Muhammad Zeeshan

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Research Vision and Academic Highlights

Research vision: Develop and engineer confined ionic microenvironments at electrified porous interfaces to understand and control molecular and ionic transport, reaction pathways, and selectivity for electrochemical CO_2 conversion and selective recovery of critical metals from aqueous solutions.
Scholarly impact: 22 peer-reviewed publications, including 10 first-author papers, published in journals including JACs, Advanced Functional Materials, Chemical Engineering Journal, Carbon, Chemical Society Reviews, Science Advances, and ACS Materials Letter.
Research leadership and translation: Developed microwave and radio-frequency sorbent regeneration and membrane gas separation setups; co-inventor on a U.S. provisional patent; contributed to awarded DOE Office of Science and Expanding Horizons Initiative proposals.
Teaching, mentoring and service: Teaching assistant experience across six courses, completed MIT's Kaufman Teaching Certificate training, mentored undergraduate and graduate researchers; and served as a reviewer for 20+ manuscripts in CO_2 capture, separations, and materials science.

Education

MS and Ph.D Chemical and Biological Engineering Feb 2017 — Dec 2021
Koç University, Istanbul, Turkey
Advisors: Prof. Alper Uzun and Prof. Seda Keskin

- **Porous composites for CO_2 capture:** Fabricated IL/MOF composites for CO_2 separation from N_2 and CH_4.
- **Thermal degradation analysis of IL/MOF composites:** Screened 29 ILs with CuBTC and ZIF-8 via thermal degradation analysis, quantifying decomposition onset temperatures to identify structural factors governing thermal stability of IL/MOF composites.
- **Gas adsorption analysis and materials performance:** Measured CO_2, N_2, and CH_4 adsorption isotherms using HPVA-II (Micromeritics) and iSorb HP2 (Quantachrome) analyzers; quantified uptake, working capacity, BET surface area, pore size, and particle size distributions.

BS Chemical Engineering Sept 2011 — Aug 2015
BUITEMS, Quetta, Pakistan
CGPA: 3.88/4 *(Recipient of University Gold Medal, ranked 1st in the class)*

Professional Experience

Postdoctoral Associate | PI: Prof. Betar Gallant March 2025 — Present
MIT, Cambridge, MA, USA

- **Reactive CO_2 capture and electrochemical reduction:** Identified hydrogen evolution reaction (HER)-active proton donor species and dominant reaction pathways in amine-based capture media.
- **Electrolyte formulation:** Designed and optimized electrolytes to suppress HER activity and promote CO_2 conversion faradaic efficiency.

Postdoctoral Researcher | PI: Prof. Burcu Gurkan Aug 2022 — March 2025
Case Western Reserve University, Cleveland, OH, USA

- **Reactive IL/MOF composites:** Designed reactive sorbents for DAC of CO_2, to enhance CO_2 capture performance and minimize mass transfer limitations for DAC.
- **Technology development and prototype validation:** Developed and established a new laboratory-scale capability for microwave and radio-frequency-assisted dielectric heating of CO_2 sorbents; evaluated material performance and demonstrated enhanced heating and CO_2 desorption rates.
- **Quantitative structure–property relationship (QSPR) analysis:** Developed a multiple linear regression-QSPR model using molecular descriptors to predict viscosity and CO_2 capture capacity of functionalized deep eutectic solvents.

Research Leadership, Funding and Intellectual Property

Proposal development experience with Prof. Burcu Gurkan, CWRU (2023–2025)

- Department of Energy (DOE) Office of Science — **awarded**
- Expanding Horizons Initiative 2025 Interdisciplinary-Large (INT-L) category — **awarded, $30000**
- DOE Energy Earthshot: Carbon Negative – Advanced Scientific Computing Research
- Boeing Co. research proposal

- **M. Zeeshan** and B. Gurkan, "Electromagnetic-Based Regeneration of CO_2-Reactive Porous Composites for Direct Air Capture," U.S. Provisional Patent Application No. 63/650,098, filed May 2024.

Publications **Muhammad Zeeshan-Google Scholar**

1. **M. Zeeshan,** V. Nozari, M.B. Yagci, T. Isık, U. Unal, V. Ortalan, S. Keskin, and A. Uzun "Core-Shell Type Ionic Liquid/Metal Organic Framework Composite: An Exceptionally High CO_2/CH_4 Selectivity" *Journal of the American Chemical Society* 140 (32) (**2018**) 10113. ***Featured a Journal Cover Art*** *and* ***highlighted in Chemical & Engineering News***
2. **M. Zeeshan,** S. Keskin, and A. Uzun "Enhancing CO_2/CH_4 and CO_2/N_2 Separation Performances of ZIF-8 by Post-Synthesis Modification with [BMIM][SCN]" *Polyhedron* 155 (**2018**) 485.
3. V. Nozari, **M. Zeeshan,** S. Keskin, and A. Uzun "Effect of Methylation in Ionic Liquids on the Gas Separation Performance of Ionic Liquid/Metal-Organic Framework Composites" *CrystEngComm* 20 (**2018**) 7137.
4. **M. Zeeshan,** V. Nozari, S. Keskin, and A. Uzun "Structural factors determining thermal stability limits of ionic liquid/MOF composites: Imidazolium ionic liquids combined with CuBTC and ZIF-8" *ACS Industrial & Engineering Chemistry Research* 58 (**2019**) 14124.
5. H.M. Polat, **M. Zeeshan,** A. Uzun, and S. Keskin, "Unlocking CO_2 Separation Performance of Ionic Liquid/CuBTC Composites: Combining Experiments with Molecular Simulations" *Chemical Engineering Journal* 373 (**2019**) 1179.
6. **M. Zeeshan**, H. Kulak, S. Kavak, H.M. Polat, O. Durak, S. Keskin, and A. Uzun "Influence of anion size and electronic structure on the gas separation performance of ionic liquid/ZIF-8 composites" *Microporous and Mesoporous Mater.* 306 **(2020)** 110446.
7. **M. Zeeshan,** K. Yalcin, F. E. S. Oztuna, U. Unal, S. Keskin, and A. Uzun "A new class of porous materials for efficient CO_2 separation: Ionic liquid/graphene aerogel composites" *Carbon* 171 **(2020)** 79-87.
8. **M. Zeeshan**, H. C. Gulbalkan, Z. P. Haslak, S. Keskin, and A. Uzun "Doubling CO_2/N_2 separation performance of CuBTC by incorporation of 1-n-ethyl-3-methylimidazolium diethyl phosphate" *Microporous and Mesoporous Mater.* 316 **(2021)** 110947.
9. O. Durak, **M. Zeeshan**, N. Habib, H. C. Gülbalkan, A. A. A. M. Alsuhile, H. P Çağlayan, S. F. Kurtoğlu-Öztulum, Y. Zhao, Z. P. Haşlak, A. Uzun, and S. Keskin "Composites of porous materials with ionic liquids: synthesis, characterization, applications, and beyond" *Microporous and Mesoporous Mater.* 111703 **(2022)**.
10. O. Durak, **M. Zeeshan,** S. Keskin, and A. Uzun, "[BMIM][OAc] Coating Layer Makes Activated Carbon Almost Completely Selective for CO_2" *Chemical Engineering Journal* 135436 **(2022)**.
11. **M. Zeeshan**, H. C. Gülbalkan, O. Durak, Z. P. Haşlak, S. Keskin, and A. Uzun "An integrated computational-experimental hierarchical approach for the rational design of an IL/UiO-66 composite offering infinite CO_2 selectivity" *Advanced Functional Materials* **(2022)** 202204149.
12. Nitasha Habib, O. Durak, **M. Zeeshan**, A. Uzun, and S. Keskin "A Novel IL/MOF/Polymer Mixed Matrix Membrane having Superior CO_2/N_2 Selectivity" *Journal of Membrane Science* 120712 **(2022)**.
13. A. Klemm, S. P. Vicchio, S. Bhattacharjee, E. Cagli, Y. Park, **M. Zeeshan,** R. Dikki, H. Liu, M. K. Kidder, R. B. Getman, B. Gurkan "Impact of Hydrogen Bonds on CO_2 Binding in Eutectic Solvents: An Experimental and Computational Study toward Sorbent Design for CO_2 Capture" *ACS Sustainable Chemistry & Engineering* 11, 9, **(2023)** 3740–3749.
14. **M. Zeeshan,** M. K. Kidder, E. Pentzer, R. B. Getman, B. Gurkan "Direct air capture of CO_2: from insights into the current and emerging approaches to future opportunities" *Frontiers in Sustainability, Sustainable Chemical Process Design* 4 **(2023)** 1167713.
15. R. Dikki, V. Khokhar, **M. Zeeshan,** S. Bhattacharjee, O. Coskan, R. B. Getman, B. Gurkan "Composition–property relationships of choline based eutectic solvents: impact of the hydrogen bond donor and CO_2 saturation" *RSC Green Chemistry* **(2024).**
16. S. Dongare, **M. Zeeshan,** A. S. Aydogdu, Ruth Dikki, S. F. K. Öztulum, O. K. Coskun, M. Muñoz, A. Banerjee, M. Gautam, R. D. Ross, J. Stanley, R. S. Brower, B. Muchharla, R. L. Sacci, J. M. Velázquez, B. Kumar, J. Y. Yang, C. Hahn, S. Keskin, C. G. M. Guio, A. Uzun, J. M. Spurgeon, B. Gurkan "Reactive capture and electrochemical conversion of CO_2 with ionic liquids and deep eutectic solvents" *RSC Chem Soc Rev (***2024)** 53, 8563-8631.
17. N. C. Starvaggi, L. Al-Mahbobi, **M. Zeeshan,** E. C. Barrios, B. Gurkan, E. B. Pentzer "Double Emulsion Microencapsulation of Ionic Liquids for Carbon Capture" *Materials Horizons, (2024), 11, 6057-6063*
18. A. Kilic, O. Abdelaty, **M. Zeeshan**, A. Uzun, R. Yildirim, D. Eroglu "Selection of ionic liquid electrolytes for high-performing lithium-sulfur batteries: An experiment-guided high-throughput machine learning analysis" *Chemical Engineering Journal* 151562 **(2024)**.

19. **M. Zeeshan,** A. Klemm, J. T. Damron, K. A. Unocic, M. K. Kidder, B. Gurkan "Ionic Liquid Functionalizes the Metal Organic Framework for Microwave Assisted Direct Air Capture of CO_2" *ACS Materials Lett. 6, 8,* **(2024)** 3854–3861
20. R.M Neria, **M. Zeeshan**, A. Kapoor, Tae K. J. Kim, N. Hoven, J. S Pigott, B. Gurkan, C. E. Duval, R. A Saylor, L. Kisley " Super-resolution imaging reveals resistance to mass transfer in functionalized stationary phases" *Science advances* **(2025)** 11, 7, 2375-2548
21. **M. Zeeshan** and B. Gurkan "Sorbent Regeneration via Radiofrequency-Assisted Dielectric Heating for Direct Air Capture of CO_2" *ACS Applied Engineering Materials* 3, 4, **(2025)** 798–802.
22. M. B. Khoshgoee, M. K. Debnath, G. Pardo, Y. Yuan, **M. Zeeshan**, E. Mao, T. G. Gray, B. Gurkan, M. J. Bertin, and M. Karayilan, "Multi-responsive polymers with degradable side-chain functionality for controlled hydrolysis and tunable thermal transition" *RSC Applied Polymers* **(2026)**

Conference Presentations

1. **Ohio Space Forum, Cleveland, Ohio, USA, April 29-30, 2024,** Y. Lee, A. Klemm, **M. Zeeshan,** and B. Gurkan "Facilitated Transport Membranes for Selective Separation of CO2 at Low Concentration**" (Poster).**
2. **Gordon Research Seminar (GRS), Grand Galvez, Galveston, Texas, USA,** Jan 20 - 21, 2024, **M. Zeeshan,** A. Klemm, J. T. Damron, M. K. Kidder, and B. Gurkan "Microwave and Moisture-Swing Regenerability of Reactive Porous Composites for Direct Air Capture of CO_2" **(Oral).**
3. **Gordon Research Conference (GRC), Galveston, Texas, USA,** Jan 21 - 26, 2024, **M. Zeeshan,** A. Klemm, J. T. Damron, M. K. Kidder, and B. Gurkan "Microwave and Moisture-Swing Regenerability of Reactive Porous Composites for Direct Air Capture of CO_2" **(Poster).**
4. **ACS Fall 2023, San Francisco, California, USA,** August 13 – 17, 2023, **M. Zeeshan,** A. Klemm, E. Cagli, and B. Gurkan "Microwave and Moisture-Swing Regenerability of Reactive Porous Composites for Direct Air Capture of CO_2" **(Oral).**
5. **Euro MOF 2019, Paris, France**, 27-30 Oct. 2019, **M. Zeeshan,** V. Nozari, M.B. Yagci, T. Isık, U. Unal, V. Ortalan, S. Keskin, A. Uzun "A Core-Shell Type Ionic Liquid/Metal Organic Framework Composite: an exceptional improvement in CO_2 uptake and CO_2/CH_4 selectivity" **(Poster)**

Teaching and Mentoring Experiences

MIT Kaufman Teaching Certificate Program Sept 2025 — Dec 2025

- Completed an intensive workshop series on evidence-based teaching focused on course design, inclusive pedagogy, and student assessment.
- Designed a Chemical Engineering Thermodynamics syllabus using backward design to align learning goals, instructional activities, and assessment.
- Delivered recorded teaching demonstrations and used peer feedback to strengthen instructional clarity and student engagement.

Research mentoring

- Experience mentoring undergraduate and graduate researchers across interdisciplinary projects

Teaching Assistant Feb 2017 — Nov 2021

Koç University, Istanbul

- Physics 102 LAB (1 semester)
- Introduction to MATLAB (1 semester)
- General Chemistry 103 Lab (3 semesters)
- Catalysis at Surfaces (1 semester)
- Advanced Reaction Engineering (2 semesters)
- Thermodynamics CHBI-204 (1 semester)

Awards and Scholarships

- Energy & Fuels Excellence in Review Award, American Chemical Society (2025)
- Poster Award, Gordon Research Conference (GRC), Chemical Separation, Galveston, Texas, USA (2024)
- Postdoc Spotlight of the Month, Case Western Reserve University Office of Postdoctoral Affairs (2024)
- Second Prize, EFSUN Best Paper Award Competition, Istanbul, Turkey (2020)
- Merit Scholarship, BUITEMS (2011-2015)

Selected Technical Skills

- **Gas adsorption and electrochemical techniques:** High pressure volumetric gas sorption analyzers, BET surface area analyzer, and dynamic CO_2 breakthrough experiments, CV, LSV, electrochemical impedance spectroscopy (EIS), chronoamperometry
- **Material characterization:** SEM, XRD, TGA, NMR, GC, XRF, XPS, and FT-IR
- **Data analysis, modeling, and visualization:** MS Office, MATLAB, Spartan Quantum chemical calculation: COSMOthermX, Python