CANAN KARAKAYA

Research Asst. Prof.
Colorado School of Mines, Mechanical Engineering Department
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RESEARCH INTEREST

Fuel conversion technologies, process intensification, gas-to-liquid (GTL) processes, heterogeneous catalysis, catalytic reactors, catalytic membrane reactors, gas-separation membranes (hydrogen and oxygen membranes), micro kinetic modeling, reaction engineering, catalytic combustion, methane reforming, , chemical kinetics, catalyst design, deactivation, coke formation, reactor design, alternative reactor designs, modeling and simulation of reactive flow, supercritical flow, catalyst, chemical vapor deposition, thermodynamic analysis, reaction network design

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Specific catalytic or gas-phase chemistries which I have developed processes for:

- Natural gas reforming (steam reforming, dry reforming or partial oxidation)—syngas synthesis
- Methane dehydroaromatization—Direct conversion of methane to benzene
- Oxidative coupling of methane: Methane to ethylene process
- CO_2 utilization: ---CO_2 hydrogenation to olefins
  ---Oxidative dehydrogenation of low value alkanes using CO2 (ethane, propane) to high value olefins.
- Catalytic membrane process: Hydrogen or Oxygen membrane enhanced catalytic processes

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EDUCATION

Doctor of Philosophy: Chemical Technologies, Karlsruhe Institute of Technology, Chemistry and Biosciences, December 2012, Karlsruhe, Germany
Thesis: A novel, hierarchically developed surface kinetics for oxidation and reforming of methane and propane over Rh/Al_2O_3
Advisor: Prof. Olaf. Deutschmann

Master of Science: Institute of Natural and Applied Sciences, Chemical Engineering Department, Kocaeli University, July 2008
Thesis: Investigation of methane catalytic activity and modeling of kinetic constants on $La_{(1-x)}Ag_xB_{(1-y)}B_yO_{3\pm\delta}$ type perovskite catalysts.
Area of study: Process control and reactor design
Advisor: Prof. Nesrin E. Machin

Bachelor of Science: Chemical Engineering Department, Kocaeli University, June 2003

Graduation recognition: 1st in the chemical engineering program (out of 120), 2nd in the engineering program (out of 1500)

PROFFESIONAL EXPERIENCE

Research Asst. Prof. Mechanical Engineering, Colorado school of Mines, Golden, Colorado, since 1/1/2016

Post-doctoral Fellow: Mechanical Engineering, Colorado school of Mines, Golden, Colorado, 2/1/2013-1/1/2016

Research Assistant: Chemical Technologies, Karlsruhe Institute of Technology, Karlsruhe, Germany, 10/27/2008-12/31/2012

Research and Teaching Assistant: Chemical Engineering Dep., Kocaeli University, Kocaeli, Turkey, 12/1/2005-7/1/2008

Research and Development Analyst: Sandoz Pharmaceutical Company, Turkey, 9/1/2003-9/1/2005

Researcher (part time) Pulver Kimya San. Tic. A.S., 7/1/2000-7/1/2003, Leader of the designing high temperature resistant powder coating designing team.

AWARDS

Best poster award: 44. Jahrestreffen Deutscher Katalytiker, Weimar/Germany (2011)

PATENTS

Karakaya C., Bifunctional catalysts and systems and methods for oxidative dehydrogenation of alkanes to olefins and high-value products, patent disclosure submitted in March 2020

RESEARCH GRANTS

CoorsTEK fellowship: (**co-PI**): Dynamic modeling of methane dehydroaromatization (MDA) in packed beds: Understanding coking behavior, 10/1/2014-10/1/2016, Budget $170,000

Industry contract: **Precision Combustion Inc.** , **(PI):** Catalytic chemistry models for the oxidative coupling of methane (OCM) on M-Na-W/SiO_2-based catalysts, 02/01/16-07/31/16, Budget:$31,844

Industry contract: **Solid State Energy Group**, (**PI**): Design and development support for membrane-enhanced ethanol reformer technology, 09/01/2016-08/31/2017, Budget: $148,528

Industry contract: **Global Power Technologies Group (PI)**: Predictive modeling of a chemical vapor deposition (CVD) process for the epitaxial growth of nitrogen-doped silicon carbide" 6/1/2017-6/1/2018: Budget: $60,000

Industry contract: **Precision Combustion Inc**. , **(PI):** Catalytic chemistry models for the oxidative coupling of methane (OCM) on M-Na-W/SiO_2-based catalysts, Phase II 10/25/17-4/9/19, Budget:$ 79.604.00,

Industry contract: **Global Power Technologies Group (PI)**: Modeling of an inlet manifold for non-premixed predictive modeling of a chemical vapor deposition (CVD) process for the

epitaxial growth of nitrogen-doped silicon carbide" 9/1/2018-8/31/2019: Budget: $65,000

II-VI foundation: Kinetics of Nitrogen Doping in Epitaxial Silicon-Carbide Chemical Vapor Deposition,$190,000 submitted 9/9/2018

Research Scholarship: KIT of the DFG Collaborative Research Centre (SFB/TRR150) "Reactive utilization of CO_2 to form olefins" $30000 October 1st 2019-January 31st 2020

PUBLICATIONS

Journal Articles

1. Zhu H., Coors W.G., Ricote S., Karakaya C., Kee R.J." Self-contained electrochemical process to produce pure compressed hydrogen from hydrocarbons and steam without an external energy supply", J. Electrochemical Society, *accepted*
2. Zhang, Z., Karakaya C., Kee R.J., Way J.D., Wolden C.A., "Barium-Promoted Ruthenium Catalysts on Yittria-Stabilized Zirconia Supports for Ammonia Synthesis', ACS Sustainable Chemistry & Engineering, 7, 18038-18047, 2019
3. Zhu H., Kee, B., Karakaya C., O'Hayre B., Kee R.J., "Equilibrium thermodynamic predictions of coking propensity in membrane-based dehydrogenation of hydrocarbons and alcohols," Catal. Today, Catal. Today 331, 7-11 (2019).
4. Jennings, D., Karakaya C.,Zhu H., Duan. C., Reimanis I., O'Hayre R., Kee R.J., "Support effect of BZY/Ni catalysis on support on the methane reforming chemistry", *Catal. Letters*.. 148 (12), 3592-3607, (2018).
5. Weddle, P.J., Karakaya C., Zhu H., Sivaramakrishnan R., Prozument K., Kee R.J., "Boundary layer model to predict chemically reacting flow within heated high-speed microtubular reactors", Combust. Flame, 189,1-11 (2018).
6. Duan C., Zhu H., Karakaya C., Ricote S., Kee R.J., O'Hayre R., "Highly durable, coking and sulfur tolerant, fuel-flexible protonic ceramic fuel cells" *Nature* ,557, 217-222. (2018).
7. Karakaya C., Zhu H., Weissman J.G., Loebick C., Kee R.J., "A detailed reaction mechanism for oxidative coupling of methane over $Mn/Na_2WO_4/SiO_2$ catalyst for non-isothermal conditions", *ChemCatChem,* 312, 10-22 (2018).
8. Kogekar G., Karakaya C., Liskovich G.J., Oehlschlaeger M.A., DeCaluwe S.C., Kee R.J., "Impact of non-ideal behavior on ignition delay and chemical kinetics in high-pressure shock tube reactors," Combust. Flame., 189,1-11 (2017).
9. Karakaya C., Zhu H., Zhour B.., Senkan S., Kee R.J., "Detailed Reaction Mechanisms for Oxidative Coupling of Methane over La_2O_3-CeO_2 Catalysts, *ChemCatChem*, 9, 4538-4551 (2017)
10. Moyer M.M., Karakaya C., Kee R.J., Trewyn B.G., "In-situ formation of metal carbide catalysts,", *ChemCatChem*, 9, 3090-3101, (2017). **invited mini review**

11. Kee B., Karakaya C., Zhu H., DeCaluwe S., Kee R.J., "The influence of hydrogen-permeable membranes and pressure on methane dehydroaromatization in packed-bed catalytic reactors" *Ind. Eng. Chem. Res*., 56, 3551-3559 (2017).
12. Karakaya C., Karadeniz H., Maier L., Deutschmann O., "Surface reaction kinetics of the oxidation and reforming of propane over Rh/Al_2O_3 catalysts," *ChemCatChem*, 9, 685-695, (2017).
13. R.J. Kee, C. Karakaya, H. Zhu "Process intensification in the catalytic conversion of natural gas to fuels and chemicals," *Proc. Combust. Inst*., 36,51-76 (2017). **(Review article)**
14. Karakaya C., Morejudo S., Zhu H., Kee R.J., "Catalytic chemistry for methane dehydroaromatization (MDA) on a bifunctional Mo/HZSM-5 catalyst in a packed bed", *Ind. Eng. Chem. Res*., 55, 9895−9906 (2016).
15. Karakaya C., Kee R.J., "Progress in the direct catalytic conversion of methane to fuels and chemicals," *Prog. Energy Combust. Sci*, 55,60-97 (2016). **(Review article)**
16. Blasi J.M., Weddle P.J., Karakaya C., Diercks D.R., Kee R.J., "Modeling reaction-diffusion processes within catalyst waschcoats: II. Macroscale processes informed by microscale simulations," *Chem. Eng. Sci*., 145,308-316 (2016).
17. Karakaya C., Weddle P.J., Blasi J.M., Diercks D.R., Kee R.J., "Modeling reaction-diffusion processes within catalyst waschcoats: I. Microscale process based on three-dimensional reconstruction," *Chem. Eng. Sci*., 145,299-307 (2016).
18. Karakaya C., Maier L., Deutschmann O., "Surface Reaction Kinetics of the Oxidation and Reforming of CH4 over Rh/Al_2O_3 Catalysts", *Int. J. Chem. Kin.*, 48,144-160 (2016).
19. Karakaya C., Ricote S., Albin D., Sanchez-Cortezon E., Linares-Zea B., Kee R.J., "Thermogravimetric analysis of $InCl_3$ sublimation at atmospheric pressure" *Thermochimica Acta,* 622,55-63 (2015).
20. Karadeniz H., Karakaya C., Tischer S., Deutschmann O., "Mass transfer effects in stagnation flows on a porous catalyst: water-gas-shift reaction over Rh/Al_2O_3", *Z. Phys. Chem.,* 229, 709-737 (2015).
21. Karakaya C., Zhu H., Kee R.J., Kinetic modeling of methane dehydroaromatization chemistry on Mo/zeolite catalysts in packed-bed reactors", *Chem. Eng. Sci*, 123, 474-486 (2015).
22. Karakaya C., Otterstätter R., Maier L., Deutschmann O., "Kinetics of the water-gas shift reaction on Rh/Al_2O_3 catalysts", *Appl. Catal.* A: General, 470, 31-44 (2014).
23. Karadeniz H., Karakaya C., Tischer S., Deutschmann O., "Numerical modeling of stagnation-flows on porous catalytic surfaces: CO oxidation on Rh/Al_2O_3, *Chem. Eng. Sci*, 104, 899-907 (2013).

24. Karakaya C., Deutschmann O.,"Kinetics of hydrogen oxidation on Rh/Al_2O_3 catalysts studied in a stagnation-flow reactor, *Chem. Eng. Sci.*, 89, 171-184 (2013).
25. Bär J.N., Karakaya C., Deutschmann O., "Catalytic ignition of light hydrocarbons over $Rh/A1_2O_3$ studied in a stagnation-point flow reactor," *Proc. Combust. Inst*. *(34th)*, 2313-2320 (2013).
26. Karakaya C., Deutschmann O., "A simple method for CO chemisorption studies under continuous-flow: Adsorption and desorption behavior of Pt/Al2O3 catalysts", *Applied Catalysis A*, 445, 221-230 (2012).
27. Celepci A., Karakaya C., Machin N., "Catalytic Combustion of Methane on La, Ce, Co Based Mixed Oxides", *Energy &Fuels*, 22 (4), 2166–2171 (2008).

BOOK CHAPTERS

Diehm C., Karadeniz H., Karakaya C., Hettel M., Deutschmann O., "Spatial resolution of species and temperature profiles in catalytic reactors: In situ sampling techniques and CFD modeling", Advances in Chemical Engineering: Modeling and simulation of heterogeneous catalytic processes, Volume 45, 41-95 Academic Press, 2014.

Manuscripts in progress

1. Cadigan C., Karakaya C., O'Hayre R., Sullivan N., Broun R., Kee R.J., "A high throughput ammonia synthesis catalyst", in preparation.
2. Kogekar G., Karakaya C.,Decaluwe S.D., Kee R.J., " Modeling supercritical Fischer-Tropsch reactions using Redlich-Kwong non-ideal gas model, in preparation.
3. Karadeniz H., Karakaya C., Tischer S., Deutschmann O., "Impact of internal diffusion on methane reforming over a porous Rh/Al2O3 catalysts in stagnation flows", *Int. J. Hydrogen Energy,* **ready to submit**

ORAL PRESENTATIONS

1. Karakaya C., Jackson G.S., Kee R.J., "Opportunities for Electrochemical and Catalytic Processes That Support Human Activity on Mars", 236th ECS Meeting, October 13-17, 2019, Atlanta, USA
2. Lin Y., Kogekar G., Karakaya C., Zhu H., Kee R.J., "Partial oxidation of methane within an opposed flow reactor with an embedded catalyst mesh" 11th U.S. National Combustion Meeting, March 24-25, 2019, Pasadena, California, US.
3. Jennings D., Karakaya C., Reimanis I., "Surface and interface studies of Ni doped BZY for catalyst applications, Solid State Ionics (SSI-22), June 16-21, 2019, PyeongChang, Korea.
4. Braun R.J., Duan C., Karakaya C., Zhu L., Sullivan N., Tang E., Pastula M., O'Hayre R.,

"Development of kW-scale protonic ceramic fuel cells and systems", International Electrochemistry Society Meeting-SOFC XVI, September 9, 2019, Kyoto, Japan

5. Sullivan N.P., Zhu L., , Duan C., O'Hayre R.P., Karakaya C., , Kee R.J., Pisciotta M., Le L.Q., Herradon Hernandez C., Butler M., Jahnke F., Ghezel-Ayagh H., "Energy storage through electrochemical ammonia synthesis using proton-conducting ceramics", Ammonia Energy Conference, November 13-14, 2019, Florida, USA
6. Ricote S., Kee B.L., Curran D.J., Karakaya C., Jarry A., Crumlin E., Kee R.J., "Membrane reactors based on proton-conducting ceramics" 19th Solid State Protonic Conductors, September 16-21, 2018 Stowe, Vermont USA.
7. Kee B., Karakaya C., Kee R.J., "Integration of catalytic ethanol reforming and hydrogen separation using protonic-ceramic membranes" 13th International conference on catalysis in membrane reactors, Houston, TX, July 10-13, 2017
8. Kee R.J., Karakaya C., Zhu H., "Opportunities for ceramic ion-transport membranes in process intensified catalytic reactors," 13th International conference on catalysis in membrane reactors, Houston, TX, July 10-13, 2017 **(invited lecture).**
9. Zhu H., Karakaya C., Jackson G.S., Euser B., Berger J., Kee R.J., "Modeling charged-defect transport within the calcium doped lanthanum ferrite oxide-ion transport membranes," 232nd Electrochemical Society Meeting, Honolulu, HI, October 2-7 2016 (**Invited Lecture**)
10. Kee R.J., Karakaya C., Zhu H., "Catalytic processes for the conversion of natural gas to logistic fuels and chemicals", 36th International symposium on combustion, Seoul South Korea, 31 July-5 August 2016. **(Plenary Lecture)**
11. Kee B.L., Karakaya C., Zhu H., "Modeling methane dehydroaromatization in catalytic packed-bed membrane reactors," 249th ACS National Meeting&Exposition, Denver, CO, USA, 22-26 March 2015.
12. Karakaya C., Zhu H., R.J. Kee, "Kinetic modeling of methane dehydroaromatization chemistry on Mo/zeolite catalysts in packed-bed reactors," 249th ACS National Meeting&Exposition, Denver, CO, USA, 22-26 March 2015.
13. Maier Lubow, Herrera Delgado,K., Kahle, L., Karakaya, C.,Deutschmann.O., Surface reaction kinetics of steam- and CO2-reforming as well as oxidation of methane over Ni, Rh, Pt- based catalysts, International Conference on Chemical Kinetics, June 28 – July 2, 2015, Ghent, Belgium.
14. Karakaya C., Zhu H., R.J. Kee, "Kinetic modeling of methane dehydroaromatization chemistry on Mo/zeolite catalysts in packed-bed reactors", 249th ACS National Meeting&Exposition, Denver, CO, USA, 22-26 March 2015.
15. Karadeniz H., Karakaya C., Tisher S., Deutschmann O., Coupling of Chemistry And External And Internal Mass Transfer In A Stagnation-Flow Reactor: A Modeling Study, 44th World Chemistry Congress, 11-16 August 2013, Istanbul, Turkey.
16. Baer J., Karakaya C., Deutschmann O., Catalytic ignition of light hydrocarbons over Rh/Al2O3 studied in a stagnation point flow reactor" 34th International symposium on combustion, Warsaw Poland, 29 July-3 August 2012.

17. Karakaya C., Maier, L., Deutschmann O., "A Hierarchically Developed Surface Reaction Kinetics for Oxidation of H_2, CO, and CH_4, WGS as well as Steam and Dry Reforming of Methane over Rh/Al_2O_3", 23rd North American Catalysis Society Meeting- NAM Louisville, Kentucky, USA, , 2. - 7. June 2013.
18. Karakaya C., Maier L., Deutschmann O., McGuire N.E., Sullivan N.P., Kee R.J., "Development of a unified surface reaction mechanism on Rh surfaces for reforming of C1-C3 species", 22. International Symposium on Chemical Reaction Engineering (22nd ISCRE), Maastricht , September 2-5, 2012.
19. Karakaya C., Maier L., Deutschmann O., McGuire N.E., Sullivan N.P., Kee R.J., "Oxidation and reforming of light hydrocarbons over Rh/Al_2O_3 catalyst studied in a stagnation-flow reactor", 15th International Congress on Catalysis (15th ICC), Munich, 1-6 July, 2012.
20. Karakaya C., Maier L., Deutschmann O., McGuire N.E., Sullivan N.P., Kee R.J., "Oxidation and reforming of light hydrocarbons over Rh/Al_2O_3 catalysts: a fundamental study using a stagnation-flow reactor", (8th ECCE), Berlin 25-29 September, 2012.

EXTENDED ABSTRACTS, DEMONSTRATIONS OR POSTERS

1. Karakaya C., Deutschmann O., Kee R.J., " Reactive utilization of CO2for oxidative dehyrogenation of alkanes to produce olefins", 10. ProcessNet-Jahrestagung und 34. DECHEMA-Jahrestagung der Biotechnologen 2020, September 20-23, 2020, Karlsruhe, Germany.
2. Karakaya C., Zhu H., Weissman J.G., Loebick C., Kee R.J., "Detailed Reaction Mechanism for Oxidative Coupling of Methane in Non-Isothermal Conditions", 25th North American Catalysis Society Meeting, Denver, CO, June 4-9, 2017.
3. Karakaya C., Zhu H., Weissman J.G., Loebick C., Kee R.J., "Detailed Reaction Mechanisms for Oxidative Coupling of Methane over La_2O_3-CeO_2 Catalysts Under Non-Isothermal Conditions", 25th North American Catalysis Society Meeting, Denver, CO, June 4-9, 2017.
4. Bär J.N., Karakaya C., Deutschmann O., Catalytic ignition of light hydrocarbons over Rh/Al2O3 studied in a stagnation point flow reactor, 45. Jahrestreffen Deutscher Katalytiker, Weimar / Germany, 14-16 March, 2012.
5. Karakaya C., Maier L., Deutschmann O., McGuire N.E., Sullivan N.P., Kee R.J., "Oxidation and reforming of light hydrocarbons over Rh/Al_2O_3 catalyst by using a stagnation-flow reactor", 45. Jahrestreffen Deutscher Katalytiker, Weimar / Germany, 14-16 March, 2012.
6. Karakaya C., Deutschmann O., "A simple method to measure the active catalytic surface area: CO Chemisorption TPD studies, International Symposium on Modeling of Exhaust-Gas After-Treatment", (MODEGAT II), Bad Herrenalb / Germany 19-20 September, 2011.

7. Karakaya C., Deutschmann O., Catalytic Oxidation of CO over Rh/Al_2O_3 and Ni/Al_2O_3 Catalysts in a Stagnation-Flow Reactor, ***poster winner***, 44. Jahrestreffen Deutscher Katalytiker, Weimar/Germany, 16-18 March, 2011.
8. Celepci A., Karakaya C., Kayan A., Machin N.E., "Catalytic combustion of methane over LaxCeyCo(2-x-y)O3 perovskite catalysts", European Combustion Meeting ECM 2007, Crete, Greece 11-13 April 2007.
9. Machin N.E., Karakaya C., Ozer E.E., "Catalytic combustion of methane on silver added perovskite-like mixed oxides", 7th International Workshop on Catalytic Combustion (IWCC7), Lake Zurich, Switzerland, September 29 – October 1, 2008.

TEACHING EXPERIENCE

Teaching Assistant, Kocaeli University, TURKEY

Heat transfer (MKM 325), (2003-2005)
Chemical kinetics and reactor design (MKM326) (2003-2005)
Numerical analysis (MKM 323) (2003-2005)
Physical Chemistry Lab.(MKM219) (2003-2005)
Chemical Engineering Lab. (MKM423) (2003-2005)

Colorado School of Mines
Thermal Fluids Graduate Seminar, Fall 2017

MENTORING EXPERIENCE

Recruited, supervised and worked together with students who conducted research at Kocaeli University, Karlsruhe Institute of Technology and Colorado School of Mines.

Kazim Sevimli : BS Chemical Engineering, Kocaeli University, Turkey
Sebnem Kemaloglu: BS Chemical Engineering, Kocaeli University, Turkey
Zerrin Yarbay : BS Chemical Engineering, Kocaeli University, Turkey
Zeynep Dizdar: BS Chemical Engineering, Kocaeli University, Turkey

Julian N. Baer: Master of Science, Chemical Technologies: (**Supervisor),** Karlsruhe Institute of Technology, Germany
Thesis: "Investigation of oxidation and partial oxidation of hydrogen, carbon monoxide, low carbon containing hydrocarbons over rhodium catalyst using stagnation flow reactor, Untersuchung zur Oxidation und Partialoxidation von Wasserstoff, Kohlenstoffmonoxid und niederen Kohlenwasserstoffen an einem mit Rhodium beschichteten Katalysator in einer Staupunktströmung", October 2011.

Brandon Carson Blakeley: Master of Science, Mechanical Engineering **(advisory board),** Colorado School of Mines, February 2014-May 2015

Thesis: Autothermal reforming of methane in a microchannel ceramic reactor

Benjamin L. Kee: Master of Science, Mechanical Engineering **(co-advisor),** Colorado School of Mines, August 2014-May 2016
***Thesis*:** Modeling methane dehydroaromatization in catalytic packed-bed membrane reactors.

Megan Otting: Doctor of philosophy, Chemistry **(co-advisor),** Colorado School of Mines, since October 2014
Thesis: Dynamic modeling of methane dehydroaromatization (MDA) in packed beds: Understanding coking behavior.

PROFESSIONAL ACTIVITIES

Professional Affiliations

Combustion Institute
American Chemical Society

Manuscript and Conference Reviews

Chemical Engineering Journal
Chemical Engineering Science
Industrial Engineering and Chemistry Research
International Journal of Hydrogen Energy
International Journal of Chemical Reactor Engineering
Journal of Natural Gas Science & Engineering
Emission Control Science & Technology
International Journal of Chemical Kinetics
25th North American Catalysis Society Meeting
CatChemCat, Wiley
Proceedings of Combustion Institute
Progress in Energy and Combustion Science
Industrial & Engineering Chemistry Research
Journal of Material Science
