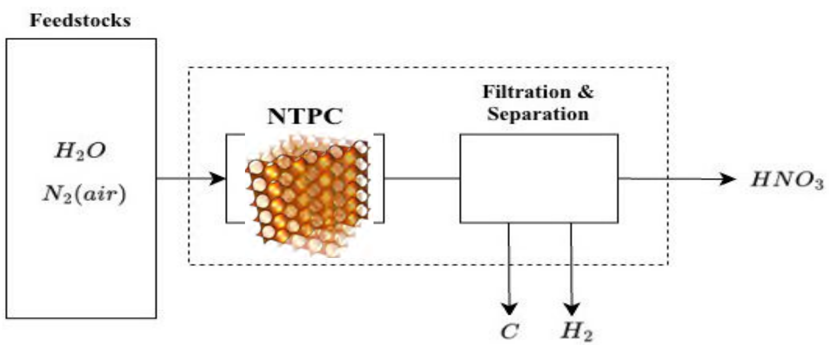
HNO3 Proposers Day Lightning Talks

12/12/25

Taylor Baugh (PI), CLR Technologies, Leonard Robinson (CEO)

Project Overview



- We seek to achieve commercially viable nitric acid production by synthesizing nitric acid and economic syngas utilizing enhanced catalyst geometries.
- We propose a biphasic non-thermal plasma direct HNO3 synthesis using a porous catalyst.
- We are dual research commercialization bridge firm
- Catalyst fouling is a primary concern
- We can contribute with commercialization efforts following successful design phases.
- Phase 1a, Phase 1b, **Phase 2 Scaled Reaction**

Teaming Overview and Capabilities

- Small Business PI - Taylor Baugh (CLR Technologies)
- Research Institution PI Dr. Lea Winter (Yale University)
- Advisor Dr. Jingguang G. Chen (Columbia University)
- ClimateHaven (Incubator), MakeHaven (Prototyping)
- N2 Fixation by Plasma-Activated Processes (Winter & Chen, 2021)
- Knitting on Helicoid Scaffolds (Niu, Rimmerman, Baugh, 2024)
- The Chen and Winter Lab are recognized national leaders in electrolysis and catalysis with sufficient equipment to run all required experiments.
- CLR Technologies is led by a team with experience in modular, ISO9001 compliant process development, validation, and scale.

Teaming Needs

Key:

- We are looking for professionals with advanced catalyst development capabilities.
- We are looking for professionals with scaled metal fabrication capabilities at the pilot stage.
- We are looking for research partners to run experiments with our catalyst designs.

Other:

- Milestone 1: Theoretical layout for phase 2 design
- Milestone 2: Catalyst fabrication
- Milestone 3: Prototype reactor development

Leonard Robinson – Leonard@clrtechnologies.co – +1(248) 971-0535

Dr. Tyler Porter, Leidos-MIT

Project Overview

- Leidos proposes an electrochemical reactor to generate reactive-promotors that are capable of direct nitrogen oxidation for sustained nitric acid synthesis.
- Typical approaches rely on high-anodic bias to directly oxidize N2 into higher ordered nitric oxides (NO_x). This approach however is competitive with the much more facile water oxidation reaction leading to O_2 evolution and anode dissolution.
- Our approach relies on the electro-generation of strong, solution-based oxidants under low-bias to inherently side-step competitive oxygen evolution while enhancing direct nitrogen reactivity.

Teaming Overview and Capabilities

Existing Team and Relevant Experience:

- (Leidos) Dr. Tyler Porter: Electrochemical synthesis utilizing renewable feedstocks; synthesis and handling of energetic materials.
- (MIT) Prof. Yogi Surendranath (MIT): Pioneer in electrochemical systems ranging from batteries to fuel cells/electrolyzer
- (Leidos-MIT) Prior work on DARPA ExCURSion utilizing renewable feedstocks for de-centralized hydrocarbon fuel production. Electrochemistry under exotic conditions including high-temp/pressure systems, molten salts, and even fuming sulfuric acid.

- Access to UCSD/MIT core facilities: TEM, SEM, XPS, NMR, IR, RAMAN, E-beam evaporators, Sputter coaters, etc...

Teaming Needs

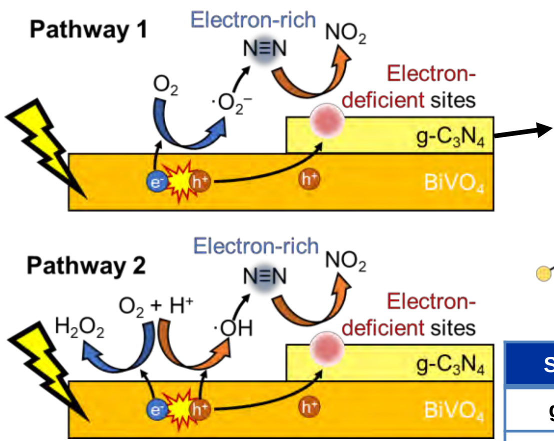
- Computational modeling of reactive intermediates and potential mechanistic pathways.
- Process intensification and novel strategies for nitric acid separation and purification from electrolyte.

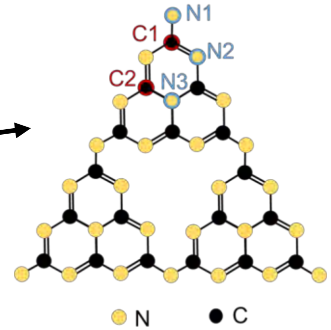
Other:

- While the main goal is a comprehensive understanding of how strong-oxidants promote nitrogen oxidation, the team also places a strong emphasis on system level integration, highlighting, modularity, safety, and ease-of-use.
- The team will pursue transition of this technology by working towards commercialization in both government and private sectors. This will be achieved in collaboration with small businesses and MITs technology licensing office to engage with end-users early on ad secure additional funding for further technology development and maturation.

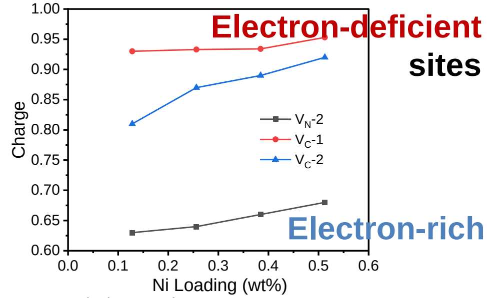
PI: Shu Hu, Yale University, Experimental Team

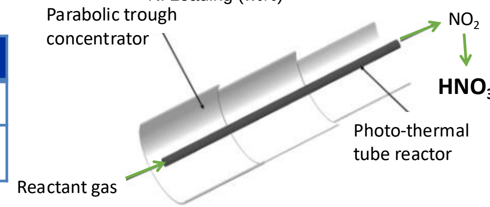
Project Overview





Sample	C	N	C/N
$g\text{-}C_3N_4$	43	49	0.87
$H_2\text{-}g\text{-}C_3N_4$	41	56	0.73





- ❑ Realize plasma-free N_2 oxidation to NO_2 via two possible photo-thermal pathways: on-demand, distributed
- ❑ **Challenge:** Leveraging photothermal effect to overcome high N≡N activation barrier
- ❑ DFT shows the C vacancy sites on $g\text{-}C_3N_4$ are electron-deficient sites, which are hypothesized to assist N_2 adsorption
- ❑ C vacancy can be introduced by H_2 annealing of $g\text{-}C_3N_4$

Teaming Overview and Capabilities

Prof. Shu Hu (PI)

- Possessing leading expertise in light-driven catalysis, i.e., understanding coupled processes during photocatalysis and designing active sites that are supported on semiconductors.

Dr. Xiaohan Ma (Postdoc)

- 7 years of research experience in $g\text{-}C_3N_4$ and $BiVO_4$ (BVO) photocatalysis and thermal catalysis (ORNL, Clemson & Yale), mainly focused on hydrogenation and dehydrogenation reactions.

Core facilities: Photo-thermal reactor, photocatalyst synthesis ALD, GC-MS, NMR, XRD, XPS, Raman, SDL

Teaming Needs

- Collaborations on *in-situ/operando* NAP-XPS techniques are needed to study the surface chemistry and reaction mechanism.
- Theory of N_2 adsorption and cascade reactions.

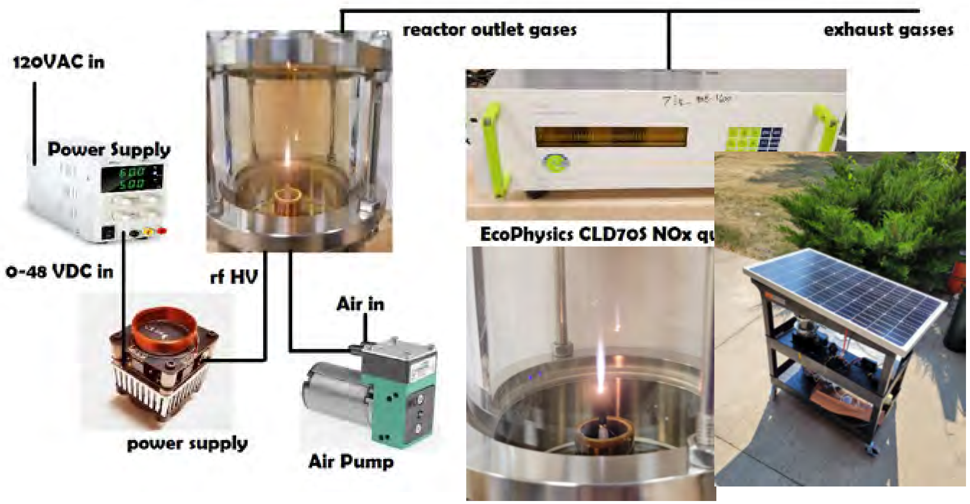
Milestones

1. Synthesis of intimate $g\text{-}C_3N_4$/BVO heterojunction and realize continuous tuning of the local surface electronic property of $g\text{-}C_3N_4$.
2. Obtain high NO_2 selectivity by suppressing competing reactions like OER and Haber-Bosch reaction.

Prof. Shu Hu, Yale University – shu.hu@yale.edu – (650)-804-8656

Davin G. Piercey, Purdue University, No full team yet (open to teaming)

Project Overview



- We have already demonstrated nitrogen fixation as nitrogen oxides and nitric acid starting from only water, air, and electricity
- We use a high-frequency plasma to do this
- Our system operates at ambient pressure
- Our system has been run off a solar panel demonstrating decentralized production
- We have a method for overcoming limitations of slow absorption of NOx gasses in water
- Possibility of preparing fuming nitric acid→ useful for explosives synthesis
- We need to optimize the efficiency of our system after proof of concept demonstrated.

Teaming Overview and Capabilities

- **Team:**

Davin Piercey: Nitrogen Chemistry and energetic materials background, built the proof-of-concept system above, published on plasma nitrogen fixation **Piercey, D. G**. *et al. Processes*. **2024**, *90* , 24-33.

Stephen Beaudoin: Chemical Engineering. Involved in projects for DoD scaling critical chemicals and energetic materials.

- **Institutional assets and core facilities:** Full chemical characterization and chemical engineering facilities. NOx quantification equipment.

Teaming Needs

Key:

- Need collaborators with experience modelling plasmas and radio frequency engineering experience for the improvement of efficiency. Numerous sources of identified inefficiencies.

Other:

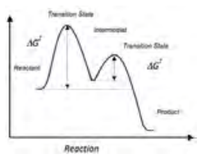
- Metrics: Improve the MJ/mol efficiency of nitrogen fixation to be better than other plasma fixation methods. Build optimized automated system.

- If successful, patent and maybe a startup company around using the modular nitrogen fixation system for fertilizer: a dual use product, energetic synthesis and agriculture.

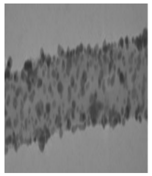
Davin Piercey– dpiercey@purdue.edu – 765 479 9929 (cell) 765 494 1504 (office)

SRI International, Fieldable, Low-energy, Air-fed Synthesis of HNO_3 (FLASH)

Catalyst and reactor modeling

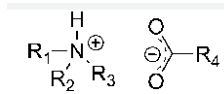


Catalyst synthesis

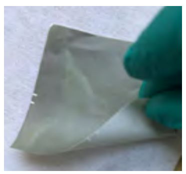


Catalyst testing

IL electrolyte testing



GDE fabrication



GDE testing

Electrode assembly

Reactor scale-up

Project Overview

Objectives:

- Use electronic structure calculations and kinetic modeling to guide catalyst discovery and selection.
- Synthesize catalysts and fabricate gas diffusion electrodes to increase mass transport and catalyst activity.
- Deploy an ionic liquid electrolyte that optimizes for low resistance and maximal N_2 absorption.
- Conduct fundamental characterization of each component of the electrode assembly (planar catalyst, GDE, IL).
- Demonstrate rate and efficiency targets at lab-scale using a reactor design that translates to sub-scale.
- Integrate additional unit operations and balance of plant to create a process for 1- and 50-L/day lab-grade HNO_3.

Team Overview and Capabilities

Leverage SRI's **10+ years** of expertise in electrochemical devices from benchtop to field deployed systems

Jonathan Bachman, Ph.D., SRI (PI)

- Electrode fabrication; reactor design (lab scale, sub-scale, and full-scale); HNO_3 production process design (sub-scale and full-scale)

Prof. Lars Grabow, UH (Co-I)

- Electronic structure calculations & kinetic modeling; machine learning for static/dynamic NOR catalyst selection

Prof. William Tarpeh, Stanford (Co-I)

- Catalyst characterization; fundamental experiments and in-operando studies

Prof. Joan Brennecke, UT Austin (Co-I)

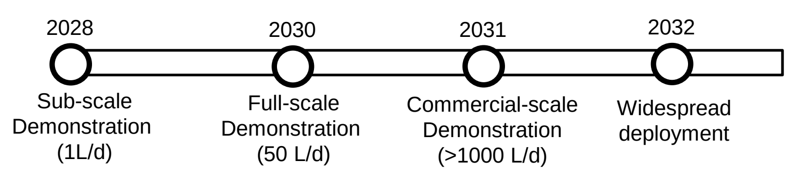
- Electrolyte characterization; gas solubility, viscosity, and conductivity testing

Teaming Needs

- Catalyst scale-up partners and commercial partnerships with end users (chemicals producers or consumers).
- Additional unique electrochemical characterization methods.

Technology Transition

- SRI regularly spins-out companies; notably Siri, Intuitive Surgical, Orchid BioSiences, and Mojave Energy, and regularly conducts commercial licensing of technologies developed.
- If successful, SRI can spin-out a company dedicated to deploying the technology for direct nitrogen oxidation.
- Market analysis will be conducted parallel to the project; the goal is to establish technical feasibility alongside product-market fit.



Contact: Anish Thukral, anish.thukral@sri.com, (650) 859-5333

Dr. John Slack, Rhoic Inc., 3D Non-Faradaic Field-Induced Reactor

Project Overview

- Developing the first volumetric, field-induced, non-Faradaic reactor to drive $N_2 \rightarrow NO_x$ chemistry.
- Concentrates strong, high-frequency AC fields at nanoscale catalysts, injecting energy directly into the N≡N bond during adsorption, forming NOx that feeds directly into an absorber to produce HNO_3.
- Program phases: demonstrate field-driven NOx formation → optimize 3D reactor core → integrate absorber for modular HNO_3 production.
- Technical challenges: high-frequency power delivery, field–catalyst coupling, and quantifying field-induced NOx rates.

Teaming Overview and Capabilities

Core Team
- Expertise in electrospinning, strong-field/material interface, RF electronics, and systems engineering

Relevant Experience
- Invented Rhoic's high-frequency AC electrospinner & 3D nanofiber reactor cores
- Executed DOE/National Lab programs in catalysis, materials, and high-voltage systems

Institutional Assets
- Custom AC-electrospinning hardware enables 3D conductive nanofiber reactor cores with tunable catalysts for field-driven NOx formation.
- In-house high-frequency HV lab + polymer synthesis
- Berkeley Lab access via Activate & Cyclotron Road

Teaming Needs

Key:
- High-frequency power delivery and impedance matching, and modeling of field–catalyst and field–molecule interactions in the 3D reactor core
- Independent characterization and performance verification

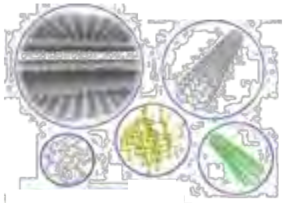
Other:
- **Milestones:** Clear measurement of field-induced NOx formation rates, energy efficiency vs. thermal baselines, and catalyst durability under high-frequency operation
- **Transition:** Partner with industrial primes and national labs to validate NOx production, demonstrate scalable reactor modules, and map pathways to distributed nitric acid production

Contact Information – john.j.slack@rhoic.co – 3303098559

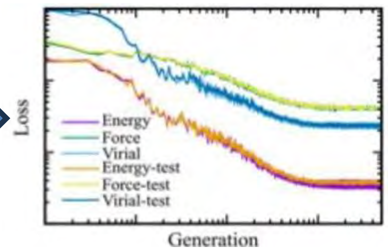
Xiangyu Li, University of Tennessee Knoxville

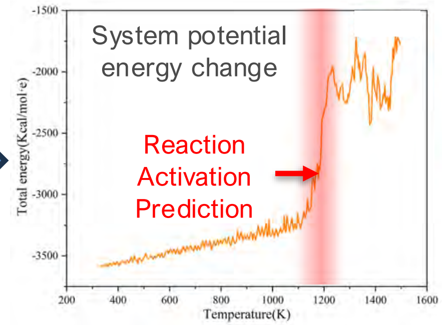
Project Overview

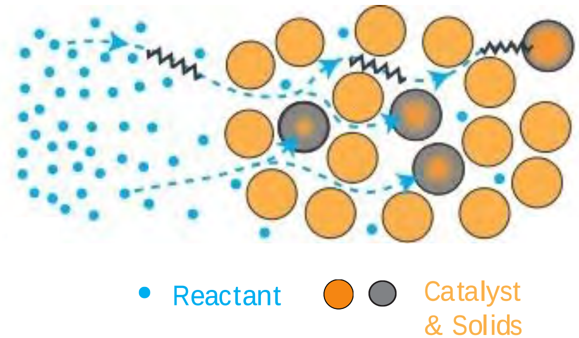
First-principles simulation

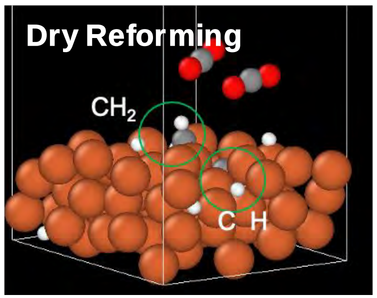


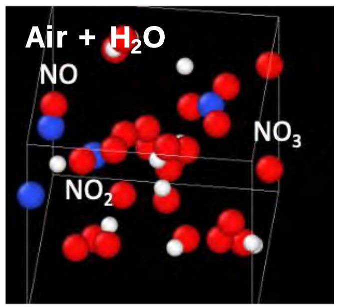
Atomic interactive potential











- Leveraging first-principle quantum simulation with iterative machine learning to predict the atomic interactions
- Material exploration integration catalyst and reactants
- Multiscale modeling to optimize reactor design and transport process

Teaming Overview and Capabilities

- PI: Dr. Xiangyu Li
- Multiscale Modeling and Heat and Mass Transport
  – From Molecules Dynamics to Porous Media Transport

Institute Resources:

- UTK ISAAC Next Generation and ORNL Frontier for computational resources
- Institute for Advanced Materials and Manufacturing (IAMM) for nanoparticle and material synthesis
- UTK-MRSEC includes ion and neutron beam sources and various surface/chemical characterization

Teaming Needs

- Material development and synthesis for catalyst
- Experimental expertise in plasma chemical reaction
- Industrial partners for commercialization and scaling up the system

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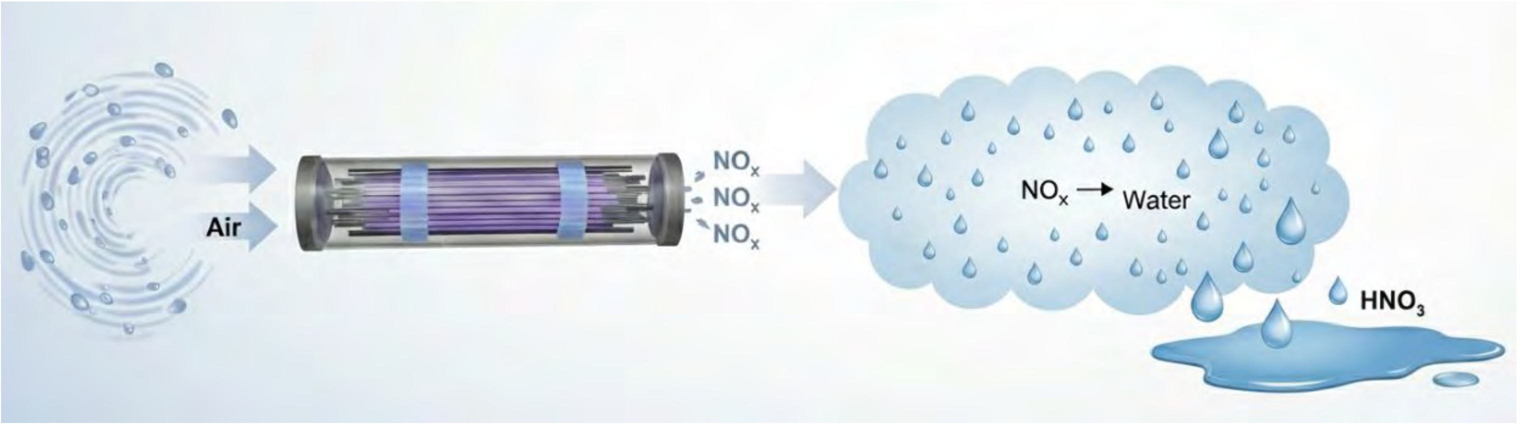
Devon Jensen, Advanced Cooling Technologies

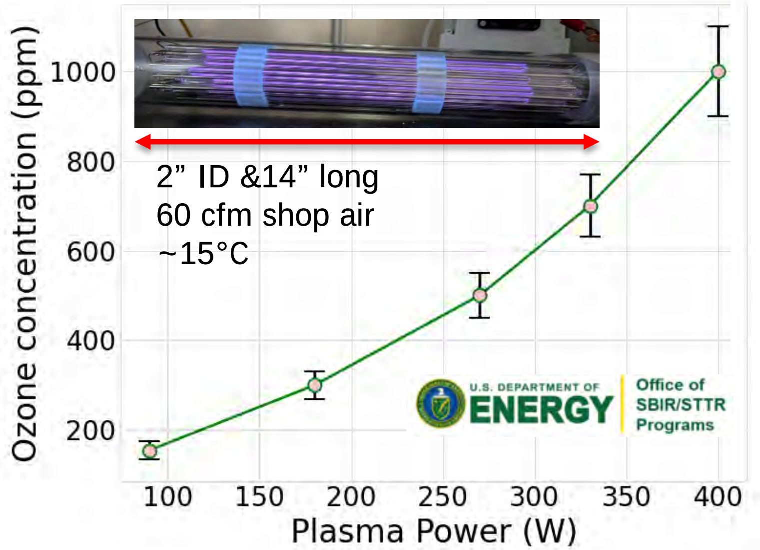
Project Overview

Utilize highly efficient volumetric dielectric barrier discharge non thermal plasma with and without catalysts for scalable production of HNO_3



Teaming Overview and Capabilities

- ACT – Dr. Devon Jensen (PI) + 2 Support Engineers: HNO3 goals experience
- 7+ years of plasma-related experience
- 4 separate SBIR programs (including several PII and PIIAs)
- > 25 plasma publications/presentations (>180 citations)
- Diffusive glowing discharge, high yield, scalable, durable



Teaming Needs

Key: Chemical processing

- Looking for chemical/ HNO_3 processing collaborator

Other:

- Unique metrics: NOx conversion efficiency, power input, reactor design parameters
- Technology transition: ACT building and selling units and or licensing IP

US Patent Pending, App # 19/008,240

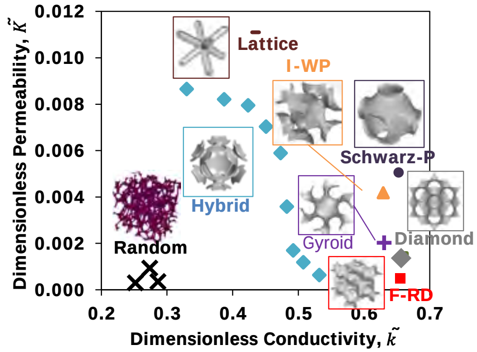
Devon Jensen – devon.Jensen@1-act.com – 717-205-0652

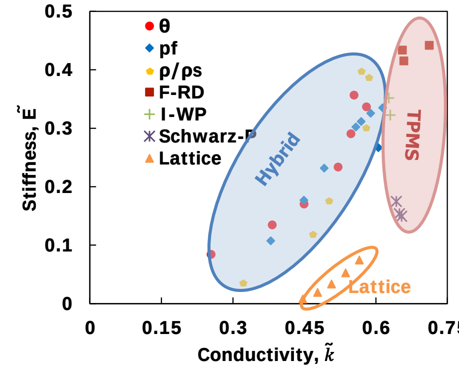
Specialized Porous High-Efficiency Reactors for Enhanced HNO3 Production (SPHERE)

Prof. Xianglin Li, WashU, Department of Mechanical Engineering and Martials Science
Email: lxianglin@wustl.edu; Phone: (314) 935-3249

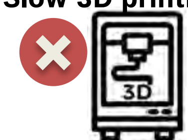
Project Overview

- Compact electrochemical or chemical reactors using high porosity architected foams with **high surface area** and **low flow resistance**.
- A comprehensive database containing TPMS-like structures exhibiting diverse thermal, electrical, hydraulic, and mechanical properties.
- Capability to mass-produce structures without relaying on 3D printing



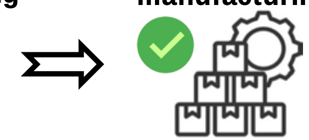


Slow 3D printing



Limited printer-compatible materials

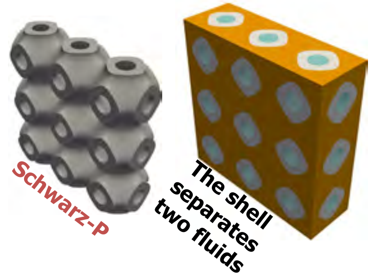
Our large-scale manufacturing



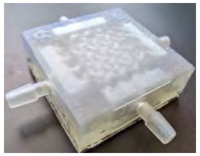
A wide range of materials

Geometry	Permeability (10^{-10} m^2)	Surface area (mm^2/mm^3)
Packed Bed	8.5	6
Extrudates	7.2	6
Laminates	5.6	6
Ours	358	12

Application 1: Microreactors

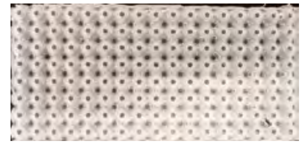


Prior Applications:
Heat Exchangers
Gas absorbent



Achieved 70 % reduction in weight and volume

Application 2: Electrochemical System



10×5 cm^2 Nafion Half-layer As a demonstration

Coat the anode electrode on one side ⇒ **Coat the cathode electrode on the other side** ⇒ **Stack multiple half-layer together to form a stack**

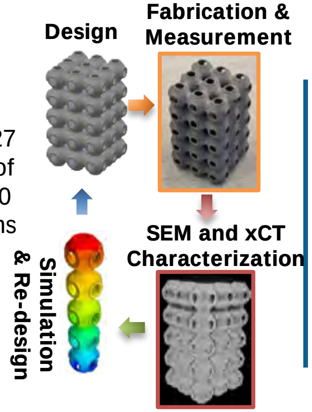
Teaming Overview and Capabilities

- **Relevant experience:**

✓ PI of an active ARPA-E project on rechargeable batteries;
✓ Multiple journal publications on design space of high-porosity foams: S Stallard, et. al., *Materials & Design* 231 (2023) 112027
✓ Multiple machine-learning-driven models to predict properties of porous media: A Adam et. al., *Energy and AI* 15 (2024) 100310
✓ A patent under application to mass produce high-porosity foams with well-controlled structures.

- **Institutional assets and core facilities:**

✓ Institute for Materials Science and Engineering (IMSE)
✓ Chemical and Environmental Analysis Facility (CEAF)
✓ Center for Cellular Imaging (WUCCI)



Teaming Needs

We are seeking collaborators who can leverage our expertise in electrode and micro-reactor topology and design.

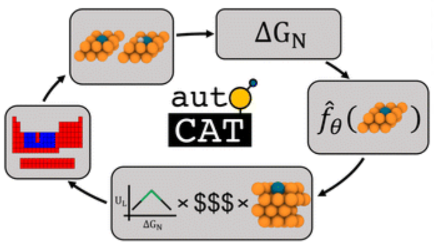
What metrics will the team aim to achieve?

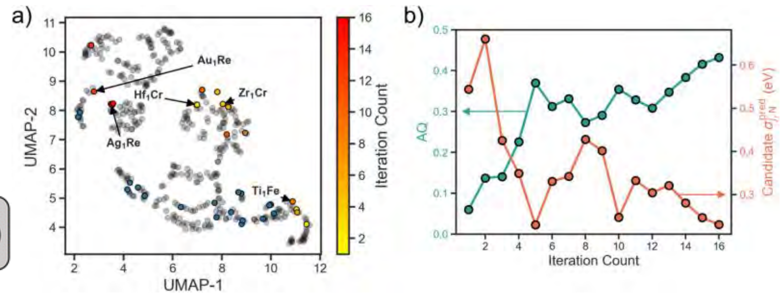
- ➢ We aim to achieve a 100× increase in permeability (or decrease in flow resistance) while maintaining the same surface area.
- ➢ The fabrication of the customized reactors and electrodes will be 100× faster than current 3D printing methods.
- ➢ The team will work closely with WashU's Office of Technology Management (OTM), who assists us on patent applications and commercialization of rechargeable batteries, to transform the technology to market.

Matthew Gerboth, Citrine Informatics, ERD

Case study – Multi-objective Optimization to Discover new catalysts with Sequential Learning (SL)

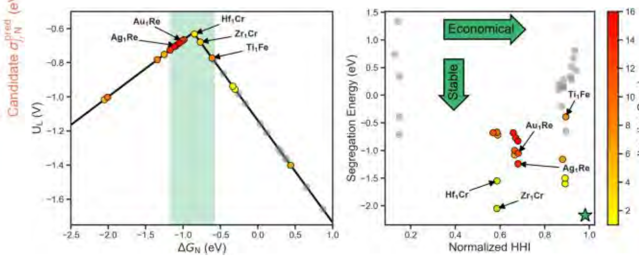
Automated ML/DFT pipeline to search for catalysts





SL acquisition function balances exploration vs exploitation. The acquisition function (AQ) improves as model uncertainty decreases (σ)

Catalytic activity increases with SL iteration while the stability and cost are balanced



Kavalsky L, Hedge V, Merdig B, Viswanathan V. A Multiobjective Closed-loop Approach Towards Autonomous Discovery of Electrocatalysts Digital Discovery, 2024, 3, 999-1010. https://doi.org/10.1039/D3DD00244F

Teaming Overview and Capabilities

- Experts in artificial intelligence/machine learning (AI/ML) for materials and chemistry
- Collaborations across universities, government labs, and industry
- Further expertise in physics-base modeling, database development, automated experiments, open-source software/web development
- Recent materials areas: polymers, nuclear waste storage, thermoelectric, corrosion-resistant alloys, batteries, catalysts, plastics, additive manufacturing

Teaming Needs

Key:

- Catalyst and reactor domain experts looking to partner for materials discovery in high-dimensional spaces with multiple objectives

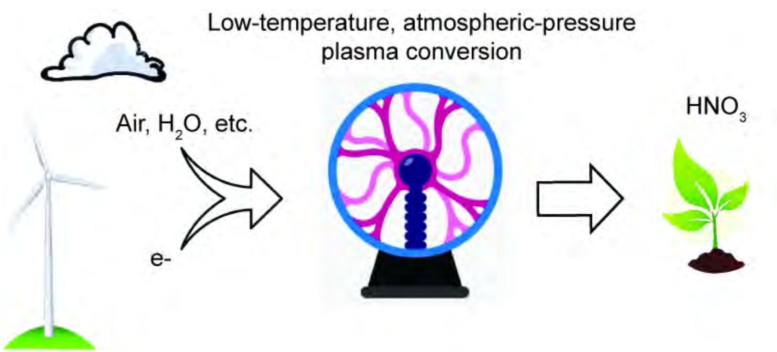
Other:

- Other approaches that could benefit from AI/ML support
- Data owners
- Experimental capacities

Contact Information – mgerboth@citrine.io – 509-396-4262

Mohan Sankaran, University of Illinois Urbana-Champaign, Industrial partners to scale up

Project Overview



- We are interested in using low-temperature, atmospheric-pressure plasmas to react the molecular nitrogen and molecular oxygen gases in air to form NO as a first step towards making HNO_3.
- As shown in the diagram on the left, air, and possibly water, are introduced to a plasma operated by electricity to react and form NO_x and HNO_3. The challenges are the energy cost which has been limited by single-pass yield and below theoretical electrical-to-chemical efficiency.
- We plan two thrusts: one to optimize plasma operation and two to combine the process with catalysts to improve yield and energy efficiency.

Teaming Overview and Capabilities

- Mohan Sankaran, Ali Eslamisaray (Postdoc), industry partners
- DARPA Cornucopia program, publications
- Testing and measurements (plasma setups, power supplies, analytical tools, in-situ and ex-situ analysis), diagnostics and modeling (spectroscopy, computing facilities)

Teaming Needs

Key:

- We are looking for an expert in catalysis and/or machine learning methods to screen different catalyst materials.

Other:

- We will look to keep capital costs low and have a process that is mostly dependent on operating costs so that there is at least a possibility of deploying in areas with cheap electricity or lack of transportability.
- We plan to file IP and license through a spin out.

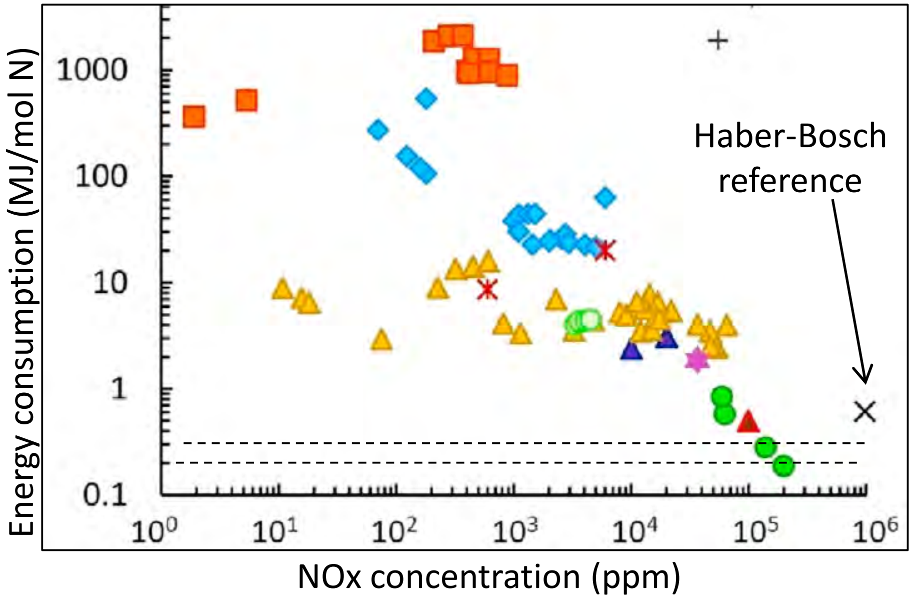
Contact Information – rmohan@illinois.edu – (217) 244-7316

DARPA: High-efficiency Nitrogen Oxidation (HNO3) Proposers Day

Southwest Research Institute

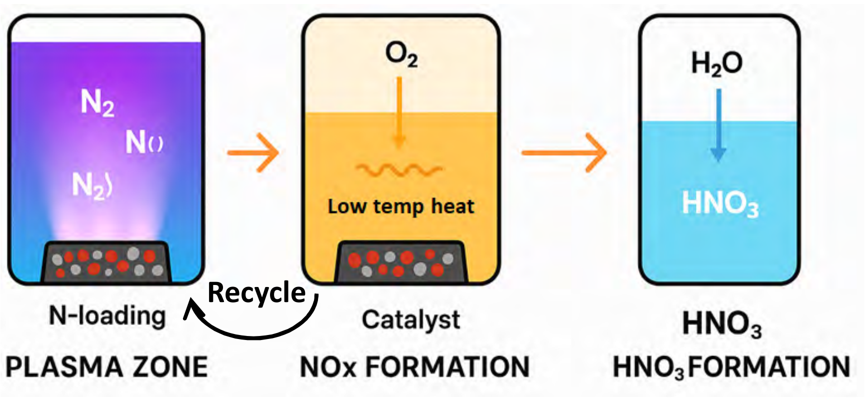
Plasma Demonstrations

Ref, Adapted: Kelley et al., Joule, 2025, 5, 3006

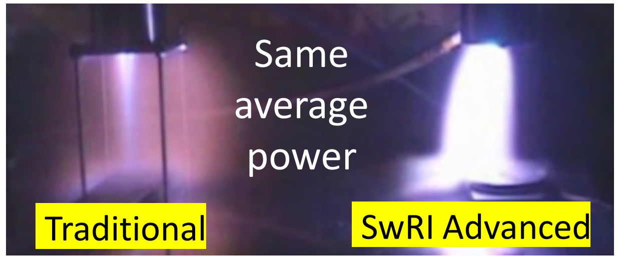


Approach	Energy consumption	Notes
Darpa Target	< 300 kJ/mol N	*reaction only
Low T plasma	200 kJ/mol N	Theoretical
Low T plasma	280 kJ/mol N	Experimental, not scalable
LT plasma + catalysts	< 300 kJ/mol N	Scalable

Plasma Assisted Chemical Looping (PACL)



- Plasma catalysis drives energy efficiency
- Must minimize major loss mechanisms
- Advanced plasma techniques developed under **DARPA LOCO program**

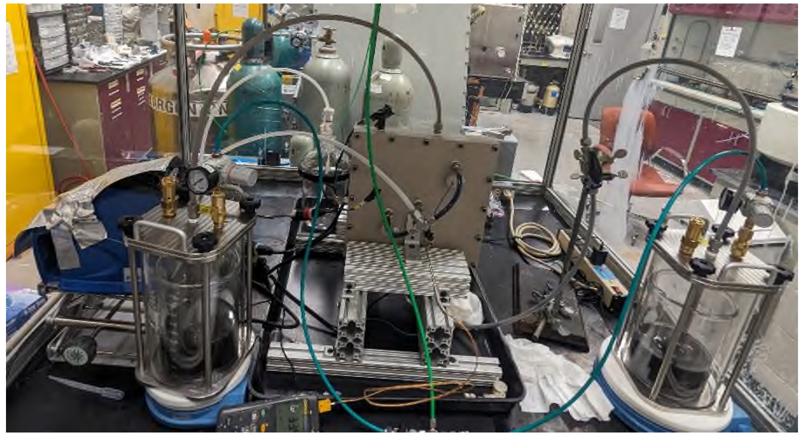


Low power, high density, low temperature

Pulsed Electrocatalytic Synthesis of Nitric Acid from Air at Near-Liquid Densities (detail proprietary)

Additional Capabilities

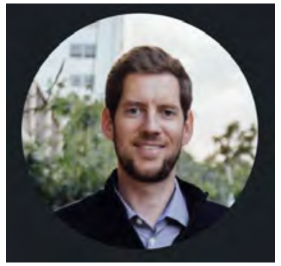
- Catalyst synthesis & high-throughput/AI-driven discovery
- Advanced characterization (TGA, ICP-OES/MS, ATR-FTIR, SEM-EDS, BET, TEM)
- Catalyst performance testing in fixed & fluidized beds (bench & pilot scale) or electrochemical systems
- System-level analysis & abuse testing of electrochemical power systems
- Destructive & non-destructive evaluation of electrochemical materials & failures
- Scale-up & integration of electrochemical processes



Novel continuous flow electrochemical systems

Collaboration Interests / Capabilities:

- Open for teaming and collaborations
- Plasma technology
- Catalyst development
- Systems engineering
- High anodic systems
- Technology scale-up



Dr. Josh Mangum
Sr. Program Manager
Southwest Research Institute
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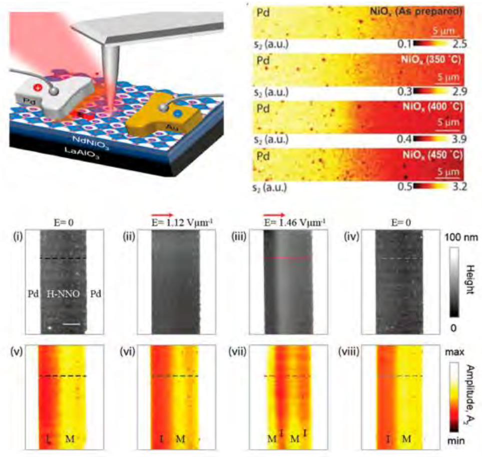
MATERIALS ENGINEERING

Yohannes Abate, The University of Georgia, Nano-Optics Laboratory



Schematics of s-SNOM IR/THz experimental setup, nanoimaging of Nox and H-NNO/LAO

Project Overview

- Nanoscale imaging and spectroscopy of nickel-based oxide devices
- Operando visible to THz nanoimaging and spectroscopy of hydrogen-doped correlated perovskite such as neodymium nickel oxide (H-NdNiO3, H-NNO) and nickel-based oxide devices, vanadates, titanates and other oxides.

Teaming Overview and Capabilities

- Operando infrared nano-imaging and nano-spectroscopy
- Tip-enhanced photoluminescence (TEPL)
- Tip-enhanced Raman spectroscopy (TERS)
- Broadband near-field nano-imaging (visible → THz)
- Advanced scanning probe microscopy: AFM, s-SNOM, KPFM, c-AFM, and related modes.
- Low-temperature and cryogenic nano-optical measurements
- Custom instrumentation development

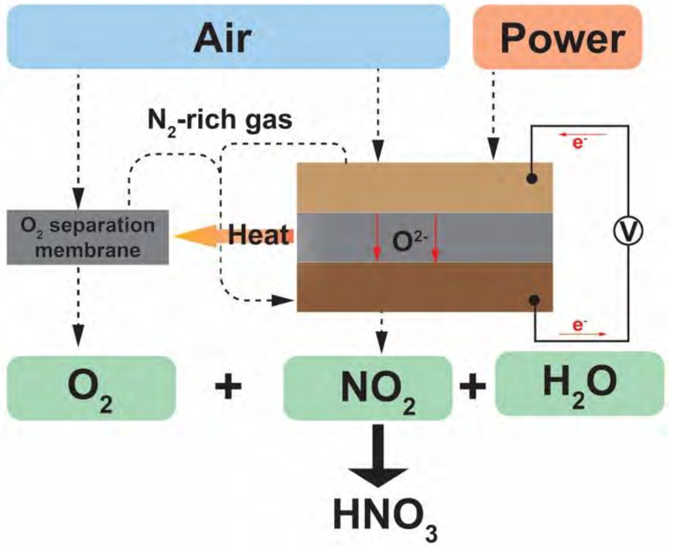
Teaming Needs

Capabilities Needed from Collaborating Teams

- Samples: Growth or synthesis of oxides or other relevant samples
- Device fabrication and nanofabrication support
- Cleanroom process expertise (lithography, etching, deposition, encapsulation) to integrate materials into functional device architectures.
- Capability to implement specialized device configurations needed for operando measurements (e.g., gating structures, heaters, current-flow geometries).

Email Address: yohannes.abate@uga.edu, – Phone Number: 510-219-7329

Chuancheng Duan, University of Utah,
SO-NACE — Solid Oxide Nitric Acid Catalytic Electroreactor



Project Overview

- We aim to create a fully compact and modular system that turns air, water, and power into nitric acid. This new method would replace the century-old ammonia-based route with a cleaner, simpler, and more efficient technology.
- Our approach uses high-temperature membrane reactor and electrochemical devices that first separates oxygen from air to make a nitrogen-rich stream, then uses electrochemical process to directly oxidize N_2 into NO_2, which reacts with water to form nitric acid.

- **Phase 1:** Proof of Feasibility (Materials & Mechanisms); Integrated Subsystem Development (Risk Reduction & Optimization).
- **Phase 2:** System-Level Demonstration

Teaming Overview and Capabilities

- PI: Prof. Chuancheng Duan at the U of U.
  Co-PI: Dr. Feng Zhao at Storagenergy Technologies, Inc

- Our team has extensive experience in solid oxide electrochemical systems, advanced catalytic membrane reactor development, and high-impact publications in journals such as Science, Nature, Nature Energy.

- Our institution provides state-of-the-art solid oxide electrochemical testing facilities, ceramic membrane fabrication capabilities, and advanced microscopy/thermal analysis cores, and we have an established track record of successful DoD-funded collaborations with Storagenergy Technologies on solid-oxide–based energy and power technologies.

Teaming Needs

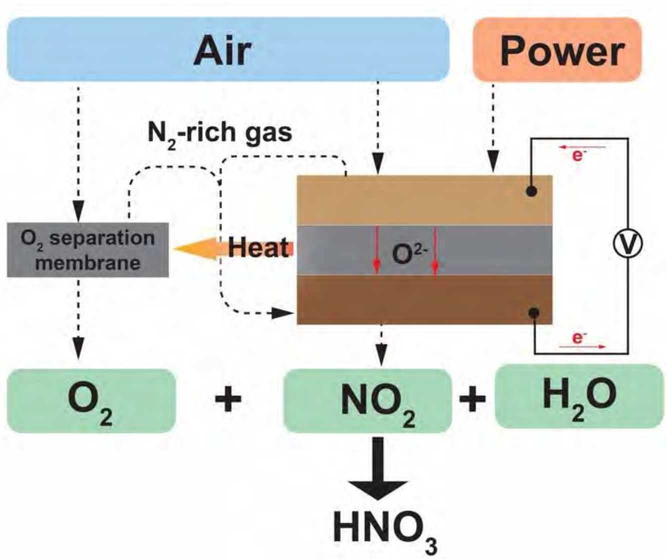
Key:

- For which technical challenges are you seeking collaborators? **Advanced catalysts characterizations**

- We will pursue transition through our established collaboration with Storagenergy Technologies-leveraging our joint DoD project experience to co-develop prototypes, align performance metrics with defense needs, and accelerate pathway to commercialization and field deployment.

Chuancheng Duan, University of Utah,

SO-NACE — Solid Oxide Nitric Acid Catalytic Electroreactor



Project Overview

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- Our approach uses high-temperature membrane reactor and electrochemical devices that first separates oxygen from air to make a nitrogen-rich stream, then uses electrochemical process to directly oxidize N_2 into NO_2, which reacts with water to form nitric acid.

Teaming Overview and Capabilities

- PI: Prof. Chuancheng Duan at the U of Utah.
  Co-PI: Dr. Deryn Chu, Army Research Lab.
  Co-PI: Dr. Feng Zhao at Storagenergy Technologies, Inc
- Our team has extensive experience in solid oxide electrochemical systems, catalysis, advanced catalytic membrane reactor development, and high-impact publications in journals such as Science, Nature, Nature Energy.
- Our institution provides state-of-the-art solid oxide electrochemical testing facilities, ceramic membrane fabrication capabilities, and advanced microscopy/thermal analysis cores, and we have an established track record of successful DoD-funded collaborations with Dr. Deryn Chu, Army Research Lab and Storagenergy Technologies on solid-oxide–based energy and power technologies.

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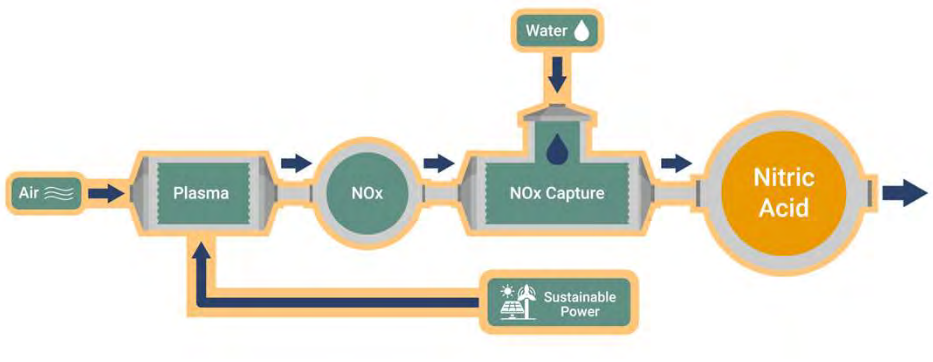
Chuancheng Duan– c.duan@Utah.edu – 720-648-7886

Mike Tooke, Plasma2X Ltd

Project Overview



- Energy efficient production of NOx using a non-thermal plasma and NOx capture into water to form nitric acid.
- Focus is on the plasma reactor and power supply. Key requirement is to further improve energy efficiency from the current 3.4kWh/kg of (68%) HNO_3.
- Demonstrator complete; 50kg/day (20%) pilot in Q1 2026; parallel R&D targeting process efficiency & operation.

Teaming Overview and Capabilities

- Tech team includes 4 PhDs, 20+ years chemical process design, plasma and catalysis technologies
- Exec team all have 30yrs+ experience inc. chemical industry, renewables, tech research & commercialization
- Based at Daresbury Labs in NW UK – Lab with space for bench scale and 50kg/day pilot; outside location for containerized plant.
- Based on research from University of Liverpool – Prof Xin Tu – world leading research on plasma chemistry
- Published peer-reviewed papers and work on plasma nitrogen fixation

Teaming Needs

Key:
- Scaling up Balance of Plant for NOx capture.
- Acid concentration to client requirements.

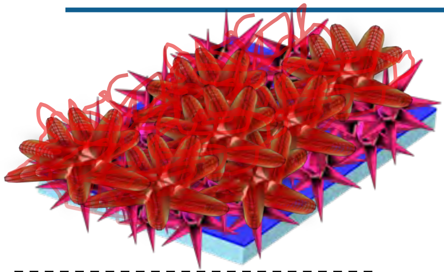
Milestone objectives:
- Efficiency better than 2kWh/kg of (68%) HNO_3
- Scaling to 1,000kg/day

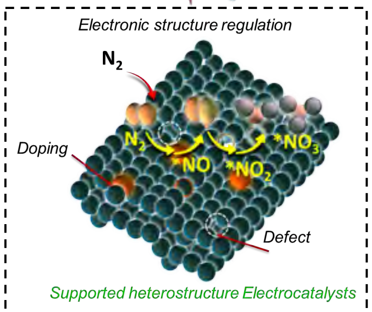
Transition
- Partner with a major commercial leading to licensing or technology transfer

Contact Information – mike.tooke@plasma2x.com – +44 7956 426445

Greeshma Gadikota, Columbia University,
Scalable Spinel Heterostructures for Selective Nitrate Oxidation

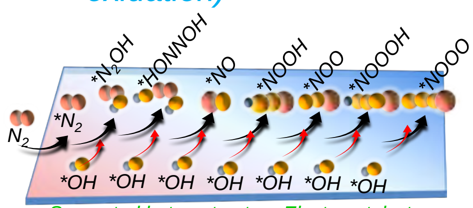
Project Overview





***1.** Spinel crystal structure allows tunable cation composition and valence distribution*

***2.** Fe sites facilitate the first N–O bond formation (activation of N_2 and initial oxidation)*



- Develop scalable electrodes and devices for electrochemical nitrogen oxidation
- As an alternative to powder – based synthesis, engineered spinel heterostructured electrodes will be developed to suppress OER and selectively promote HNO_3 formation
- Specific transition metal centers supply O (or OH) species needed to produce nitrate ions

Teaming Overview and Capabilities

- Team comprising faculty and postdocs at Columbia U. have extensive experience and expertise in architecting spinel heterostructures for energy and environmental applications
- Development of multifunctional, scalable electrodes that tune multiple reactions (e.g., suppress OER, promote nitrogen oxidation, and are highly conductive) that replace additional unit operations to achieve selective nitrate formations
- Extensive experience in developing customized electrodes for chlorine gas suppression to produce HCl and NaOH via brine electrolysis

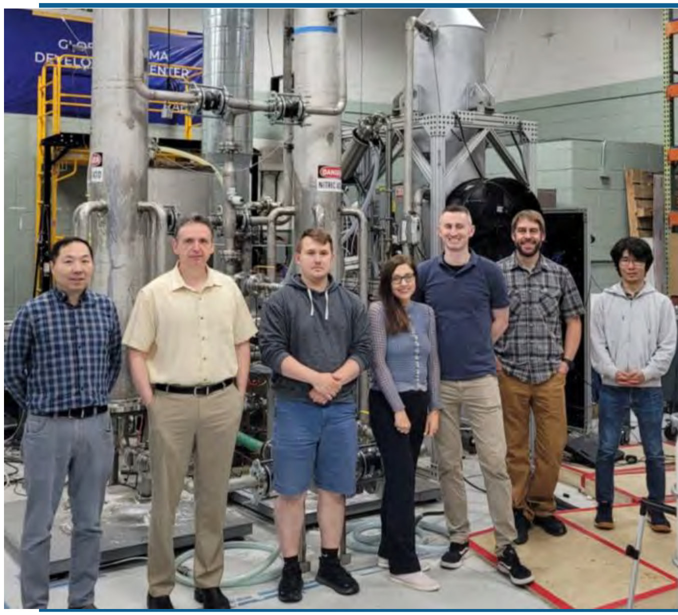
Teaming Needs

Key:
- Seeking collaborators to develop devices that can incorporate this electrode

Other:
- Key milestones of interest include:
  - Establishing continuous operation for nitrate oxidation
  - Suppressing undesired side reactions by 90% or higher
  - Demonstrating electrode stability and performance over multiple cycles of performance
- Technology transition will occur through the filing and licensing of patents to an entity for device development and scale – up.

Greeshma Gadikota – ge2131@columbia.edu – 857 – 253 – 8724

Ian McKinney, Ph.D., Radom Corporation, R&D



Project Overview

- The Radom team is striving to achieve economical, modular, decentralized nitric acid production at industry-relevant scale via high-throughput atmospheric-pressure plasma.
- Radom Corporation has already demonstrated the ability to produce 135 lbs. of HNO_3 per day from water, air, and electricity via a 100-kW microwave plasma torch pilot system at an efficiency of 5.3 MJ/mol of HNO_3.
- Radom's strength is in high-power microwave plasma, but we seek collaboration to improve the efficiency of our process via catalysis, advanced heat exchangers, and optimized absorption columns. We estimate that the efficiency can improved to 1.5 MJ/mol of HNO_3 with these improvements.
- The program will proceed through component-level optimization of key tech., integrated system assembly, and end-to-end performance testing.

Teaming Overview and Capabilities

- The Radom team brings Ph.D.-level expertise in plasma physics, computational chemistry, chemical engineering, and electrical engineering, supported by advanced mechanical and controls engineering capability, with demonstrated experience executing industrial-scale HNO_3 systems.
- Radom Corporation has published a peer-reviewed validation of its plasma-based HNO_3 pilot system, demonstrating production of nitric acid at commercially relevant concentration (~30%) and throughput.[1]
- Radom Corporation has invested over $5M in the development of an on-site, industrial-scale HNO_3 pilot facility, supported by in-house chemistry laboratories, engineering test infrastructure, precision machining capability, and advanced scientific computing resources for system development and optimization.

Teaming Needs

Key tech.:

- Advanced heat exchanger development
- Absorption column optimization
- Catalyst integration

Other:

- Radom hopes to achieve an overall process efficiency of 1.5 MJ/mol of HNO_3 or better by integrating solutions to the key technical challenges listed above.
- The team will pursue technology transition via pilot deployments, partner-integration demonstrations, and scale-up of Radom's pilot nitric acid production system for relevant defense and industrial environments.

Ian McKinney, Ph.D. – imckinney@radomcorp.com – (414) 719-3229

Dimosthenis Sokaras, SLAC National Accelerator Laboratory & Stanford University

Project Overview

Develop a compact zero gap electrochemical "air-to-acid" device that meets **<300 kJ/mol HNO_3** energy target by driving **>70 % Faradaic efficiency (FE)** for nitrogen oxidation.

Approach

- **Dynamic pulsed electrolysis** to exploit kinetic differences between NOR and OER, suppressing parasitic oxygen evolution.
- **NOR-tailored catalysts** designed for fast N–O intermediate formation and slow OER induction accounting the specifics of a pulsed operation.
- **Operando modulation X-ray methods** to resolve NOR vs OER intermediates in real time and tune pulse waveforms accordingly.
- **MEA/GDE reactor platform** building on our prior high-rate gas-fed electrolyzer work, scaled toward 1 L/day → 50 L/day nitric acid production.

Teaming Overview and Capabilities

•**Team**: SLAC (SSRL and SUNCAT), Stanford University Chem-Eng.

•**Electrolyzer engineering:** Experience scaling zero gap CO_2/CO-electrolyzers to high current density.
•**Dynamic catalysis:** Established frequency-domain operation to suppress side reactions.
•**Operando spectroscopy:** Tools to differentiate NOR and OER intermediates, linking/optimizing catalyst structure, waveform, and FE.
•**Techno-economic analysis:** In-house TEA to track energy use, stack design, and system architecture against the <300 kJ/mol requirement

Teaming Needs

Technical Challenges Needing Collaborators

- **Balance-of-plant integration** (air handling, compression, thermal management, power electronics for pulsed MEA operation, etc.).
- **Downstream processing** to potentially convert a nitrate-rich stream into field-ready nitric acid in a compact format.
- **System packaging & ruggedization** for operational deployment in Phase 2.

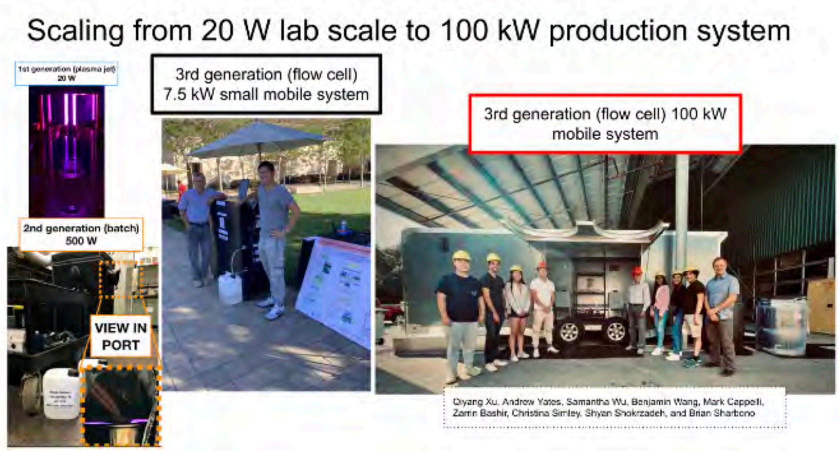
Transition Path

- Partner with industrial or defense teams experienced in compact chemical systems to integrate the NOR reactor core into a field-deployable platform for the 50 L/day target demonstration.

Dimosthenis Sokaras – dsokaras@slac.stanford.edu – 650-743-5933

Stanford Plasma Physics Laboratory - Stanford University
PI: Mark Cappelli

Project Overview



- Goal: Produce concentrated nitric acid (68%) directly from air and water using electricity—no ammonia, no natural gas, no imported chemicals. Enable decentralized production using low cost and massively scalable plasma reactors.

Mass-Scalable DBD Plasma Reactors: Atmospheric dielectric barrier discharge generates NOx directly from air. Modular reactor architecture enables distributed manufacturing at any scale—from forward operating bases to industrial facilities.

Optimized Surface Chemistry: Patent-pending multilayer electrode design with engineered surface treatments maximizes nitrogen oxidation rates while minimizing energy losses. Inline NOx/pH sensing with AI model-predictive control maintains optimal operating conditions.

High-Efficiency MHz Power Systems: Most DBD generators operate at kHz frequencies, but discharge activity peaks at maximum voltage slew rate—meaning higher frequencies yield more plasma generation. We have developed a MHz Class E power amplifier with frequency selection that achieves 91.5% peak efficiency and outputs 600W at 12.4 MHz and 15.5 MHz. This breakthrough in electrical-to-plasma conversion efficiency is critical for meeting HNO3 energy targets and enabling operation on limited field power.

Reactor Optimizations: Proven reactor geometry and flow configurations that maximize mass transfer efficiency.

Teaming Overview and Capabilities

- Dr. B. Wang (Stanford Plasma Engineer), Prof. S. Ding (Cal Poly – Plant Pathologist), **Prof. M. Cappelli** (Stanford Plasma Chemist), Dr. K. Brasier (Vilmorin-Mikado, Plant Horticulture), Prof. A. Guzman (Stanford, Biologist), Dr. A. Pastrana (Farm Advisor UC ANR). Mr. B. Sharbono (Program Manager, Woods Institute, Agriculture Economist)
- Relevant experience: Produced several thousands of gallons of nitrate-concentrated water and delivered/shipped to partners, where we have completed > 10 field studies
- Published two-peer reviewed journal papers and have been highlighted in reports of two third-party vineyard studies.
    - Sze, C., Wang, B., Xu, J., Rivas-Davila, J., & Cappelli, M. A. (2021). Plasma-fixated nitrogen as fertilizer for turf grass. RSC advances, 11(60), 37886-37895.
    - Wang, Benjamin, et al. "Plasma-fixed Nitrogen Improves Lettuce Field Holding Potential." HortTechnology 34.2 (2024): 187-189.

Teaming Needs

Key:
- Engineering for production at scale under acidic conditions
- Corrosion-resistant materials and reactor components for concentrated HNO3 handling
- Technoeconomic modeling and life-cycle analysis

Milestones

- Pilot-scale production of 50 kg_N per day (25x of where we are now)
- First large-scale field demonstrator with first adopter.
- Defense: Partner with DoD manufacturers; pilot decentralized production at strategic locations.
- Commercial: Vilmorin-Mikado agricultural network for fertilizer deployment; mining/construction applications
- Scale-up: Modular containerized systems for licensing to defense contractors and chemical manufacturers
- IP: Stanford OTL patent portfolio; exclusive defense licensing, non-exclusive commercial