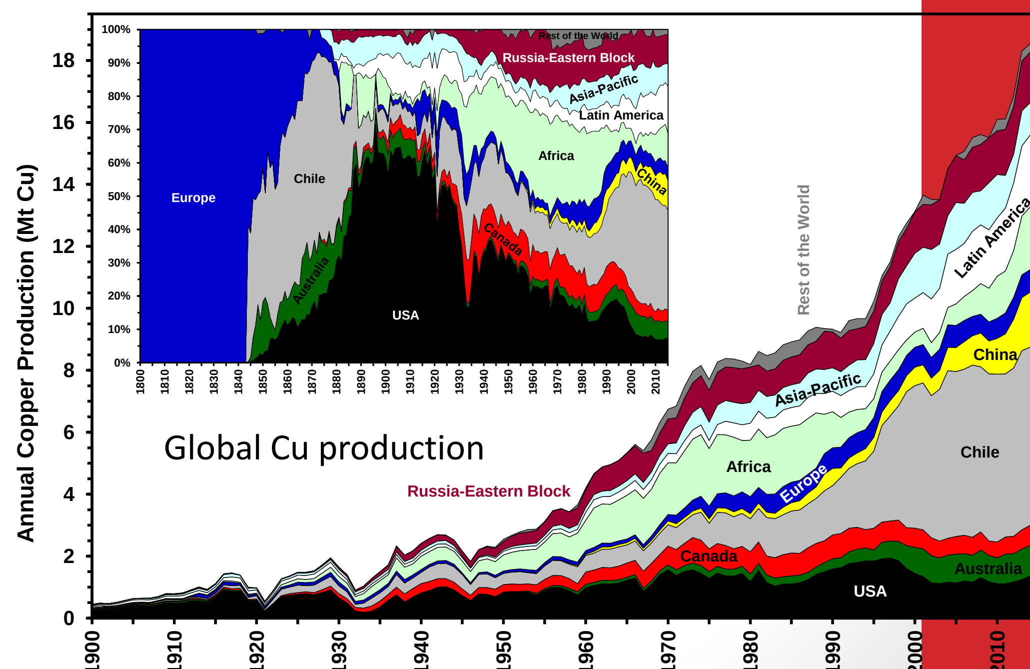
Mineral economics

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



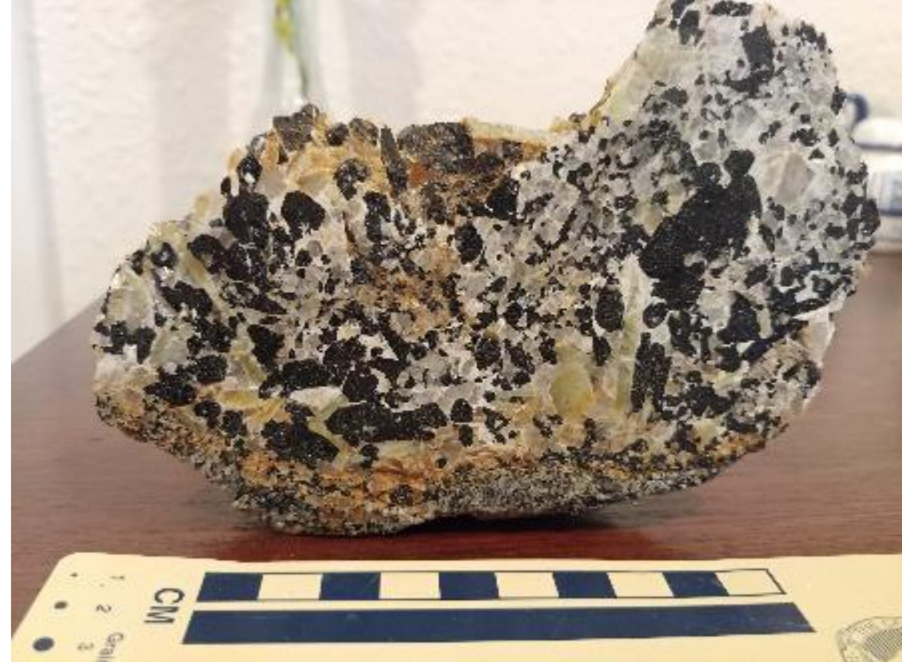
Understanding global metal reserves and production





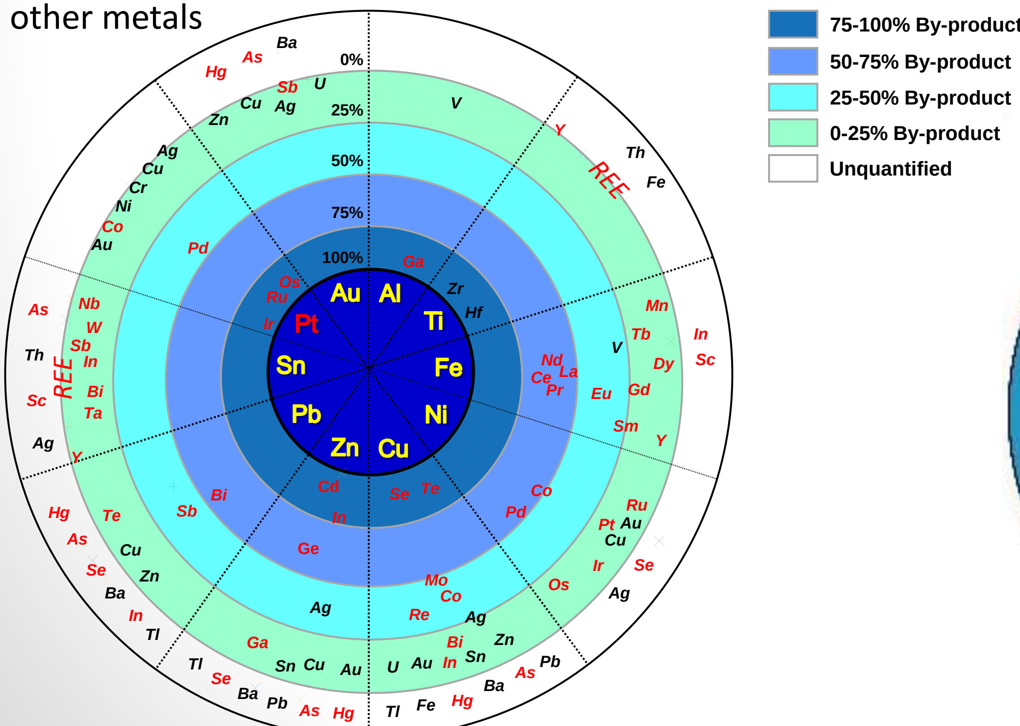
Critical metals

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

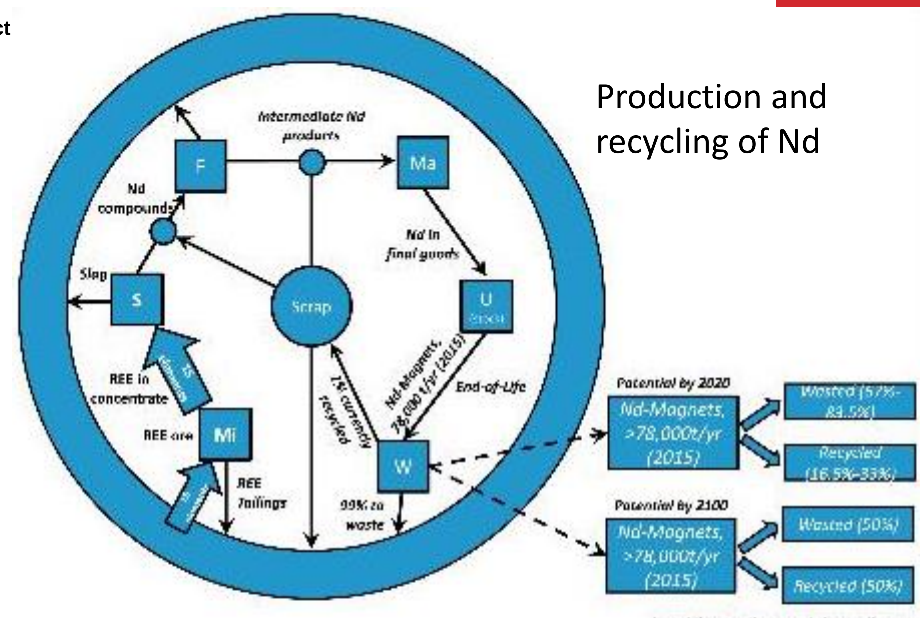


Be-bearing rare metal pegmatite, southern Nevada

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

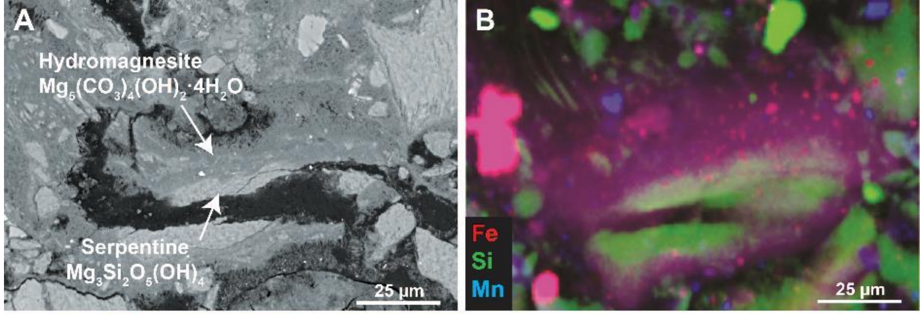


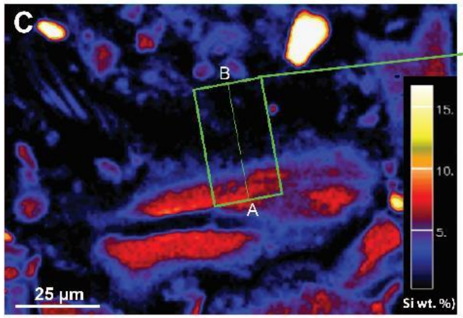
Production and recycling of Nd

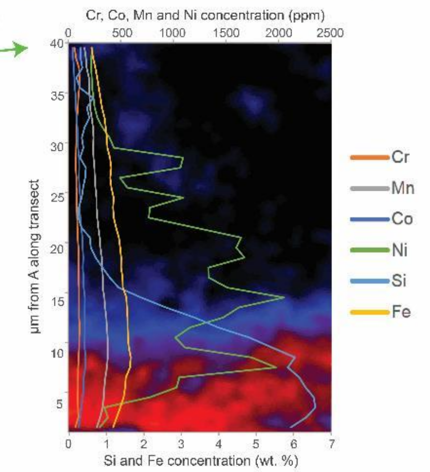


Environmental impact of mining

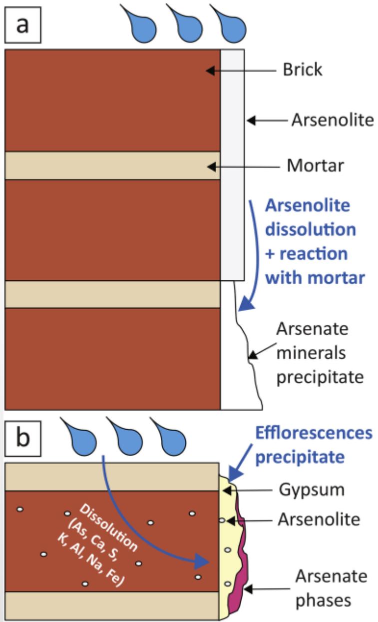
- Assessing environmental impacts
- Potential of wealth from waste; assessing mining waste metal production and CO_2 sequestration potential







BSE and Synchrotron XFM mapping of CO_2 sequestration reactions



Understanding arsenic mobility in mining and mineral processing environments

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

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.

Organic Materials Chemistry

Dong-Chan Lee, Ph.D.

Associate Professor

Department of Chemistry & Biochemistry

Phone: 702-895-1486

Email: dong-chan.lee@unlv.edu

Expertise

- Organic semiconductors with tunable electronic properties
- Self-assembly (nanomaterials, organogels, etc.)
- All organic room-temperature phosphors
- Materials development for solid-state emission with high quantum yield

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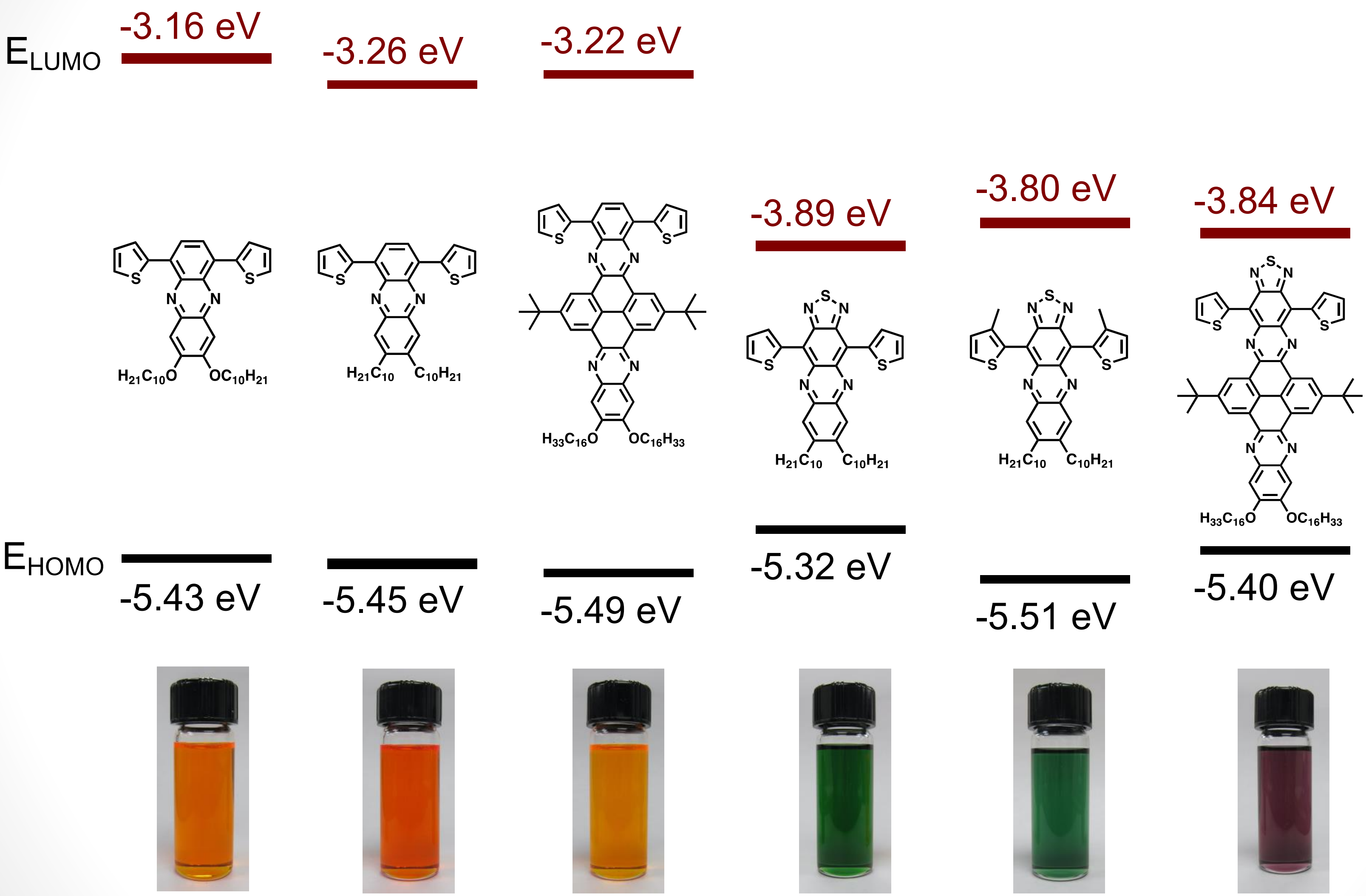
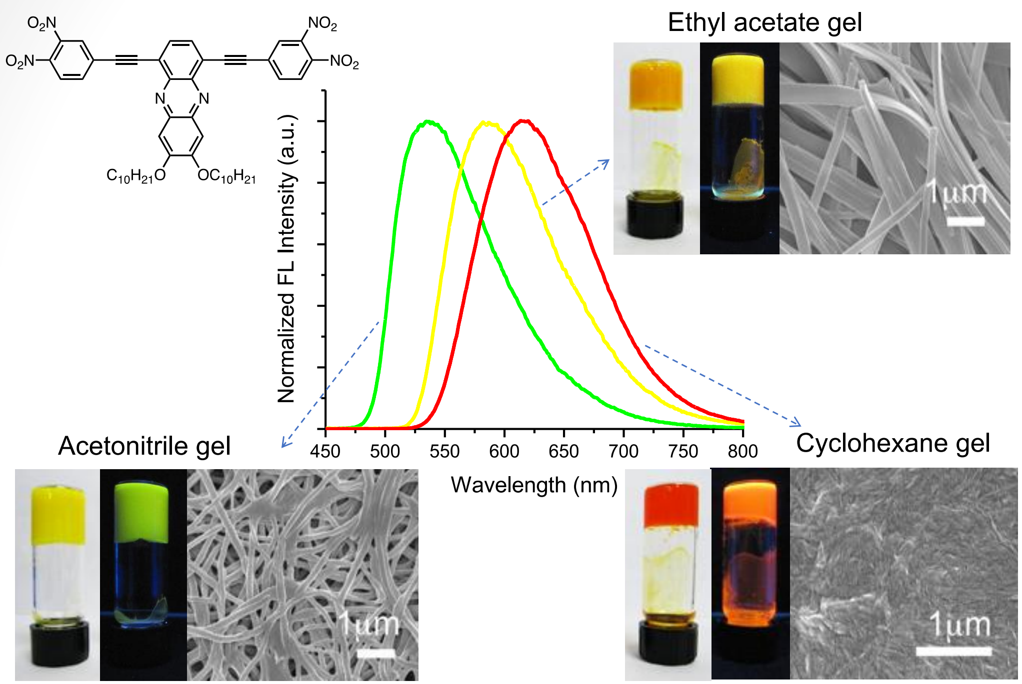
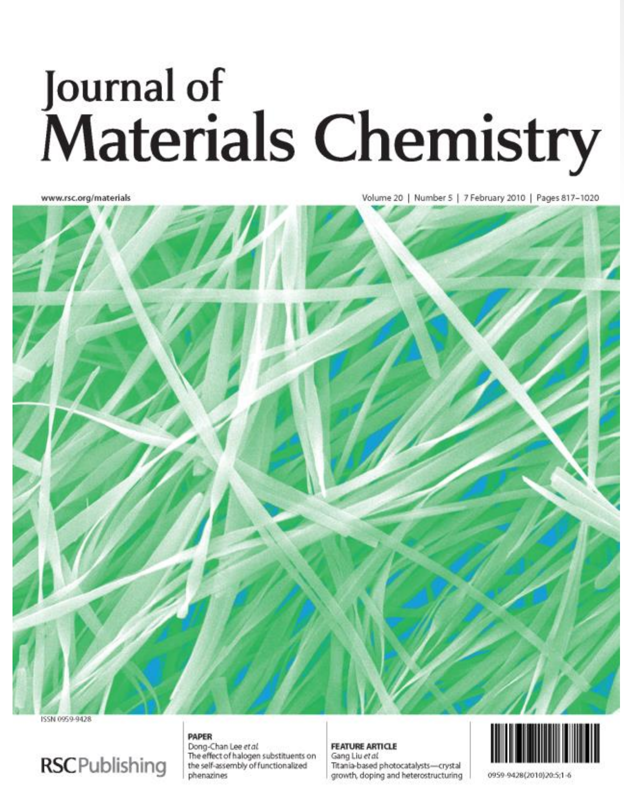
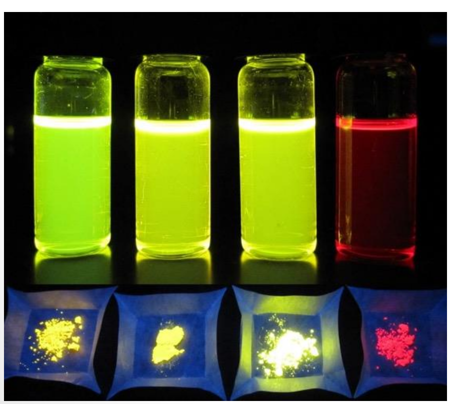
Electronic-Property Tuning with Smart Molecular Design



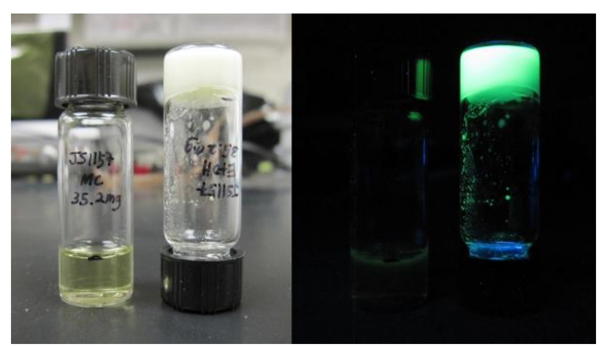
Solvent-Dependent Morphology Control through Organogelation







Solid-State Emission with High Quantum Yield



Gel-Induced Room Temperature Phosphorescence

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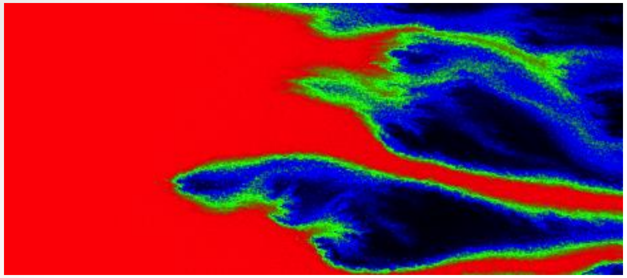
Hydrology

Dr. Michael Nicholl
Department of Geoscience
Phone: (702) 895-4616
Email: michael.nicholl@unlv.edu

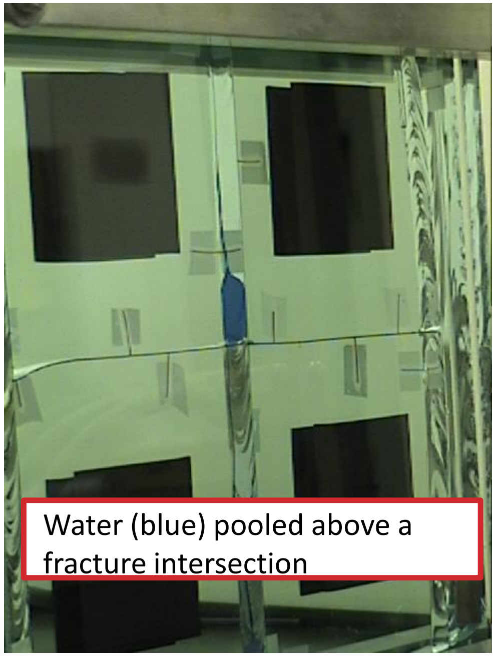
Expertise:

- Unsaturated zone hydrology
- Fractured rock hydrology
- Environmental fluid mechanics

Fractured Rock Hydrology



False color image of a miscible displacement experiment in a single fracture



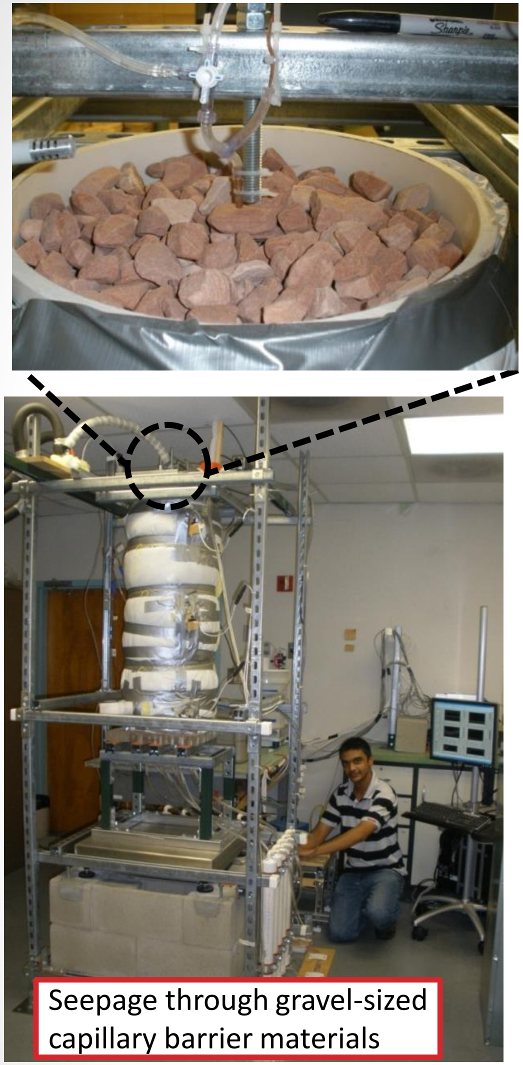
Water (blue) pooled above a fracture intersection

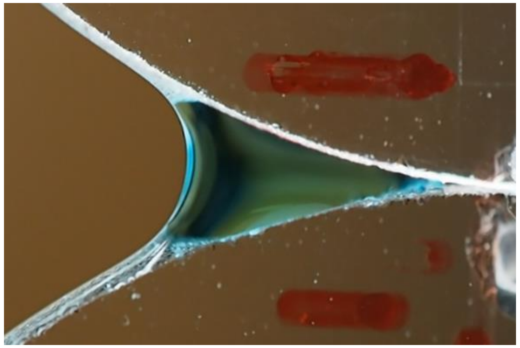
Field mapping of fracture networks
blue dye (right foreground) is from an infiltration test

Isothermal flow across a single rock fracture (matrix-to-matrix flow)

- Two-phase flow and transport in fractured rock
- Laboratory experimentation, field mapping, numerical simulations
- Contaminant transport, geothermal energy, enhanced petroleum recovery

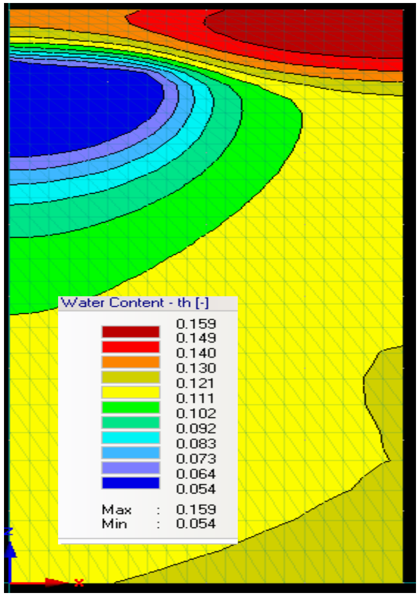
Unsaturated Porous Media


Seepage through gravel-sized capillary barrier materials


Millimeter-scale transport experiment


Sampling Chloride as a proxy for root-driven horizontal flow


Hydraulic conductivity of a rock slab



2D simulation of root-driven transport

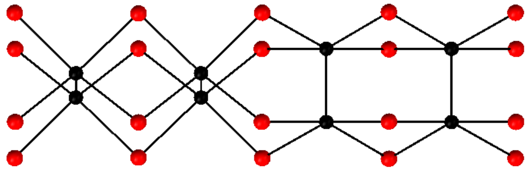
- ❑ Challenging existing conceptual models for unsaturated and two-phase flow
- ❑ Design and execution of critical laboratory/field/numerical experiments

Technetium and Uranium Chemistry

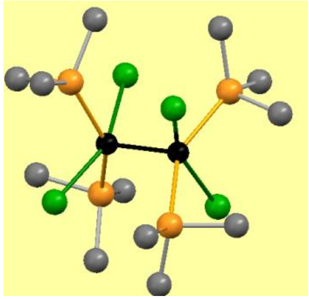
Frederic Poineau, Ph.D.
Radiochemistry

→ Synthetic and coordination chemistry

Technetium binary and ternary halide compounds
Compounds with multiple metal-metal bonds



$TcCl_2$: a unique structure-type



$Tc_2Cl_4(PMe_3)_4$

→ Chemistry relevant to remediation and fuel cycle applications

Separation, vitrification, and waste forms (alloys)

Demonstration of the separation of uranium from technetium for fuel cycle application

Preparation of U-Tc alloys by arc melting

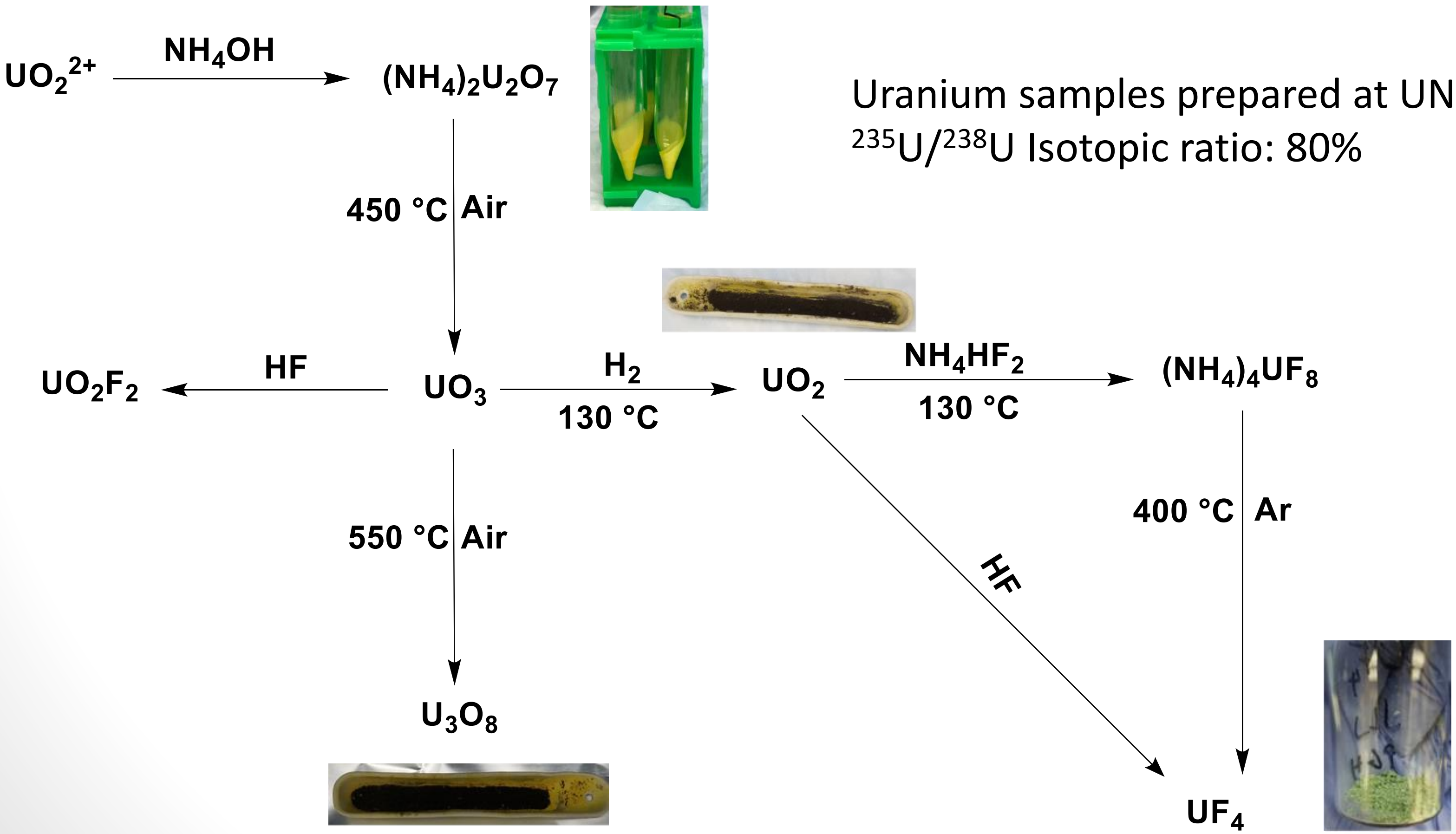
Technetium and Uranium Chemistry

Frederic Poineau, Ph.D.
Radiochemistry

→ Collaborative work relevant to nuclear forensics

Analysis of Uranium Isotopic Ratios by Thermal Ionization Mass Spectrometry (TIMS)

- **Uranium compounds found throughout the fuel cycle (UO_2, U_3O_8, UF_4) prepared at UNLV**
- **$^{235}U/^{238}U$ isotopic ratio measurements using TIMS at LANL**



Uranium samples prepared at UNLV
$^{235}U/^{238}U$ Isotopic ratio: 80%

Climate Change; Renewable Energy; Astronomy

Dr. George Rhee
Department of Physics and Astronomy
Phone: (702) 895-4453
email: grhee@physics.unlv.edu

Expertise

- Observational Astronomy/Cosmology
- Renewable Energy
- Colorado River Flow Projections

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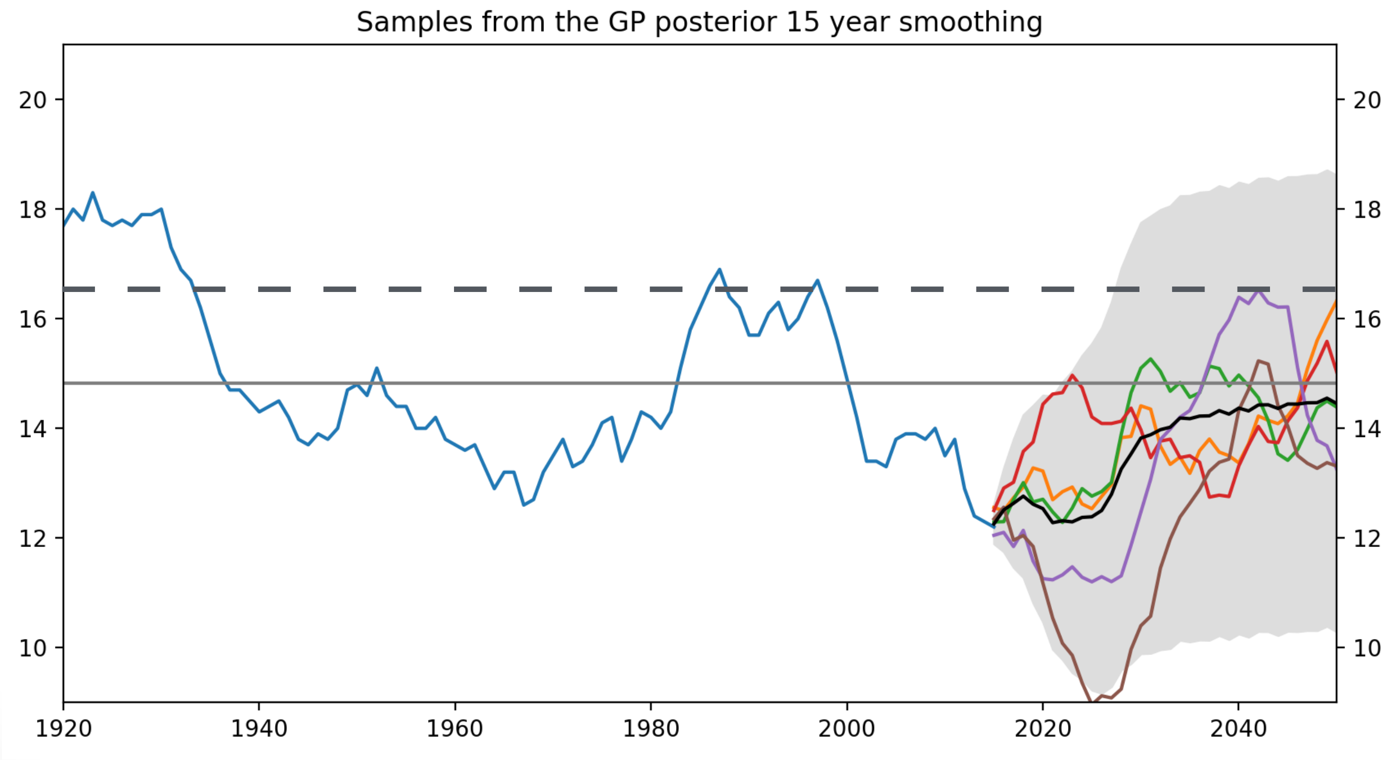
Climate Change

River flow projections using statistics from tree ring data from the upper Colorado River Basin. Gaussian processes with known covariance can be used to predict properties of river flows. Figure shows predictions for Colorado river flow 2015-2050.



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Renewable Energy

Created an online calculator allowing the user to choose supply and demand options to make plans to zero out emissions in Nevada by 2050. http://nv2050.physics.unlv.edu/. I

Interview on KPNR and writeup describing the idea: https://knpr.org/desert-companion/2018-12/do-math

Supply Choices

Nuclear Energy	no nuclear energy ever
Wind energy	add two new wind farms by 2050
Hydroelectric power	Lake Mead dries up by 2030 and generation stops
Geothermal Energy	increase generation by 3% per year
Rooftop Solar power	keep rooftop solar at its 2015 value
Solar PV power plants	solar PV increases by 10 percent a year to 2050
Concentrating Solar Power	build one new Tonopah plant every ten years
Solar Thermal (hot water)	increase to 10% of demand by 2050
Electricity imports	keep electricity imports at 0.15 GW
Carbon Capture and Storage	no CCS, business as usual

Demand Choices

International aviation	factor of three increase in international visitors by 2050
Nevada transport	electrify transport completely by 2050
Nevada freight	business as usual freight travels by road
Industry growth	energy demand increases by 1.5% per year
Commercial heating and cooling	5% increase in efficiency
Commercial light and appliances	energy demand increases by 25% by 2050
Home heating and cooling	energy demand increases by 1.5% per year
Home lighting and appliances	electricity demand increases by 70% from 2015 to 2050
Home insulation	no extra effort on home insulation
Average home temperature	no thermostat adjustment

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Astrophysics

Interested in:

Dark matter distribution in galaxies inferred from the rotation of neutral hydrogen gas in disks

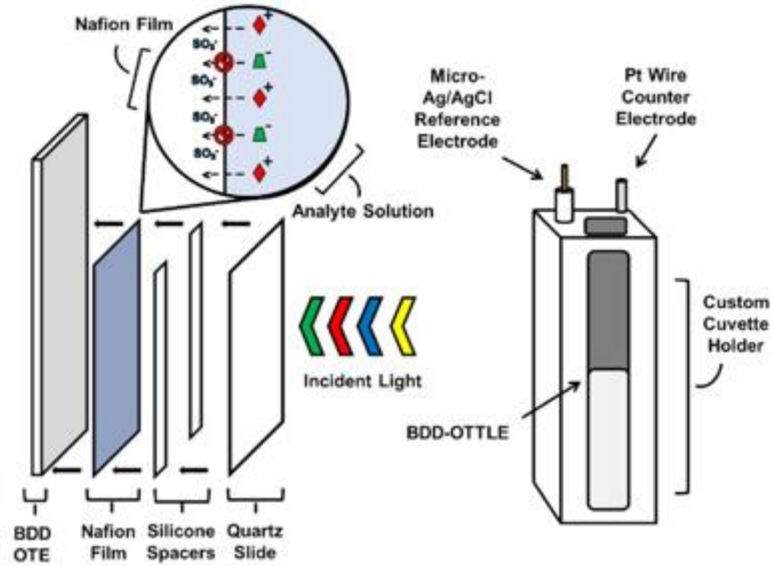
Properties of galaxies in extreme low density environments (voids)

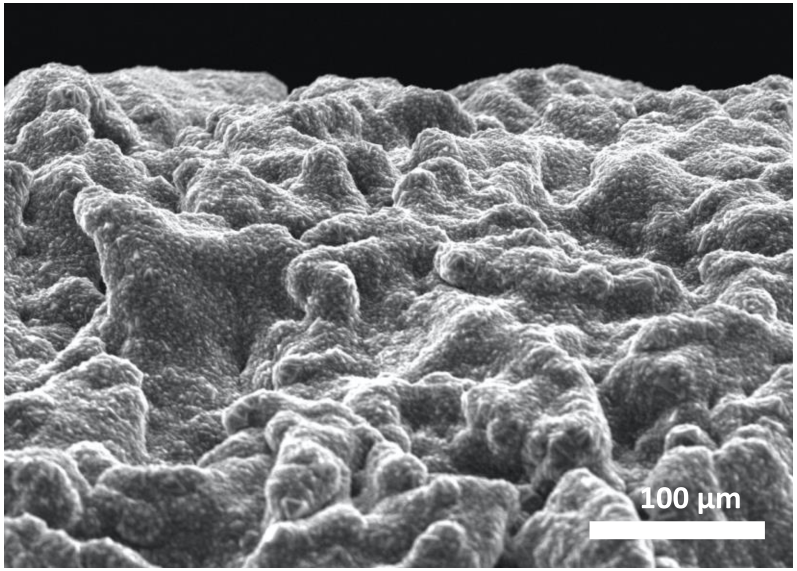
Measuring the masses of black holes using the variability of the central region in Seyfert galaxies and quasars. spectral and brigtness measurements

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

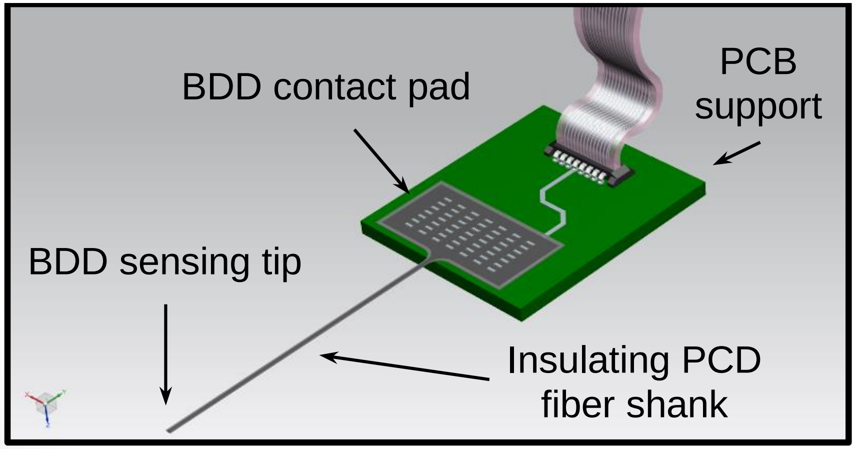


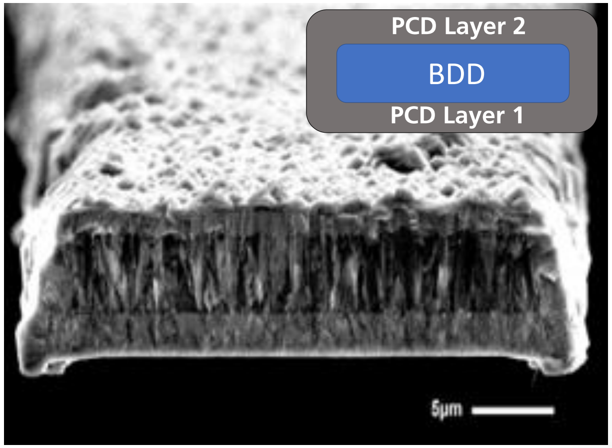


SEM image of diamond film

Detection of clinically- and environmentally-relevant analytes with electrochemical sensors

- The all-diamond microfiber electrodes are a supremely biocompatible electrode. With the advantagouss properties of diamond electrodes, the suite of potential analytes is expanded.
- The conductive BDD core is covered along the shank with un-doped diamond, there by making the device non-reactive.
- The batch-fabricated nature of these devices make them attractive compared to others.





Publication track record

"Polymer-coated Boron Doped Diamond Optically Transparent Electrodes for Spectroelectrochemistry" C.A Rusinek, M. Becker, R. Rechenberg, D. Zhao, K. Ojo, N. Kaval, and W.R. Heineman. Electroanalysis, 2016, 28, 2228-2236.

"Fabrication and characterization of boron doped diamond microelectrode arrays of varied geometry" C.A Rusinek, M. F. Becker, R. Rechenberg, T. Schuelke, Electrochemistry Communications, 2016, 73, 10-14

.

"Large-scale, All Polycrystalline Diamond Structures Transferred on Flexible Parylene-C Films for Neurotransmitter Sensing" B. Fan, Y. Zhu, R. Rechenberg, C.A Rusinek, M.F. Becker, W. Li, Lab-on-a-Chip, 2017, 17, 3159-3167.

"Isatin Detection using an All Boron-doped Diamond 3-in-1 Sensing Platform" M. Ensch, V.Y. Maldonado, G. M. Swain, R. Rechenberg, M.F. Becker, T. Schuelke, C.A Rusinek, Analytical Chemistry, 2018, 90, 1951-1958.

"Analysis of Ag(I) Biocide in Water Samples using Anodic Stripping Voltammetry with a Boron-doped Diamond Disk Electrode" V.Y. Maldonado, P.J. Espinoza, C.A Rusinek, G.M. Swain, Analytical Chemistry, 2018, 90 (11), 6477–6485.

"All Diamond Microfiber Electrodes for Neuroelectrochemistry" C.A Rusinek, Y. Guo, R. Rechenberg, E. Purcell, C. McKinney, M.F Becker, W. Li, Journal of the Electrochemical Society, 2018, 165 (12), G3087-G3092.

"Indium Tin Oxide Film Characteristics for Cathodic Stripping Voltammetry" M. Ensch, B. Wehring, G.D Landis, M.F Becker, T. Schuelke, C.A Rusinek, ACS Applied Materials and Interfaces, 2019, 11 (18), 16991-17000.

"Detemination of Lead with a Copper-Based Electrochemical Sensor" W. Kang, X. Pei, C.A Rusinek, A Bange, E.N Haynes, W.R Heineman, I. Papautsky. Analytical Chemistry, 2017, 89, 3345-3352.

Google Scholar: https://scholar.google.com/citations?user=uZyA2VUAAAAJ&hl=en&authuser=1

Advanced Numerical Methods for Moving Domain/Interface Multi-Physics Problems

Dr. Pengtao Sun
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Department of Mathematical Sciences
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Expertise

- Numerical Solutions of Partial Differential Equations (PDE)
- Numerical Analysis (Well-posedness, Stability, Convergence)
- Finite Element/Volume/Difference Methods
- Scientific and Engineering Computing
- Fluid-Structure Interaction (FSI) Modeling and Simulation
- Fuel Cell Dynamics, Fluid Dynamics, Electrohydrodynamics

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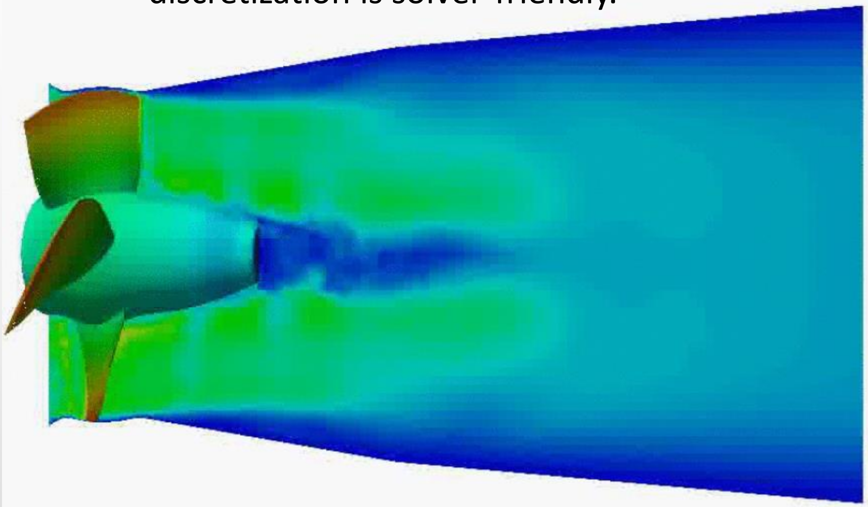
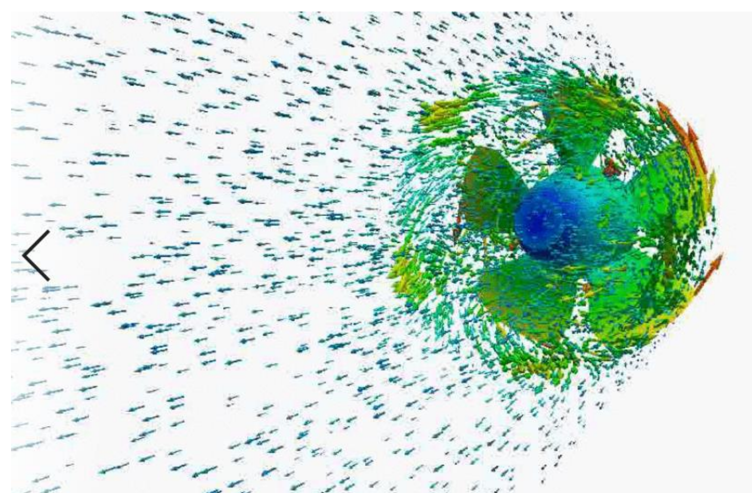
Fluid-Hydro Turbine Interaction Problems

- Hydroelectric power generating system produces renewable energy and remains crucial for society and industry. The most significant part of this system is the hydro turbine interacting with the water flow, which involves elastic solid materials and viscous fluids and belongs to the category of fluid-structure interaction (FSI). The developments of mathematical models and numerical methodologies are critical in practice for efficient simulations of the hydro turbine, which in turn guides the design and evaluation.
- We approach the challenges in different aspects. First, based on the observation that the hydro turbine, although exhibiting large rotations, has relatively small deformation, we develop linearized elasticity equations that alleviate the burden on nonlinear solver and improves the well-posedness of spatial discretization. Second, we propose a new approach to solve the arbitrary Lagrangian-Eulerian mesh motion for rotating structure. Moreover, we analyzed the well-posedness and convergence of the finite element discretization and demonstrated the discretization is solver-friendly.





Hemodynamic Fluid-Structure Interaction (FSI) Problems

- FSI simulation has become the most promising solution method to solve the hemodynamic problem existing in the clinical cardiovascular system. However, the complexity of cardiovascular environment, the artificial heart pump model, the vascular rupture, the aneurysm progression and the aortic dissection cause the deficiency of the existing FSI simulation package towards the clinical demands.
- We devoted our research to the new modeling and numerical techniques for the bloodstream-vascular-stent graft/artificial heart pump interaction problems, aiming at overcoming numerical difficulties and challenges, and developed advanced numerical methodologies to improve the efficiency and accuracy of corresponding FSI simulations. and to deliver more instructive numerical results to medical professionals for helping out patients on an efficient and accurate diagnosis and treatment.