Center for Programmable Energy Catalysis

Data Management in the Center for Programmable Energy Catalysis

Paul J. Dauenhauer (UMN)
Director
Susannah Scott (UCSB)
Deputy Director

U.S. DEPARTMENT OF ENERGY | Office of Science

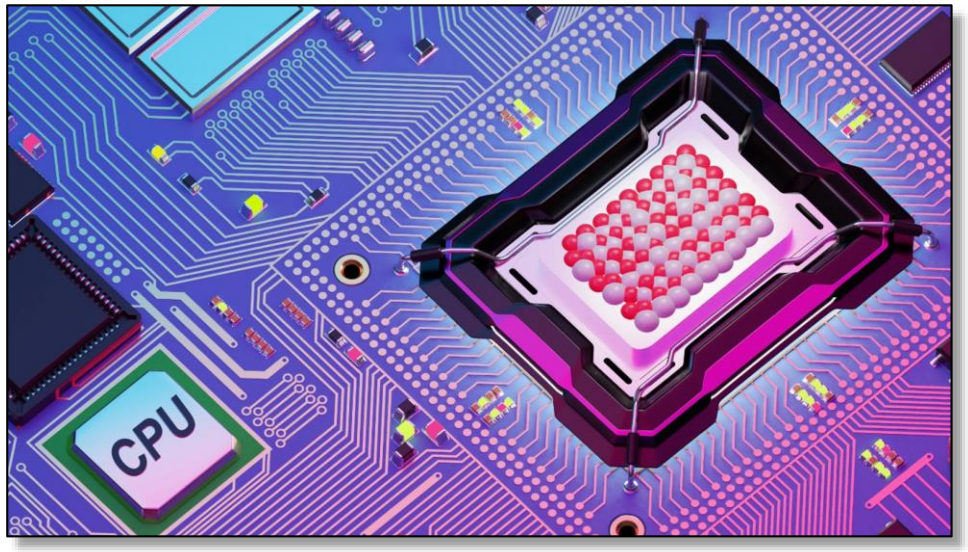
Funded by the U.S. Department of Energy, Office of Basic Energy Sciences

Center for Programmable Energy Catalysis (CPEC)

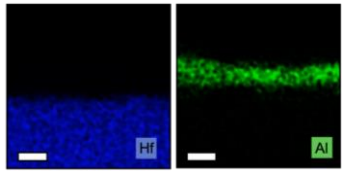
Inventing **tomorrow's advanced catalysts** through integration of chemical sciences

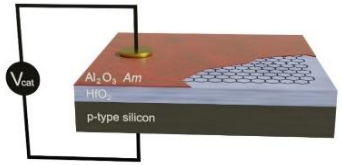
The DOE Center for Programmable Energy Catalysis (CPEC) **integrates expertise** in electronic materials, surface science, catalysis, and computational chemistry to invent and understand dynamic, programmable heterogeneous catalysts

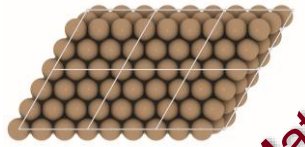
Programmable catalysts **change with time** at the frequency of surface reaction via a prescribed electronic 'program' that accelerates and controls reactions

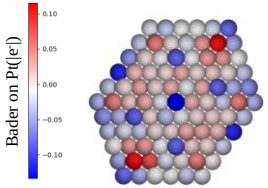


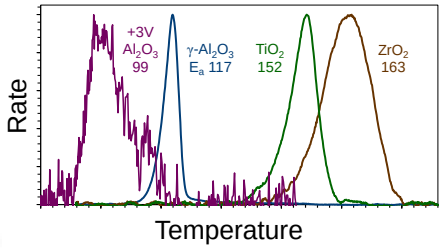
How is CPEC multidisciplinary?











Electronic Materials

Computational Materials &Surface Chemistry

Catalysis & Surface Chemistry

Kinetic Modeling

Photocatalysis

← Binding Energy | Material Energy →

← Binding Energy | Material Energy →

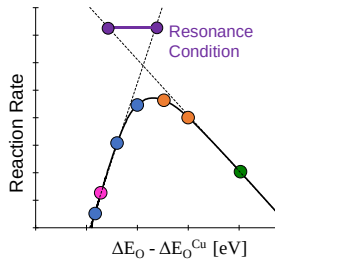
← Binding Data | Binding Prediction →

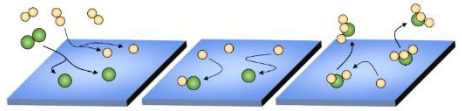
↓ Model Inputs Model Requirements ↑

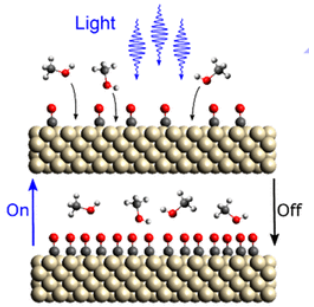
← Reaction Data | Rate Prediction →

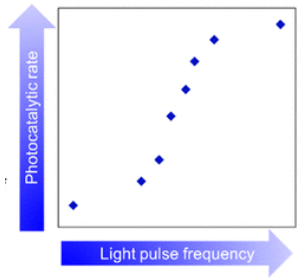
↓ Adsorbate Behavior Light Behavior ↑

← Reaction Rate Data | Rate Prediction →









CPEC: Unique Methods and Techniques → New Data

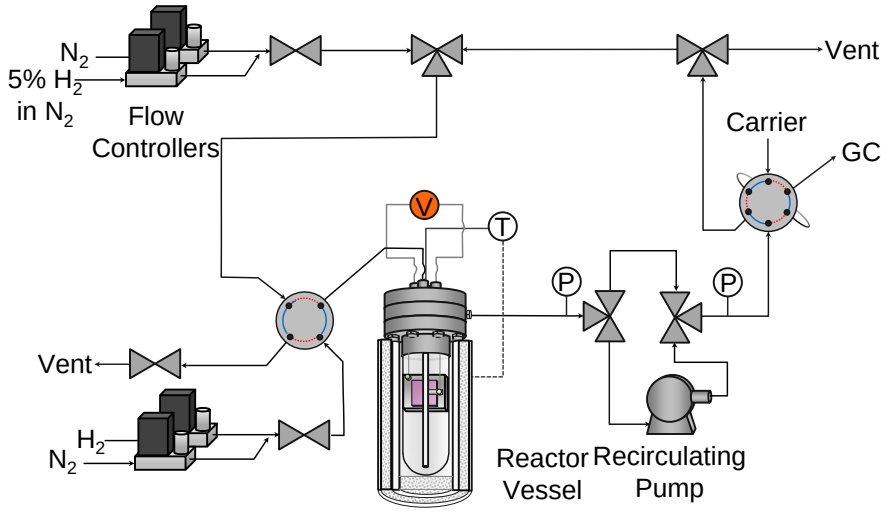
CPEC has created an array of new methods, tools, and techniques for fundamental research

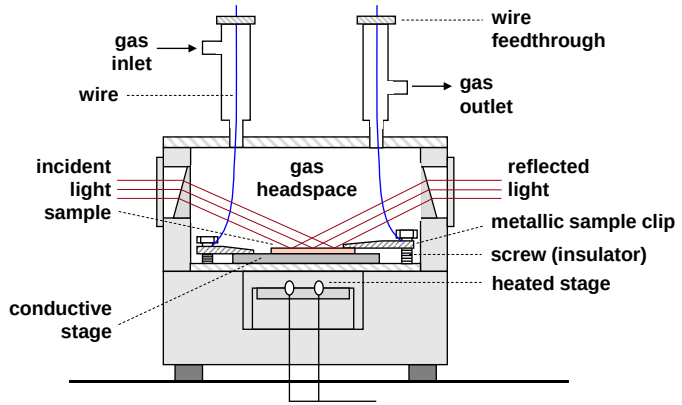
Custom 1 cm^2 condenser reactor
Condenser cartridge holder
Isopotential titration (IPT)
In situ charge spectroscopy for condensers
- XPS / UPS, XAS

In situ reactor charge characterization
Scanning tunneling microscopy with charge
In situ IR reactor with charge application

Customized IR catalytic reactor
Transient IR reactor method

L^3 computational scaling for charge
Dynamic microkinetic modeling
Dynamic kinetic Monte Carlo modeling
Bayesian optimization for dynamic reaction kinetic models





CPEC Data and Organization Policies

SHORT Term Data Sharing

Monthly Meetings - Required Attendance

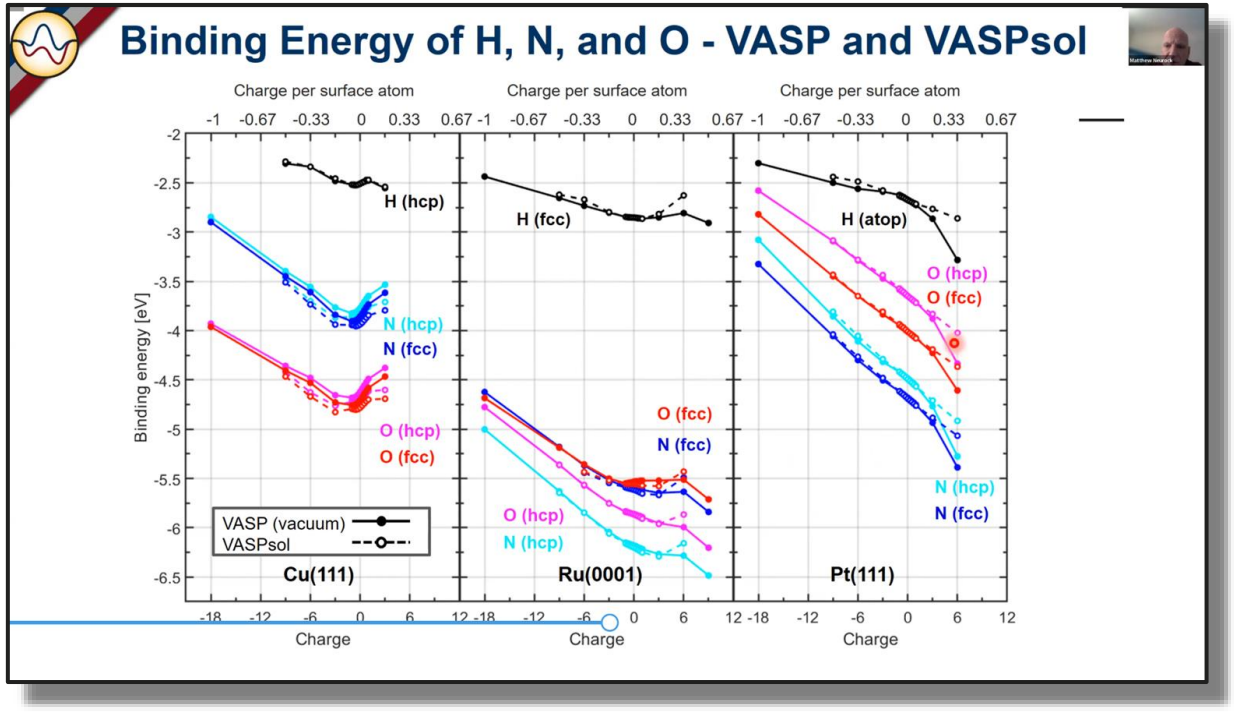
Monthly Team Meetings (each team)
Quarterly Executive Committee Meetings
<u>Monthly All-Center Meetings</u>
All researchers meet on zoom once per month: date organized by Magdalene

Start with confidentiality policy, safety spot discussion, and center updates

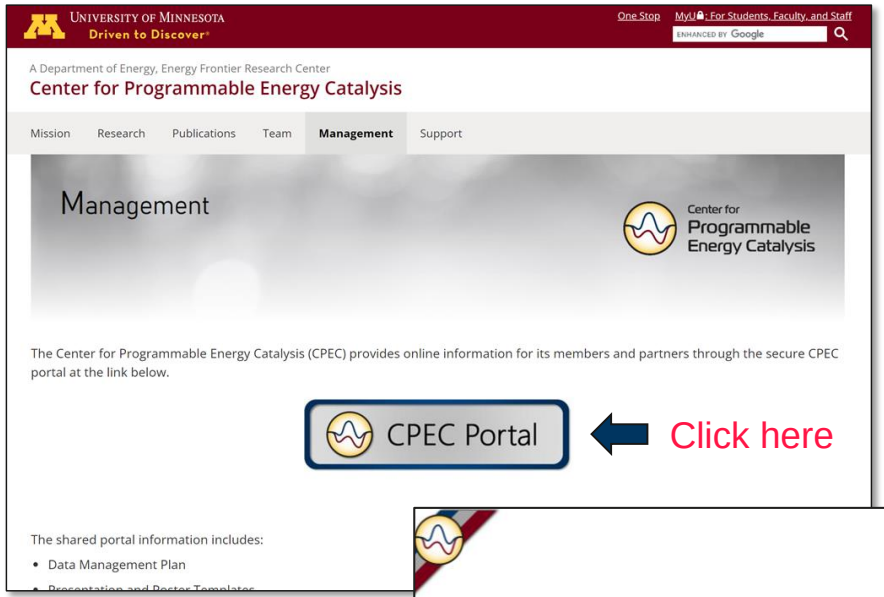
Technical content selected by Dauenhauer and Scott with input from executive committee

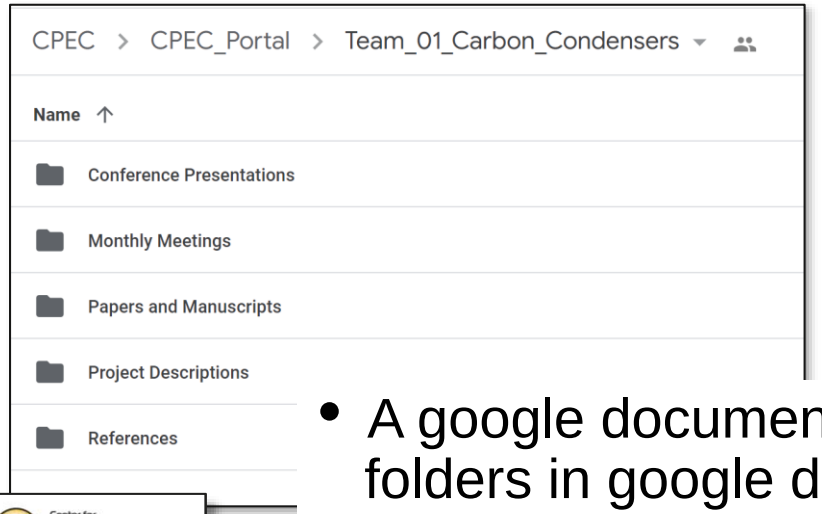
- Single CPEC PI presentation
- Two student talks (20 min each)
- External guest speakers

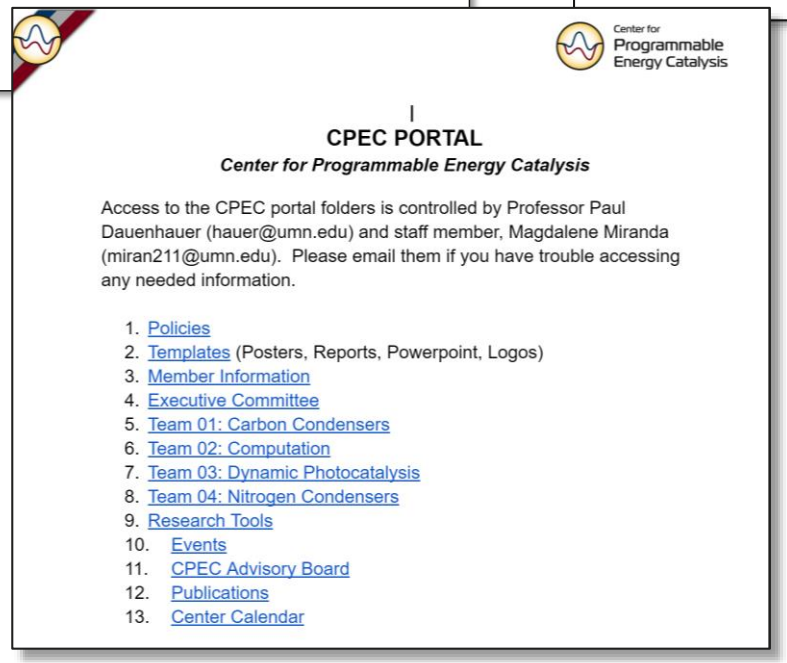
CPEC All-Center Meeting
Zoom - December 2023
Presenter: Prof. Matt Neurock



CPEC Portal – Single place for all information







Google Docs

- A google document with links to different folders in google drive
- Each folder has different access permissions assigned by Dauenhauer or Miranda
- Some folders are read only; others are editable
- Content is updated as generated
- Recordings of meetings

CPEC - Spring & Fall Annual Meetings

Goal: A combined research, training, education, and strategy session

Mechanism:

- Advisory board, faculty, and students fly to Minneapolis for a Friday + Saturday

Content:

- Workshop
- Poster sessions
- Discuss scientific progress
- Goals for next 6 months
- Advisory board meeting
- Open discussion & feedback
- Guest dinner speaker(s)

AIChE
The Global Home of Chemical Engineers

Day 1 of 2

CPEC SPRING MEETING
Friday, May 5, to Saturday, May 6, 2023
Location: Graduate Minneapolis Hotel, 615 Washington Ave. SE, Minneapolis, MN 55414

Friday, May 5 (All events in Graduate Hotel, Pinnacle Room & Foyer)		
Time (central)	**Event/Topic**	**Speaker(s)**
Before Noon	Arrive in Minneapolis (MSP Airport, Light Rail)	
Noon – 2:00 pm	Registration, Lunch, Hotel Check-in, Tours	
2:00 – 2:30	Introductions	Paul Dauenhauer Susannah Scott
2:30 – 3:30	Teams #1 & #4 – Catalytic Condensers	Lead: O. Abdelrahman
3:30 – 3:50	Coffee Break	
3:50 – 4:30	Programmable Catalysis Training Session (everyone)	Dauenhauer, Frisbie, Christopher
4:30 – 6:00	Poster Presentations + Coffee	
6:00 – 7:00	Dinner, Cash Bar	
7:00 – 8:00	Dessert + Cash Bar Featured Speakers Presentations (25+5 min each)	Tracy Lohr, Ph.D. Shell Javier Guzmann, Ph.D. ExxonMobil Chemical Company
8:00	Adjourn for the day	

CPEC Portal – Single place for all information

Center for Programmable Energy Catalysis
Membership List & Contact Information

Uni	Professor	Student / Post-Doc	Project #	Email	Phone	ORCID	Team	Member	Affiliate
	Staff: Becky Wyatt (Accountant)			huntx043@umn.edu	612/625-4071			X	
	Staff: Magdalene Miranda (General Manager)			miran210@umn.edu				X	
	Staff: Dan McDonald (Data & IT Manager)			mcdo0486@umn.edu				X	
University of Minnesota									
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		Onn, Tzia Ming	1.4.1	tonn@umn.edu			4	X	
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		Student 1 (TBD)	1.1.3				1	X	
		Student 2 (TBD)	1.4.2				4	X	
	Bhan, Aditya			abhan@umn.edu	612-626-3981	0000-0002-6069-7626	1	X	
		First year student (To be c	1.1.3				1	X	
	Jalan, Bharat			bjalan@umn.edu			1,4	X	
		Shivasheesh Varshney	1.1.4	varsh022@umn.edu			1,4	X	
	Neurock, Matthew			mneurock@umn.edu			2	X	
		Kaida Liu	1.2.1	liu01485@umn.edu			2	X	

[1] www.cpec.umn.edu/management

CPEC Data and Organization Policies

LONG Term Data Sharing

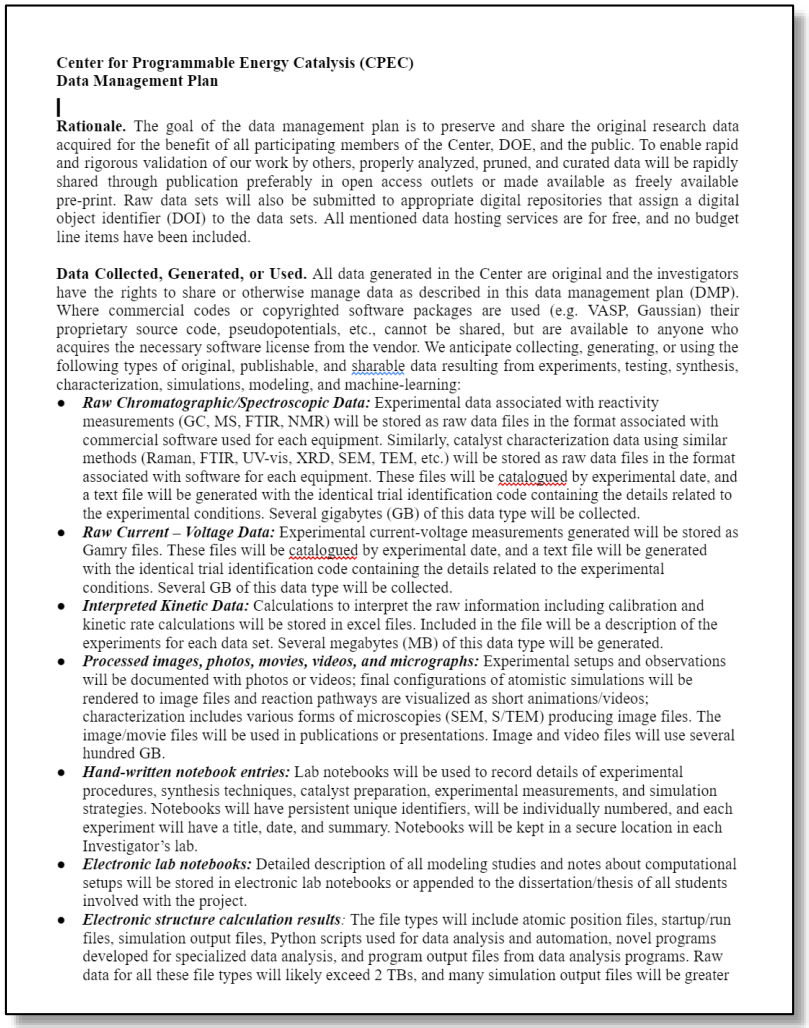
CPEC Data Management – Challenges & Policy

Data sharing:

- To share machine-readable and digitally accessible data, including data that is published in charts and figures
- Transparency of post-processing
- Sharing more data than necessary, which could be useful to researchers inside and outside of CPEC, who can potentially re-use or re-interpret data that was inconclusive at the time

Data preservation:

- To preserve data so that it can be used inside and outside of CPEC for years or decades to come



Center for Programmable Energy Catalysis (CPEC)
Data Management Plan

Rationale. The goal of the data management plan is to preserve and share the original research data acquired for the benefit of all participating members of the Center, DOE, and the public. To enable rapid and rigorous validation of our work by others, properly analyzed, pruned, and curated data will be rapidly shared through publication preferably in open access outlets or made available as freely available pre-print. Raw data sets will also be submitted to appropriate digital repositories that assign a digital object identifier (DOI) to the data sets. All mentioned data hosting services are for free, and no budget line items have been included.

Data Collected, Generated, or Used. All data generated in the Center are original and the investigators have the rights to share or otherwise manage data as described in this data management plan (DMP). Where commercial codes or copyrighted software packages are used (e.g. VASP, Gaussian) their proprietary source code, pseudopotentials, etc., cannot be shared, but are available to anyone who acquires the necessary software license from the vendor. We anticipate collecting, generating, or using the following types of original, publishable, and sharable data resulting from experiments, testing, synthesis, characterization, simulations, modeling, and machine-learning:

- ***Raw Chromatographic/Spectroscopic Data:*** Experimental data associated with reactivity measurements (GC, MS, FTIR, NMR) will be stored as raw data files in the format associated with commercial software used for each equipment. Similarly, catalyst characterization data using similar methods (Raman, FTIR, UV-vis, XRD, SEM, TEM, etc.) will be stored as raw data files in the format associated with software for each equipment. These files will be catalogued by experimental date, and a text file will be generated with the identical trial identification code containing the details related to the experimental conditions. Several gigabytes (GB) of this data type will be collected.
- ***Raw Current – Voltage Data:*** Experimental current-voltage measurements generated will be stored as Gamry files. These files will be catalogued by experimental date, and a text file will be generated with the identical trial identification code containing the details related to the experimental conditions. Several GB of this data type will be collected.
- ***Interpreted Kinetic Data:*** Calculations to interpret the raw information including calibration and kinetic rate calculations will be stored in excel files. Included in the file will be a description of the experiments for each data set. Several megabytes (MB) of this data type will be generated.
- ***Processed images, photos, movies, videos, and micrographs:*** Experimental setups and observations will be documented with photos or videos; final configurations of atomistic simulations will be rendered to image files and reaction pathways are visualized as short animations/videos; characterization includes various forms of microscopies (SEM, S/TEM) producing image files. The image/movie files will be used in publications or presentations. Image and video files will use several hundred GB.
- ***Hand-written notebook entries:*** Lab notebooks will be used to record details of experimental procedures, synthesis techniques, catalyst preparation, experimental measurements, and simulation strategies. Notebooks will have persistent unique identifiers, will be individually numbered, and each experiment will have a title, date, and summary. Notebooks will be kept in a secure location in each Investigator's lab.
- ***Electronic lab notebooks:*** Detailed description of all modeling studies and notes about computational setups will be stored in electronic lab notebooks or appended to the dissertation/thesis of all students involved with the project.
- ***Electronic structure calculation results:*** The file types will include atomic position files, startup/run files, simulation output files, Python scripts used for data analysis and automation, novel programs developed for specialized data analysis, and program output files from data analysis programs. Raw data for all these file types will likely exceed 2 TBs, and many simulation output files will be greater

CPEC Data Management – Sharing *Strategy*

Primary focus is on making data available via publication and associated methods

Part 1: Promote preprints and ensure publications are openly available

Include data sets within the supporting information files

Center for Programmable Energy Catalysis — ChemRxiv™

Title of Your Preprint Goes Here for All to Read

Author[1,2], Author[1,2], Author[2], Author[3], Author[2], Author[4], Author[5], Author[1,2], Author[1,3], Author[2], Author[1,4], Author[1,2], CorrespondingAuthor[1,2*]

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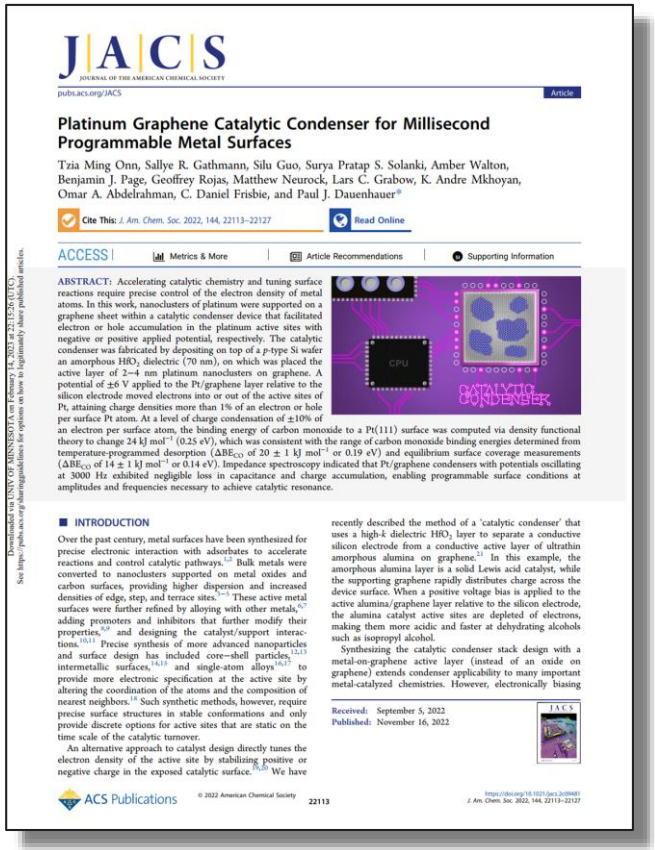
* Corresponding author: hauer@umn.edu

Abstract. Accelerating catalytic chemistry and tuning surface reactions requires precise control of the electron density of metal atoms. In this work, nanoclusters of platinum were supported on a graphene sheet within a catalytic condenser device that facilitated electron or hole accumulation in the platinum active sites with negative or positive applied potential, respectively. The catalytic condenser was fabricated by depositing on top of a p-type Si wafer an amorphous HfO_2 dielectric (70 nm), on which was placed the active layer of 2–4 nm platinum nanoclusters on graphene. Potential of +/-6V applied to the Pt/graphene layer relative to the silicon electrode moved electrons into or out of the active sites of Pt, attaining charge densities more than 1% of an electron or hole per surface Pt atom. At a level of charge condensation of 1-10% of an electron per surface atom, the binding energy of carbon monoxide to a Pt(111) surface was computed via density functional theory to vary from 5 to 48 kJ mol^{-1} (0.05-0.50 eV), which was consistent with the range of carbon monoxide binding energies determined from temperature programmed desorption (ΔBE_{CO} of 20±1 kJ mol^{-1} or 0.19 eV) and equilibrium surface coverage measurements (ΔBE_{CO} of 14±1 kJ mol^{-1} or 0.14 eV). Impedance spectroscopy indicated that Pt/graphene condensers with potentials oscillating at 3,000 Hz exhibited negligible loss in capacitance and charge accumulation, enabling programmable surface conditions at amplitudes and frequencies necessary to achieve catalytic resonance.

1.0 Introduction. The emergence of cost-competitive solar and wind power in the past decade has transformed the landscape for renewable energy economics and applications.[1,2] Produced in rural locations frequently far from industrial and urban centers, the challenge remains to store renewable energy for on-demand use across daily and seasonal requirements.[3] Batteries, compressed air, and pumped water storage are potentially viable options for local electrical storage, but they remain stationary preferably near the location of energy generation.[4,5] Alternatively, conversion of renewable electrical power to baseload power provided by conventional fossil-fuel-derived power and high rates of renewable energy implementation.[8]

2.0 Results and Discussion. Programmable catalysis is a proposed design strategy capable of accelerating catalytic reaction rates above the Sabatier limit for a given reaction[18] and selectively pushing reactions away from equilibrium via work input directly to the catalytic surface.[23] The properties of inorganic catalysts are typically invariant with time (with the exceptions of restructuring and deactivation); therefore,



J|A|C|S JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

pubs.acs.org/JACS — Article

Platinum Graphene Catalytic Condenser for Millisecond Programmable Metal Surfaces

Tzia Ming Onn, Sallye R. Gathmann, Silu Guo, Surya Pratap S. Solanki, Amber Walton, Benjamin J. Page, Geoffrey Rojas, Matthew Neurock, Lars C. Grabow, K. Andre Mkhoyan, Omar A. Abdelrahman, C. Daniel Frisbie, and Paul J. Dauenhauer*

Cite This: J. Am. Chem. Soc. 2022, 144, 22113−22127 — Read Online

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ABSTRACT: Accelerating catalytic chemistry and tuning surface reactions require precise control of the electron density of metal atoms. In this work, nanoclusters of platinum were supported on a graphene sheet within a catalytic condenser device that facilitated electron or hole accumulation in the platinum active sites with negative or positive applied potential, respectively. The catalytic condenser was fabricated by depositing on top of a p-type Si wafer an amorphous HfO_2 dielectric (70 nm), on which was placed the active layer of 2−4 nm platinum nanoclusters on graphene. A potential of ±6 V applied to the Pt/graphene layer relative to the silicon electrode moved electrons into or out of the active sites of Pt, attaining charge densities more than 1% of an electron or hole per surface Pt atom. At a level of charge condensation of ±10% of an electron per surface atom, the binding energy of carbon monoxide to a Pt(111) surface was computed via density functional theory to change 24 kJ mol^{-1} (0.25 eV), which was consistent with the range of carbon monoxide binding energies determined from temperature-programmed desorption (ΔBE_{CO} of 20 ± 1 kJ mol^{-1} or 0.19 eV) and equilibrium surface coverage measurements (ΔBE_{CO} of 14 ± 1 kJ mol^{-1} or 0.14 eV). Impedance spectroscopy indicated that Pt/graphene condensers with potentials oscillating at 3000 Hz exhibited negligible loss in capacitance and charge accumulation, enabling programmable surface conditions at amplitudes and frequencies necessary to achieve catalytic resonance.

■ INTRODUCTION

Over the past century, metal surfaces have been synthesized for precise electronic interaction with adsorbates to accelerate reactions and control catalytic pathways.[1,2] Bulk metals were converted to nanoclusters supported on metal oxides and carbon surfaces, providing higher dispersion and increased densities of edge, step, and terrace sites.[3−5] These active metal surfaces were further refined by alloying with other metals,[6,7] adding promoters and inhibitors that further modify their properties,[8,9] and designing the catalyst/support interactions.[10,11] Precise synthesis of more advanced nanoparticles and surface design has included core−shell particles,[12,13] intermetallic surfaces,[14,15] and single-atom alloys[16,17] to provide more electronic specification at the active site by altering the coordination of the atoms and the composition of nearest neighbors.[18] Such synthetic methods, however, require precise surface structures in stable conformations and only provide discrete options for active sites that are static on the time scale of the catalytic turnover.

An alternative approach to catalyst design directly tunes the electron density of the active site by stabilizing positive or negative charge in the exposed catalytic surface.[19,20] We have recently described the method of a 'catalytic condenser' that uses a high-k dielectric HfO_2 layer to separate a conductive silicon electrode from a conductive active layer of ultrathin amorphous alumina on graphene.[21] In this example, the amorphous alumina layer is a solid Lewis acid catalyst, while the supporting graphene rapidly distributes charge across the device surface. When a positive voltage bias is applied to the active alumina/graphene layer relative to the silicon electrode, the alumina catalyst active sites are depleted of electrons, making them more acidic and faster at dehydrating alcohols such as isopropyl alcohol.

Synthesizing the catalytic condenser stack design with a metal-on-graphene active layer (instead of an oxide on graphene) extends condenser applicability to many important metal-catalyzed chemistries. However, electronically biasing

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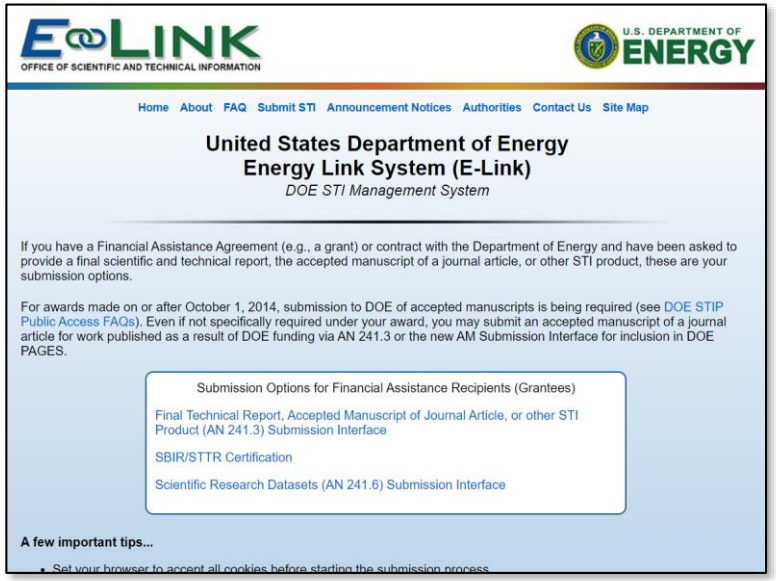
Published: November 16, 2022

We provide the OSTI to all CPEC publications on our website



E-LINK OFFICE OF SCIENTIFIC AND TECHNICAL INFORMATION — U.S. DEPARTMENT OF ENERGY

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United States Department of Energy Energy Link System (E-Link)

DOE STI Management System

If you have a Financial Assistance Agreement (e.g., a grant) or contract with the Department of Energy and have been asked to provide a final scientific and technical report, the accepted manuscript of a journal article, or other STI product, these are your submission options.

For awards made on or after October 1, 2014, submission to DOE of accepted manuscripts is being required (see DOE STIP Public Access FAQs). Even if not specifically required under your award, you may submit an accepted manuscript of a journal article for work published as a result of DOE funding via AN 241.3 or the new AM Submission Interface for inclusion in DOE PAGES.

Submission Options for Financial Assistance Recipients (Grantees)

Final Technical Report, Accepted Manuscript of Journal Article, or other STI Product (AN 241.3) Submission Interface

SBIR/STTR Certification

Scientific Research Datasets (AN 241.6) Submission Interface

A few important tips...

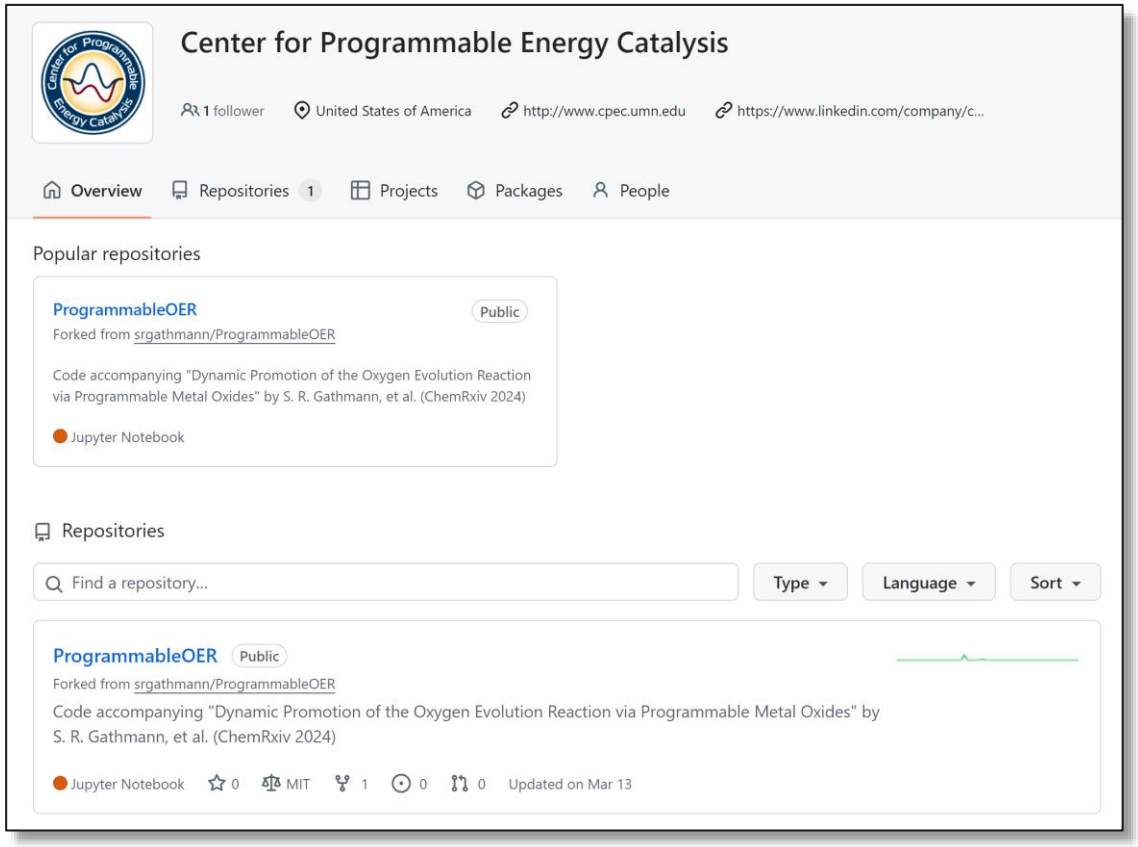
- Set your browser to accept all cookies before starting the submission process

CPEC Data Management – Sharing *Strategy*

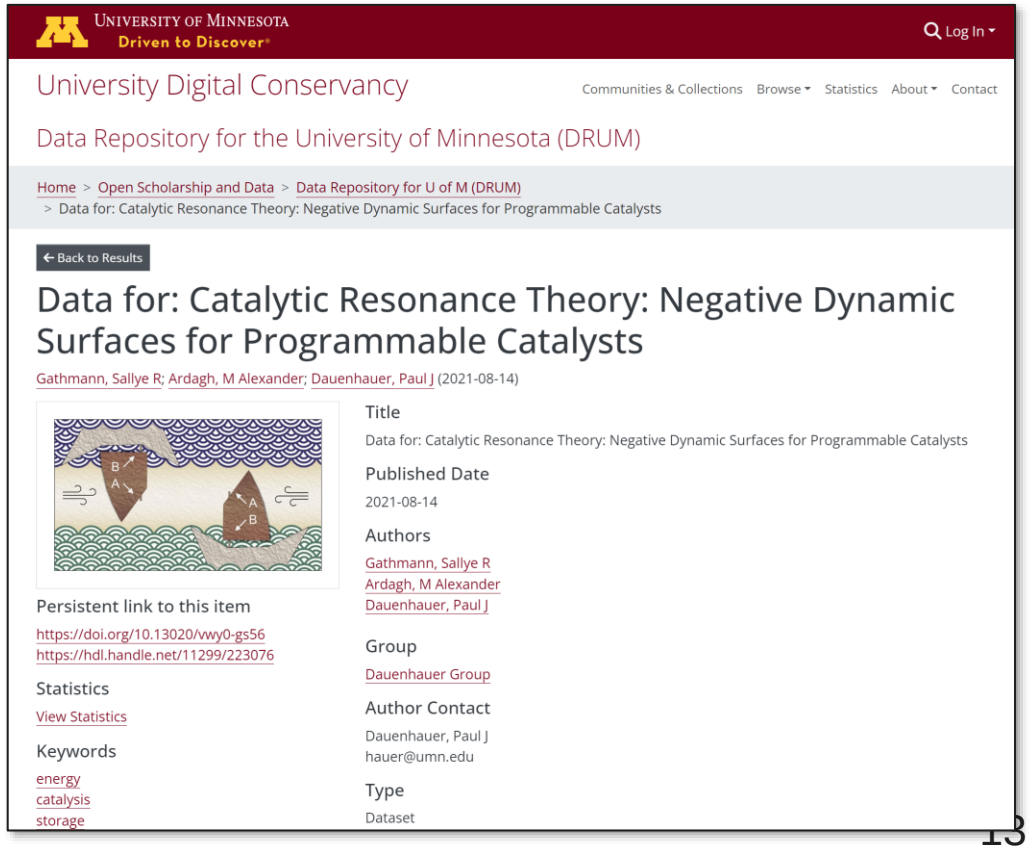
Primary focus is on making data available via publication and associated methods

Part 2: Require code & data set sharing with prescribed methods

Simulation Codes: CPEC Github Site



Large Data Sets: CPEC Data Conservancy



CPEC Data Management – Sharing *Strategy*

Primary focus is on making data available via publication and associated methods

Part 3: Review and compliance via data tracking within the Portal

Paper #	Title	Preprint?	OSTI	Peer Reviewed	Accepted?	Publication Year	Journal	DOI#	Journal IF (2022)
P024	Epitaxially Grown Single-Crystalline SrTiO3 Membranes using a Solution-Processed, amorphous SrCa2Al2O6 Sacri	No	2430017	Yes	Yes	2024	Journal of Materials Chemistry	10.1039/D4TC02030H	
P023	Catalytic Resonance Theory: Forecasting the Flow of Programmable Catalytic Loops	Yes	TBD	Yes					
P022	ATLAS-MAP: An Automated Test Station for Gated Electronic Transport Measurements	Yes	2439068	Yes	Yes	2024	ACS Measurement Science Au		
P021	Catalytic Resonance Theory: The Catalytic Mechanics of Programmable Ratchets	Yes	2407234	Yes	Yes	2024	Chemical Science	10.1039/D4SC04069D	
P020	Alumina-Titania Nanolaminate Condensers for Hot Programmable Catalysis	Yes	2377755	Yes	Yes	2024	ACS Materials Letters	10.1021/acsmaterialslett.4c00652	
P019	Anomalous frequency and temperature dependent scattering in the dilute metallic phase in lightly doped SrTiO3	Yes	2427951	Yes	Yes	2024	Physical Review Letters	arXiv:2402.18767	
P018	Isopotential Titration for Quantifying Metal-Adsorbate Charge Transfer	Yes	TBD	Yes					
P017	CatTestHub: A Benchmarking Database of Experimental Heterogeneous Catalysis for Evaluating Advanced Materials	Yes	TBD	Yes					
P016	Accelerated Steam Methane Reforming by Dynamically Applied Charges	Yes	TBD	Yes	Yes	2024	Journal of Physical Chemistry	10.1021/acs.jpcc.4c01311	
P015	Dynamic Promotion of the Oxygen Evolution Reaction via Programmable Metal Oxides	Yes	2335550	Yes	Yes	2024	ACS Energy Letters	10.1021/acsenergylet	22
P014	Bond Selective Photochemistry at Metal Nanoparticle Surfaces: CO Desorption from Pt and Pd	No	2350681	Yes	Yes	2024	JACS Journal of the American	10.1021/jacs.3c13874	15
P013	Is There a Discernible Photochemical Effect Beyond Heating for Visible Photon-Mediated NH3 Decomposition over Ru/	No	2337785	Yes	Yes	2024	Journal of Physical Chemistry	10.1021/acs.jpcc.4c0	3.7
P012	Deciphering the Olefin Isomerization-Polymerization Paradox of Palladium(II) Diimine Catalysts: Discovery of Simultan	No	2267576	Yes	Yes	2023	Journal of the American Chem	10.1021/jacs.3c01513	15
P011	Hybrid Molecular Beam Epitaxy for Single-Crystalline Oxide Membranes with Binary Oxide Sacrificial Layers	Yes	2283938	Yes	Yes	2024	ACS Nano	10.1021/acsnano.3c1	17.1
P010	Up Up Down Down Left Right Left Right B A Start for the Catalytic Hackers of Programmable Materials	Yes	2228578	Yes	Yes	2023	Matter	10.1016/j.matt.2023.1	19.8
P009	Catalytic Resonance Theory: Circumfluence of Programmable Catalytic Loops	Yes	2290247	Yes	Yes	2024	Journal of Catalysis	10.1016/j.jcat.2024.11	7.3
P008	Flexible and Extensive Platinum Ion Gel Condensers for Programmable Catalysis	Yes	2263306	Yes	Yes	2024	ACS Nano	10.1021/acsnano.3c0	17.1
P007	Fabrication of Large Area Metal-on-Carbon Catalytic Condensers for Programmable Catalysis	Yes	2263446	Yes	Yes	2023	ACS Applied Materials & Interf	10.1021/acsami.3c14	9.5
P006	Programmable Catalysis by Support Polarization: Elucidating and Breaking Scaling Relations	Yes	2222558	Yes	Yes	2023	Nature Communications	10.1038/s41467-023-	16.6
P005	Energy Flows in Static and Programmable Catalysts	Yes	1971068	Yes	Yes	2023	ACS Energy Letters	10.1021/acsenergylet	22
P004	Writing the Programs of Programmable Catalysis	Yes	1971823	Yes	Yes	2023	ACS Catalysis	10.1021/acscatal.3c0	12.9
P003	Sn-modified BaTiO3 thin film with enhanced polarization	No	1924658	Yes	Yes	2023	Journal of Vacuum Science &	10.1116/6.0002208	2.6
P002	Overcoming the Entropy Penalty of Direct Air Capture for Efficient Gigatonne Removal of Carbon Dioxide	Yes	1914328	Yes	Yes	2023	ACS Engineering Au	10.1021/acsengineeri	NA
P001	Platinum Graphene Catalytic Condenser for Millisecond Programmable Metal Surfaces	Yes	1899709	Yes	Yes	2022	Journal of the American Chem	10.1021/jacs.2c0948	15

CPEC Data and Organization Policies

CURATED Data Sharing - CatTestHub

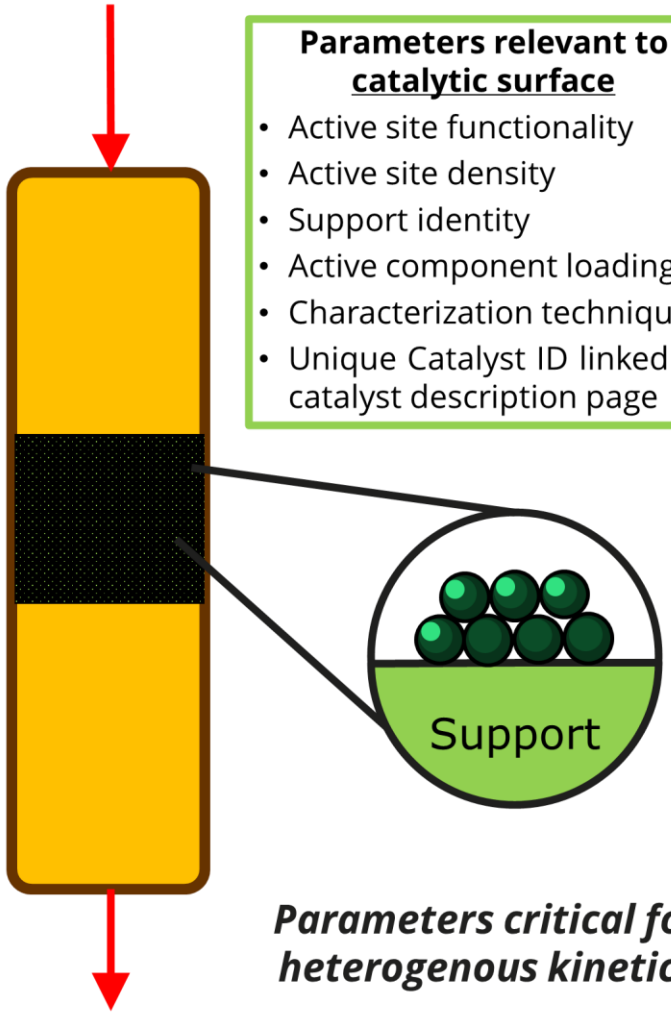
Curated Data: CatTestHub

Parameters relevant to <u>reactor type</u>
- Reactor configuration
- Reactor ID linking to a reactor description page

Parameters relevant to <u>fluid phase</u>
- Reaction Conditions – Pressure/ Temperature
- Feed Chemical Composition
- Total molar flow rate

Parameters relevant to <u>catalytic bed</u>
- Pellet Diameter
- Space Velocity

Parameters relevant to <u>observable macroscopic quantities</u>
- *Apparent* rate of catalytic turnover
- Product Selectivity
- Reactant conversion
- Atom/Mole Balance

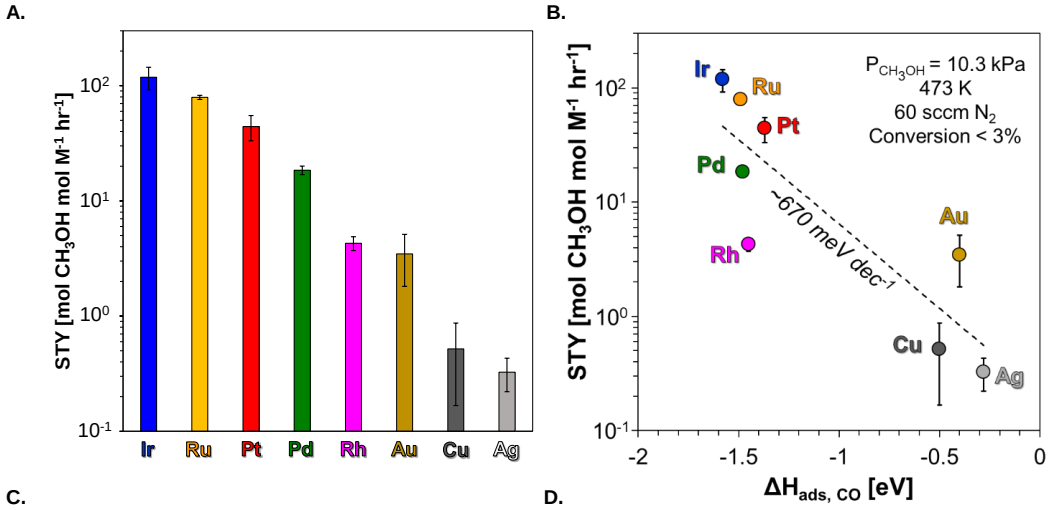


Parameters relevant to <u>catalytic surface</u>
- Active site functionality
- Active site density
- Support identity
- Active component loading
- Characterization techniques
- Unique Catalyst ID linked to catalyst description page

Parameters critical for heterogenous kinetics

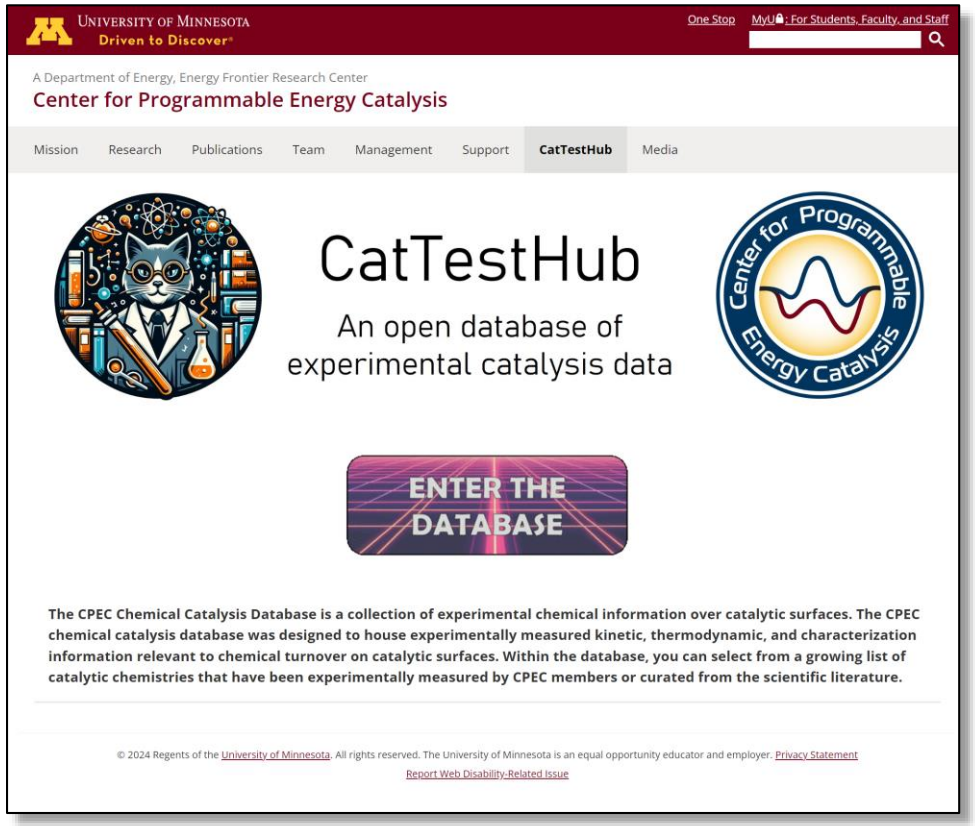
Goals:

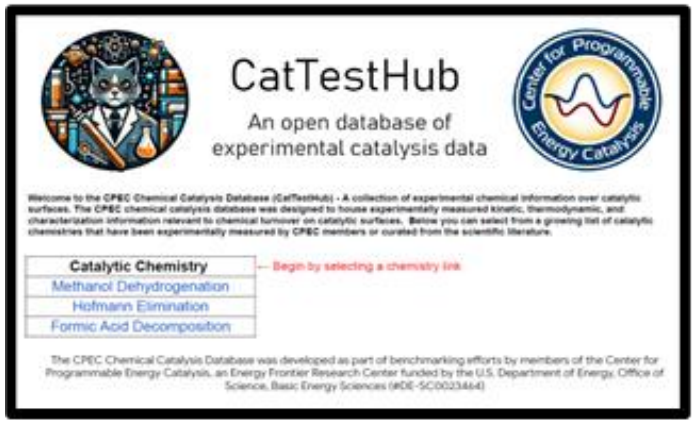
(1) Create a high quality data set for comparison with dynamic kinetics
(2) Capture all relevant experimental and characteristic data

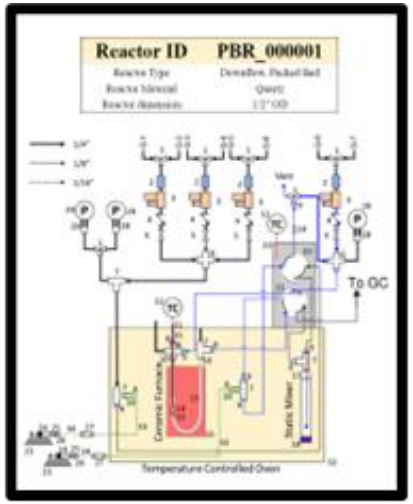


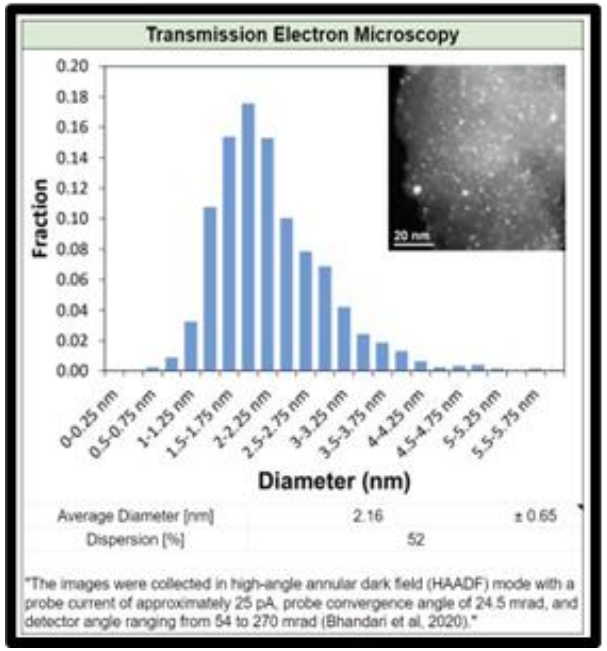
Methanol Dehydrogenation

Curated Data: CatTestHub









Metal Catalysts

Metal	Support	Loading	Description
Platinum	Silica	1	Cat_M_000001
Platinum	Silica	3.1	Cat_M_000002
Iridium	Carbon	1	Cat_M_000003
Platinum	Silica	1	Cat_M_000004
Platinum	Carbon	5	Cat_M_000005
Palladium	Carbon	5	Cat_M_000006
Ruthenium	Carbon	5	Cat_M_000007
Rhodium	Carbon	5	Cat_M_000008
Gold	Carbon	5	Cat_M_000009
Silver	Carbon	5	Cat_M_000010
Platinum	Carbon	1	Cat_M_000011
Copper	Carbon	5	Cat_M_000012
Palladium	Carbon	1	Cat_M_000013
Gold	Silica carbide	1	Cat_M_000014
Nickel	Carbon	5	Cat_M_000015

Structure – People – Teams – Executive Committee

Leaders

Director Paul Dauenhauer

Deputy Director Susannah Scott

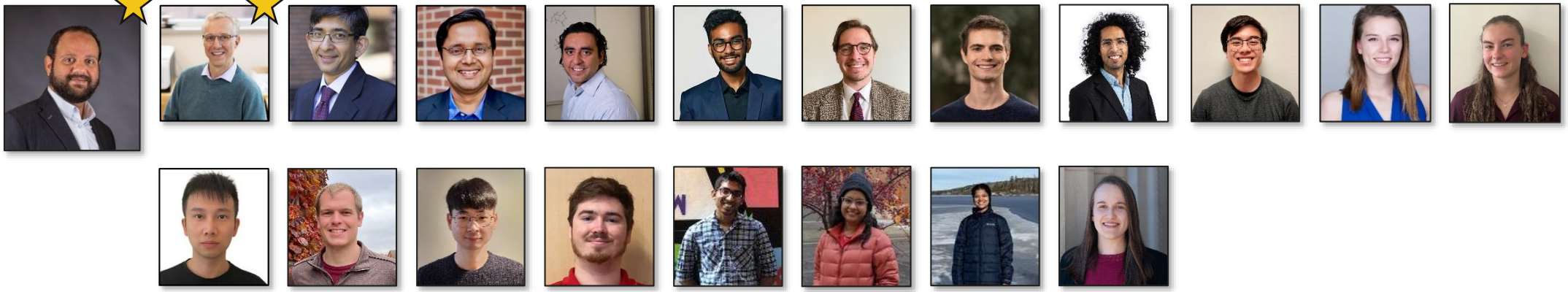
Managing Director Magdalene Miranda

Accountant Stephanie Pederson

★ Executive Committee

Team 1

Lead Omar Abdelrahman



Team 2

Lead Rachel Getman

Team 3

Lead Phil Christopher