Stanford

Matthew Kanan

Associate Professor of Chemistry and Senior Fellow at the Precourt Institute for Energy

CONTACT INFORMATION

- **Administrative Contact**

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Bio

BIO

Associate Professor of Chemistry Matthew Kanan develops new catalysts and chemical reactions for applications in renewable energy conversion and CO2 utilization. His group at Stanford University has recently developed a novel method to create plastic from carbon dioxide and inedible plant material rather than petroleum products, and pioneered the study of “defect-rich” heterogeneous electro-catalysts for converting carbon dioxide and carbon monoxide to liquid fuel.

Matthew Kanan completed undergraduate study in chemistry at Rice University (B.A. 2000 Summa Cum Laude, Phi Beta Kappa). During doctoral research in organic chemistry at Harvard University (Ph.D. 2005), he developed a novel method for using DNA to discover new chemical reactions. He then moved into inorganic chemistry for his postdoctoral studies as a National Institutes of Health Postdoctoral Research Fellow at the Massachusetts Institute of Technology, where he discovered a water oxidation catalyst that operates in neutral water. He joined the Stanford Chemistry Department faculty in 2009 to continue research into energy-related catalysis and reactions. His research and teaching have already been recognized in selection as one of Chemistry & Engineering News’ first annual Talented 12, the Camille Dreyfus Teacher-Scholar Award, Eli Lilly New Faculty Award, and recognition as a Camille and Henry Dreyfus Environmental Mentor, among other honors.

The Kanan Lab addresses fundamental challenges in catalysis and synthesis with an emphasis on enabling new technologies for scalable CO2 utilization. The interdisciplinary effort spans organic synthesis, materials chemistry and electrochemistry.

One of the greatest challenges of the 21st century is to transition to an energy economy with ultra-low greenhouse gas emissions without compromising quality of life for a growing population. The Kanan Lab aims to help enable this transition by developing catalysts and chemical reactions that recycle CO2 into fuels and commodity chemicals using renewable energy sources. To be implemented on a substantial scale, these methods must ultimately be competitive with fossil fuels and petrochemicals. With this requirement in mind, the group focuses on the fundamental chemical challenge of making carbon–carbon (C–C) bonds because multi-carbon compounds have higher energy density, greater value, and more diverse applications that one-carbon compounds. Both electrochemical and chemical methods are being pursued. For electrochemical conversion, the group studies how defects known as grain boundaries can be exploited to improve CO2/CO electro-reduction catalysis. Recent work has unveiled quantitative correlations between grain boundaries and catalytic activity, establishing a new design principle for electrocatalysis, and developed grain boundary-rich copper catalysts with unparalleled activity for converting carbon monoxide to liquid fuel. For chemical CO2 conversion, the

group is developing C–H carboxylation and CO2 hydrogenation reactions that are promoted by simple carbonate salts. These reactions provide a way to make C–C bonds between un-activated substrates and CO2 without resorting to energy-intensive and hazardous reagents. Among numerous applications, carbonate-promoted carboxylation enables the synthesis of a monomer used to make polyester plastic from CO2 and a feedstock derived from agricultural waste.

In addition to CO2 chemistry, the Kanan group is pursuing new strategies to control selectivity in molecular catalysis for fine chemical synthesis. Of particular interest in the use of electrostatic interactions to discriminate between competing reaction pathways based on their charge distributions. This effort uses ion pairing or interfaces to control the local electrostatic environment in which a reaction takes place. The group has recently shown that local electric fields can control regioselectivity in isomerization reactions catalyzed by gold complexes.

ACADEMIC APPOINTMENTS

- Associate Professor, Chemistry
- Member, Bio-X
- Member, Maternal & Child Health Research Institute (MCHRI)

HONORS AND AWARDS

- Selected one of first annual Talented 12, Chemistry & Engineering News (2015)
- Camille Dreyfus Teacher-Scholar Award, Camille & Henry Dreyfus Foundation (2014)
- Hellman Faculty Scholar Award, Hellman Fellows Program (2013)
- Camille and Henry Dreyfus Environmental Mentor, Camille & Henry Dreyfus Foundation (2012)
- Thieme Journal Award, Thieme Medical Publishers (2010)
- Eli Lilly New Faculty Award, Eli Lilly and Company (2009)

BOARDS, ADVISORY COMMITTEES, PROFESSIONAL ORGANIZATIONS

- Editorial Advisory Board Member, ACS Central Science (2015 - present)

PROFESSIONAL EDUCATION

- Postdoc, Massachusetts Institute of Technology , Water-Oxidation Catalysis (2005)
- PhD, Harvard University , Organic Chemistry (2005)
- BA Summa Cum Laude, Rice University , Chemistry (2000)

LINKS

- The Kanan Lab: http://kananlab.stanford.edu/

Teaching

COURSES

2022-23

- Organic Polyfunctional Compounds: CHEM 123 (Aut)
- Understanding the Natural and Unnatural World through Chemistry: CHEM 121 (Spr)

2021-22

- Organic Polyfunctional Compounds: CHEM 123 (Aut)
- Understanding the Natural and Unnatural World through Chemistry: CHEM 121 (Spr)

2020-21

- Organic Polyfunctional Compounds: CHEM 123 (Win)
- Understanding the Natural and Unnatural World through Chemistry: CHEM 121 (Aut, Spr)

2019-20

- Organic Chemistry of Bioactive Molecules: CHEM 121 (Spr)

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Jasper Ainsworth, Jeffrey Babicz, Raj Balaji, David Boyle, David Fanelli, Conor Galvin, Alex Su

Postdoctoral Faculty Sponsor

Rishi Agarwal

Doctoral Dissertation Advisor (AC)

Ben Charnay, Yuxuan Chen, Kyle Disselkoen, Chastity Li, Josh Rabinowitz, Lucas Sanchez, Kesha Tamakuwala, Cristian Woroch, Gage Wright

Publications

PUBLICATIONS

- **Improving the Energy Efficiency of CO Electrolysis by Controlling Cu Domain Size in Gas Diffusion Electrodes** *ACS ENERGY LETTERS*
  Rabinowitz, J. A., Ripatti, D. S., Mariano, R. G., Kanan, M. W.
  2022: 4098-4105
- **Carbonate-catalyzed reverse water-gas shift to produce gas fermentation feedstocks for renewable liquid fuel synthesis** *CELL REPORTS PHYSICAL SCIENCE*
  Li, C. S., Frankhouser, A. D., Kanan, M. W.
  2022; 3 (9)
- **Hypophosphite addition to alkenes under solvent-free and non-acidic aqueous conditions.** *Chemical communications (Cambridge, England)*
  Huang, Z., Chen, Y., Kanan, M. W.
  1800
- **A framework for automated structure elucidation from routine NMR spectra.** *Chemical science*
  Huang, Z., Chen, M. S., Woroch, C. P., Markland, T. E., Kanan, M. W.
  2021; 12 (46): 15329-15338
- **A High-T-g Polyamide Derived from Lignocellulose and CO2** *MACROMOLECULES*
  Woroch, C. P., Lankenau, A. W., Kanan, M. W.
  2021; 54 (21): 9978-9983
- **Microstructural origin of locally enhanced CO2 electroreduction activity on gold.** *Nature materials*
  Mariano, R. G., Kang, M., Wahab, O. J., McPherson, I. J., Rabinowitz, J. A., Unwin, P. R., Kanan, M. W.
  2021
- **Carbonate-promoted C-H carboxylation of electron-rich heteroarenes** *CHEMICAL SCIENCE*
  Porter, T. M., Kanan, M. W.
  2020; 11 (43): 11936–44
- **Carbonate-promoted C-H carboxylation of electron-rich heteroarenes.** *Chemical science*
  Porter, T. M., Kanan, M. W.
  2020; 11 (43): 11936-11944
- **Phase Behavior That Enables Solvent-Free Carbonate-Promoted Furoate Carboxylation.** *The journal of physical chemistry letters*
  Frankhouser, A. D., Kanan, M. W.
  2020: 7544–51

- **Point-of-Care Analysis of Blood Ammonia with a Gas-Phase Sensor.** *ACS sensors*
  Veltman, T. R., Tsai, C. J., Gomez-Ospina, N., Kanan, M. W., Chu, G.
  2020
- **Comparing Scanning Electron Microscope and Transmission Electron Microscope Grain Mapping Techniques Applied to Well-Defined and Highly Irregular Nanoparticles.** *ACS omega*
  Mariano, R. G., Yau, A., McKeown, J. T., Kumar, M., Kanan, M. W.
  2020; 5 (6): 2791–99
- **Polyamide monomers via carbonate-promoted C-H carboxylation of furfurylamine** *CHEMICAL SCIENCE*
  Lankenau, A. W., Kanan, M. W.
  2020; 11 (1): 248–52
- **The future of low-temperature carbon dioxide electrolysis depends on solving one basic problem.** *Nature communications*
  Rabinowitz, J. A., Kanan, M. W.
  2020; 11 (1): 5231
- **Polyamide monomers via carbonate-promoted C-H carboxylation of furfurylamine.** *Chemical science*
  Lankenau, A. W., Kanan, M. W.
  2019; 11 (1): 248-252
- **A closed cycle for esterifying aromatic hydrocarbons with CO2 and alcohol.** *Nature chemistry*
  Xiao, D. J., Chant, E. D., Frankhouser, A. D., Chen, Y., Yau, A., Washton, N. M., Kanan, M. W.
  2019
- **Gaseous carbon waste streams uilization: Status and research needs**
  Tway, C., Allen, D., Barteau, M., Burkart, M., Dunn, J., Gaffney, A., Gupta, R., Hazari, N., Kanan, M., Kenis, P., Klee, H., Sant, G.
  AMER CHEMICAL SOC.2019
- **Carbon Monoxide Gas Diffusion Electrolysis that Produces Concentrated C-2 Products with High Single-Pass Conversion** *JOULE*
  Ripatti, D. S., Veltman, T. R., Kanan, M. W.
  2019; 3 (1): 240–56
- **Carbonate-Promoted Hydrogenation of Carbon Dioxide to Multicarbon Carboxylates.** *ACS central science*
  Banerjee, A., Kanan, M. W.
  2018; 4 (5): 606–13
- **Editorial overview: Seeds for a bioenergy future** *CURRENT OPINION IN CHEMICAL BIOLOGY*
  Kanan, M. W.
  2017; 41: A1–A2
- **Editorial overview: Seeds for a bioenergy future.** *Current opinion in chemical biology*
  Kanan, M. W.
  2017; 41: A1-A2
- **Selective increase in CO2 electroreduction activity at grain-boundary surface terminations** *SCIENCE*
  Mariano, R. G., McKelvey, K., White, H. S., Kanan, M. W.
  2017; 358 (6367): 1187–91
- **Imaging the Hydrogen Absorption Dynamics of Individual Grains in Polycrystalline Palladium Thin Films in 3D.** *ACS nano*
  Yau, A., Harder, R. J., Kanan, M. W., Ulvestad, A.
  2017
- **Bragg coherent diffractive imaging of single-grain defect dynamics in polycrystalline films** *SCIENCE*
  Yau, A., Cha, W., Kanan, M. W., Stephenson, G. B., Ulvestad, A.
  2017; 356 (6339): 739-?
- **.** *Chemical science*
  Beh, E. S., Basun, S. A., Feng, X., Idehenre, I. U., Evans, D. R., Kanan, M. W.
  2017; 8 (4): 2790-2794

- **Electrostatic Control of Regioselectivity in Au(I)-Catalyzed Hydroarylation** *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY*
  Lau, V. M., Pfalzgraff, W. C., Markland, T. E., Kanan, M. W.
  2017; 139 (11): 4035-4041
- **Molecular catalysis at polarized interfaces created by ferroelectric BaTiO3** *CHEMICAL SCIENCE*
  Beh, E. S., Basun, S. A., Feng, X., Idehenre, I. U., Evans, D. R., Kanan, M. W.
  2017; 8 (4): 2790-2794
- **A Direct Grain-Boundary-Activity Correlation for CO Electroreduction on Cu Nanoparticles.** *ACS central science*
  Feng, X., Jiang, K., Fan, S., Kanan, M. W.
  2016; 2 (3): 169-174
- **Carbon dioxide utilization via carbonate-promoted C-H carboxylation.** *Nature*
  Banerjee, A., Dick, G. R., Yoshino, T., Kanan, M. W.
  2016; 531 (7593): 215-219
- **Probing the Active Surface Sites for CO Reduction on Oxide-Derived Copper Electrocatalysts** *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY*
  Verdaguer-Casadevall, A., Li, C. W., Johansson, T. P., Scott, S. B., McKeown, J. T., Kumar, M., Stephens, I. E., Kanan, M. W., Chorkendorff, I.
  2015; 137 (31): 9808-9811
- **Correction: Electrostatic control of regioselectivity via ion pairing in a Au(i)-catalyzed rearrangement.** *Chemical science*
  Lau, V. M., Gorin, C. F., Kanan, M. W.
  2015; 6 (5): 3268
- **Pd-catalyzed electrohydrogenation of carbon dioxide to formate: high mass activity at low overpotential and identification of the deactivation pathway.** *Journal of the American Chemical Society*
  Min, X., Kanan, M. W.
  2015; 137 (14): 4701-4708
- **Grain-Boundary-Dependent CO2 Electroreduction Activity.** *Journal of the American Chemical Society*
  Feng, X., Jiang, K., Fan, S., Kanan, M. W.
  2015; 137 (14): 4606-4609
- **Controlling H+ vs CO2 Reduction Selectivity on Pb Electrodes** *ACS CATALYSIS*
  Lee, C. H., Kanan, M. W.
  2015; 5 (1): 465-469
- **Alkaline O2 reduction on oxide-derived Au: high activity and $4e^-$ selectivity without (100) facets.** *Physical chemistry chemical physics*
  Min, X., Chen, Y., Kanan, M. W.
  2014; 16 (27): 13601-13604
- **Electroreduction of carbon monoxide to liquid fuel on oxide-derived nanocrystalline copper** *NATURE*
  Li, C. W., Ciston, J., Kanan, M. W.
  2014; 508 (7497): 504-?
- **Alkaline O-2 reduction on oxide-derived Au: high activity and 4e(-) selectivity without (100) facets** *PHYSICAL CHEMISTRY CHEMICAL PHYSICS*
  Min, X., Chen, Y., Kanan, M. W.
  2014; 16 (27): 13601-13604
- **Electrostatic control of regioselectivity via ion pairing in a Au(I)-catalyzed rearrangement** *CHEMICAL SCIENCE*
  Lau, V. M., Gorin, C. F., Kanan, M. W.
  2014; 5 (12): 4975-4979
- **Interfacial electric field effects on a carbene reaction catalyzed by rh porphyrins.** *Journal of the American Chemical Society*
  Gorin, C. F., Beh, E. S., Bui, Q. M., Dick, G. R., Kanan, M. W.
  2013; 135 (30): 11257-11265
- **Aqueous CO2 Reduction at Very Low Overpotential on Oxide-Derived Au Nanoparticles** *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY*
  Chen, Y., Li, C. W., Kanan, M. W.
  2012; 134 (49): 19969-19972

- **CO2 Reduction at Low Overpotential on Cu Electrodes Resulting from the Reduction of Thick Cu2O Films** *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY*
  Li, C. W., Kanan, M. W.
  2012; 134 (17): 7231-7234
- **Tin Oxide Dependence of the CO2 Reduction Efficiency on Tin Electrodes and Enhanced Activity for Tin/Tin Oxide Thin-Film Catalysts** *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY*
  Chen, Y., Kanan, M. W.
  2012; 134 (4): 1986-1989
- **An Electric Field-Induced Change in the Selectivity of a Metal Oxide-Catalyzed Epoxide Rearrangement** *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY*
  Gorin, C. F., Beh, E. S., Kanan, M. W.
  2012; 134 (1): 186-189

PRESENTATIONS

- News article: Stanford scientists make renewable plastic from carbon dioxide and plants - Bio-based News (March 15, 2016)
- News article: Scientists discover a novel way to make ethanol without corn or other plants - Phys.org (April 9, 2014)