

## **Christopher M. Boyce**

Assistant Professor

Columbia University

Department of Chemical Engineering

Email: [cmb2302@columbia.edu](mailto:cmb2302@columbia.edu)

### **EDUCATION**

#### **University of Cambridge, Trinity College, Cambridge UK**

Ph.D. Chemical Engineering, 2015

Advisor: Prof. John Dennis

Faculty Collaborators: Profs. John Davidson, Lynn Gladden; Drs. Daniel Holland, Stuart Scott

Honors:

- Danckwerts-Pergamon Prize for the best PhD thesis related to chemical engineering, 2015
- Gates Cambridge Scholar (2011-2014)

#### **Massachusetts Institute of Technology, Cambridge, MA**

B.S. 2011

Majors: Chemical Engineering and Physics

Minor: Nuclear Science and Engineering

Honors:

- Phi Beta Kappa Academic Honor Society
- Tau Beta Pi Engineering Honor Society
- Sigma Pi Sigma Physics Honor Society

### **RESEARCH EXPERIENCE**

#### **Columbia University**

Assistant Professor, January 2018-Present

Department of Chemical Engineering

Description: My research group aims to uncover and characterize hydrodynamic instabilities and other flow phenomena in multiphase and granular flows. Such discovery can be used to introduce structure into multiphase granular flows to ultimately enable efficient scale-up and control of industrial processes. We seek to connect these flow dynamics with heat and mass transport and chemical reactions to generate a deeper understanding of the coupled multi-physics in a variety of complex systems. We look to apply this knowledge gained to problems in geophysics as well as to optimize processes and engineer new technologies in the health, energy and construction sectors, such as in pharmaceutical production, carbon capture, solar thermal energy generation and cement mixing. Our research is enabled by the development and utilization of novel optical and magnetic resonance imaging as well as physics-based, multi-scale computational modeling.

#### **ETH Zürich**

Postdoctoral Researcher, January 2017-December 2017

Department of Mechanical and Process Engineering

Advisor: Prof. Christoph Müller

Description: My second postdoctoral work focused on using ultrafast MRI as a means to visualize flow and chemical reactions in opaque multiphase flow systems in a quantitative and spatially resolved manner.

**Princeton University**

Postdoctoral Associate, January 2015 – December 2016

Department of Chemical and Biological Engineering

Advisor: Prof. Sankaran Sundaresan

Description: My first postdoctoral work focused on the physics of fluid-particle flows influenced by interparticle forces, such as cohesive liquid bridging and electrostatic forces. Non-dimensional characterization of these flows was achieved by developing and utilizing computational models which captured the multiphysics in an efficient manner.

**University of Cambridge**

Ph.D. Candidate, October 2011 – December 2014

Department of Chemical Engineering and Biotechnology

Advisor: Prof. John Dennis

Dissertation: *Fundamental Studies of the Physics of Gas-Solid Fluidization*

Description: My doctoral research focused on the hydrodynamics of fluidized beds by developing and validating experimental and computational techniques to reveal new insights into the physics of these multiphase flows. Experiments focused on development and use of magnetic resonance imaging to visualize the physics of particle and gas flow under bubbling fluidization conditions. Computational work focused on developing and validating a 3D cylindrical Euler-Lagrange model of fluidized beds and utilizing the model to uncover fundamental aspects of the physics of fluidization, including the origin of pressure oscillations in bubbling fluidized beds.

**Stanford University**

Research Collaboration as Co-Founder and Engineer for Infinite Corridor Technology, LLC  
August, 2008 – March 2013

Department of Mechanical Engineering

Stanford Collaborators: Prof. Beth Pruitt and Dr. Rebecca Taylor

Description: My research designed a stretchable micro-electrode using the patterned substrate technology that I invented and developed for making circuit boards stretchable and applied this technology to a Stanford project on electro-mechanical stimulation of heart cells.

**Massachusetts Institute of Technology**

Undergraduate Researcher, June 2009 – December 2010

Department of Chemical Engineering

Advisor: Prof. Karen Gleason

Graduate Student: Dr. Miles Barr

Description: My research used chemical vapor deposition to deposit organic electrodes necessary to create solar cells on arbitrary materials. It helped to launch the solar energy company Ubiquitous Energy.

**RESEARCH ADVISING EXPERIENCE****Columbia University**

*Postdoctoral Researchers*

Wasif Zia

2020-Present

Qiang Guo

2019-Present

*PhD Students*

Alireza Bordbar	<i>MRI of Multiphase Flow Dynamics</i>	2020-Present
Jagan Mohan Sanghishetty	<i>Rheological Behavior of Fluidized Particles</i>	2019-Present
Azin Padash	<i>Bubble Dynamics in Complex Fluids</i>	2018-Present

*MS Students*

Shaohan Xu		2019
Yijin Li		2019
Kai Yang		2018-2019
Zhongsheng Sang		2018
Nick Mutsakis		2018
Tom Kovar		2018-2020

*Undergraduates*

Yuxuan Zhang		2020-Present
Boyuan Chen		2019-Present
Carolina Vazquez		2019-Present
Sean Kim		2019-2020

*High School Students*

Yamin Titikpina		2021
Brios Olivares		
Mitchel James		2020
Silvester Nava		2020
Chloe Levison		2019
El-Hassan Salem		2019

*Visiting Students*

Marianna Beard	Undergraduate from Tuskegee University	2021
Albany Hornbuckle	Undergraduate from Tuskegee University	2021
Amana Mohiuddin	Undergraduate from Barnard College	2021
Kenan Xi	PhD Student from Xi'an Jiaotong University	2020
Fabio Nierhoff	Undergraduate from U. of Minnesota	2020

**ETH Zürich**

Advisor, Master's Thesis Project, November 2017 – Present

- Supervised Master's student research project studying the Rayleigh-Taylor instability in dense suspensions using optical imaging and computational modeling

Advisor, Bachelor's Thesis Project, September 2017 – Present

- Supervised undergraduate student research project studying granular fingering

Advisor, Master's Thesis Project, June 2017 – Present

- Supervised Master's student research project building a system for controlled injection of single or multiple gas bubbles into a fluidized bed for study of bubble shape, motion and coalescence using ultrafast MRI

**University of Cambridge**

Co-Supervisor, MPhil Research Project, March 2014 – August 2014

- Supervised Master's student research project using MRI to measure gas flow patterns in the freeboard of fluidized beds and compare against existing theories and computational models. Assisted student in learning MRI, compressed gas circulation and computational modelling techniques prior to his PhD studies in the field in October 2014

Co-Supervisor, MPhil Research Project, March 2013 – August 2013

- Supervised Master’s student research project comparing X-ray, MRI and PEPT imaging techniques of fluidized beds; provided input on how to properly analyze and compare data. Research project led to publication of an article in *Chemical Engineering Science*

## **TEACHING EXPERIENCE**

### **Columbia University**

Assistant Professor, Department of Chemical Engineering, January 2018-Present

- Developed a summer undergraduate and graduate course Applications of Multiphase Flows to Environmental Technologies with Prof. Park (2020)
- Developed and instructed a graduate elective course in Computational Fluid Dynamics (2018-Present)
- Instructor for undergraduate course Transport Phenomena I, focusing on fluid mechanics (2018-Present)

### **University of Cambridge**

Supervisor, Heterogeneous Reactors Course, January 2013 – April 2014

- Supervised 3<sup>rd</sup> year undergraduates in groups of 2 or 3 for one-hour-long sessions going over practice problems and core concepts for advanced chemical reaction engineering course

## **PROFESSIONAL SERVICE**

- Journal Paper Reviewer:
  - PNAS
  - Science Advances
  - PLoS ONE
  - AIChE Journal
  - Chemical Engineering Science
  - Industrial and Engineering Chemistry Research
  - Chemical Engineering Research and Design
  - Journal of Fluid Mechanics
  - Physical Review Fluids
  - Physics of Fluids
  - International Journal of Multiphase Flow
  - Powder Technology
- PhD Thesis Examiner:
  - ETH Zürich, Chen Yong, “Lattice Boltzmann simulations of fluid-solid momentum and heat transfer in gas solid flows comprising cubic particles”, 2017
  - Columbia University, Jack Davis, “Membraneless Electrolyzers for Solar Fuels Production”, 2019
  - Columbia University, Richa Batra, “Particle Robotics: Achieving Deterministic Behaviors through Stochastic Interactions of Loosely Coupled Components”, 2019
- University Service
  - Undergraduate Committee Member, Department of Chemical Engineering, 2018-Present

- Undergraduate Enrollment Committee Member, Department of Chemical Engineering, 2021-Present
- Columbia-Amazon Summer Undergraduate Research Experience (SURE) Program Committee Member, 2021-Present
- Undergraduate Education Reform Committee Member, SEAS, 2019
- Service to Discipline
  - Session Co-Chair, AIChE Annual Meeting, Powder Technology Forum, 2021-Present
  - Session Chair, Fluidization XVI Conference, 2019
- Public Outreach
  - Hosted lab tours for NYC middle school students through Columbia’s Inside Engineering Program, 2019-Present
  - Hosted 2 high school students for laboratory research each summer through Columbia’s Engineering the Next Generation Program, 2019-Present
  - Created research videos published online with thousands of views, including features in *Gizmodo* and *Popular Mechanics*, 2019-Present

## **GRANTS**

### ***Current:***

*Sponsor:* National Science Foundation, Division: CBET PMP

*Title:* Magnetic Resonance Imaging and Modeling of Gas and Particle Flow in Fluidized Beds

*Lead PI:* C.M. Boyce

*Award Period:* 1/1/2021-12/31/2023

*Sponsor:* Columbia University

*Title:* Take a Look Inside – Magnetic Resonance Imaging of Magma Analogues to Study Volcanic Eruptions

*Lead PIs:* C.M. Boyce and E. Lev

*Award Period:* 9/1/2020-8/31/2022

*Sponsor:* Pall Corporation

*Title:* Magnetic Resonance Imaging of Filtration

*Lead PIs:* C.M. Boyce and J. Guo

*Award Period:* 1/1/2020-12/31/2021

*Sponsor:* Columbia University

*Title:* Summer Research Experience in Chemical Engineering at Columbia University for Underrepresented Minority Undergraduates from Tuskegee University: Multiphase Flows

*Lead PI:* C.M. Boyce

*Award Period:* 1/1/2021-12/31/2021

*Sponsor:* Columbia University

*Title:* Sustainable Mining via Novel Separation of Granular Particles

*Lead PIs:* C.M. Boyce, N. Nagaraj, R. Farinato

*Award Period:* 9/1/2021-8/31/2022

## **HONORS AND AWARDS**

- Janette and Armen Avanesians Diversity Award, Columbia University SEAS, 2021

- Columbia Provost’s Grants Program for Junior Faculty who Contribute to the Diversity Goals of the University, 2020
- Sabic Young Professional Award from the AIChE for outstanding contributions to particle technology from an individual under 40, 2019
- Forbes 30 Under 30 in Science, 2019
- Danckwerts-Pergamon Prize for the best PhD thesis related to chemical engineering, University of Cambridge, 2015
- Gates Cambridge Scholar, 2011-2014
- 2<sup>nd</sup> Prize, third year presentation, Department of Chemical Engineering and Biotechnology, University of Cambridge, 2014
- 1<sup>st</sup> Prize, second year poster presentation, Department of Chemical Engineering and Biotechnology, University of Cambridge, 2013
- Phi Beta Kappa Academic Honor Society, MIT, 2011
- Sigma Pi Sigma Physics Honor Society, MIT, 2011
- Tau Beta Pi Engineering Honor Society, MIT, 2010

## **PUBLICATIONS**

- 41) Guo, Q.; Zhang, Y.; Padash, A.; Xi, K.; Kovar, T. M.; Boyce, C. M. Dynamically Structured Bubbling in Vibrated Gas-Fluidized Granular Materials. *Proc. Natl. Acad. Sci.* **2021**, *Accepted*.
- 40) Xi, K.; Guo, Q.; Boyce, C. M. Comparison of CFD-DEM and TFM Simulations of Single Bubble Injection in 3D Gas-Fluidized Beds with MRI Results. *Chem. Eng. Sci.* **2021**, *243*, 116738. [Link](#)
- 39) Xi, K.; Kovar, T.; Fullmer, W. D.; Penn, A.; Musser, J.; Boyce, C. M. CFD-DEM Study of Bubble Properties in a Cylindrical Fluidized Bed of Geldart Group D Particles and Comparison with Prior MRI Data. *Powder Technol.* **2021**, *389*, 75–84. [Link](#)
- 38) Xi, K.; Guo, Q.; Boyce, C. M. Comparison of Two-Fluid Model Simulations of Freely Bubbling Three-Dimensional Gas-Fluidized Beds with Magnetic Resonance Imaging Results. *Ind. Eng. Chem. Res.* **2021**, *60* (19), 7429–7442. [Link](#)
- 37) McLaren, C. P.; Metzger, J. P.; Boyce, C. M.; Müller, C. R. Reduction in Minimum Fluidization Velocity and Minimum Bubbling Velocity in Gas-Solid Fluidized Beds Due to Vibration. *Powder Technol.* **2021**, *382*, 566–572. [Link](#)
- 36) Guo, Q.; Padash, A.; Boyce, C. M. A Two Fluid Modeling Study of Bubble Collapse Due to Bubble Interaction in a Fluidized Bed. *Chem. Eng. Sci.* **2021**, *232*, 116377. [Link](#)
- 35) Lev, E.; Boyce, C. M. Opportunities for Characterizing Geological Flows Using Magnetic Resonance Imaging. *iScience* **2020**, *23* (9). [Link](#)
- 34) Penn, A.; Padash, A.; Lehnert, M.; Pruessmann, K. P.; Müller, C. R.; Boyce, C. M. Asynchronous Bubble Pinch-off Pattern Arising in Fluidized Beds Due to Jet Interaction: A Magnetic Resonance Imaging and Computational Modeling Study. *Phys. Rev. Fluids* **2020**, *5* (9), 094303. [Link](#)
- 33) Padash, A.; Boyce, C. M. Collapse of a Bubble Injected Side-by-Side with Another Bubble into an Incipiently Fluidized Bed: A CFD-DEM Study. *Phys. Rev. Fluids* **2020**, *5* (3), 034304. [Link](#)

- 32) Penn, A.; Boyce, C. M.; Pruessmann, K. P.; Müller, C. R. Regimes of Jetting and Bubbling in a Fluidized Bed Studied Using Real-Time Magnetic Resonance Imaging. *Chem. Eng. J.* **2020**, 123185. [Link](#)
- 31) McLaren, C. P.; Kovar, T. M.; Penn, A.; Müller, C. R.; Boyce, C. M. Gravitational Instabilities in Binary Granular Materials. *Proc. Natl. Acad. Sci.* **2019**, 201820820. [Link](#)
- 30) Boyce, C. M.; Penn, A.; Lehnert, M.; Pruessmann, K. P.; Müller, C. R. Characteristics of a Single Jet Injected into an Incipiently Fluidized Bed: A Magnetic Resonance Imaging Study. *Adv. Powder Technol.* **2019**. [Link](#)
- 29) Boyce, C.M.; Penn, A.; Lehnert, M.; Pruessmann, K.P.; Müller, C. R. Magnetic Resonance Imaging of Interaction and Coalescence of Two Bubbles Injected Consecutively into an Incipiently Fluidized Bed. *Chem. Eng. Sci.* **2019**, 115152. [Link](#)
- 28) Boyce, C. M.; Penn, A.; Padash, A.; Lehnert, M.; Pruessmann, K. P.; Müller, C. R. Anomalous Collapse of Interacting Bubbles in a Fluidized Bed: A Magnetic Resonance Imaging Study. *Phys. Rev. Fluids* **2019**, 4, 034303. [Link](#)
- 27) Boyce, C. M.; Penn, A.; Lehnert, M.; Pruessmann, K. P.; Müller, C. R. Magnetic Resonance Imaging of Single Bubbles Injected into Incipiently Fluidized Beds. *Chem. Eng. Sci.* **2019**, 200, 147–166. [Link](#)
- 26) Boyce, C. M.; Penn, A.; Lehnert, M.; Pruessmann, K. P.; Müller, C. R. Wake Volume of Injected Bubbles in Fluidized Beds: A Magnetic Resonance Imaging Velocimetry Study. *Powder Technol.* **2019**. (Invited). [Link](#)
- 25) Penn, A.; Boyce, C. M.; Conzelmann, N.; Bezinge, G.; Pruessmann, K. P.; Müller, C. R. Real-Time Magnetic Resonance Imaging of Fluidized Beds with Internals. *Chem. Eng. Sci.* **2019**, 198, 117–123 (Cover Article). [Link](#)
- 24) Boyce, C. M.; Penn, A.; Lehnert, M.; Pruessmann, K. P.; Müller, C. R. Effect of Liquid Bridging on Bubbles Injected into a Fluidized Bed: A Magnetic Resonance Imaging Study. *Powder Technol.* **2019**, 343, 813–820. [Link](#)
- 23) Boyce, C. M. Gas-Solid Fluidization with Liquid Bridging: A Review from a Modeling Perspective. *Powder Technol.* **2018**, 336, 12–29. [Link](#)
- 22) Penn, A.; Boyce, C. M.; Kovar, T.; Tsuji, T.; Pruessmann, K. P.; Müller, C. R. Real-Time Magnetic Resonance Imaging of Bubble Behavior and Particle Velocity in Fluidized Beds. *Ind. Eng. Chem. Res.* **2018**, 57 (29), 9674–9682 (Invited). [Link](#)
- 21) Boyce, C. M.; Penn, A.; Pruessmann, K. P.; Müller, C. R. Magnetic Resonance Imaging of Gas–Solid Fluidization with Liquid Bridging. *AIChE J.* **2018**, 64 (8), 2958–2971 (Invited). [Link](#)
- 20) Penn, A.; Tsuji, T.; Brunner, D. O.; Boyce, C. M.; Pruessmann, K. P.; Müller, C. R. Real-Time Probing of Granular Dynamics with Magnetic Resonance. *Science Advances* **2017**, 3 (9), e1701879. [Link](#)
- 19) Kolehmainen, J.; Sippola, P.; Raitanen, O.; Ozel, A.; Boyce, C. M.; Saarenrinne, P.; Sundaresan, S. Effect of Humidity on Triboelectric Charging in a Vertically Vibrated Granular Bed: Experiments and Modeling. *Chem. Eng. Sci.* **2017**, 173, 363–373. [Link](#)

- 18) Boyce, C. M.; Ozel, A.; Kolehmainen, J.; Sundaresan, S.; McKnight, C. A.; Wormsbecker, M. Growth and Breakup of a Wet Agglomerate in a Dry Gas–solid Fluidized Bed. *AIChE J.* **2017**, *63* (7), 2520–2527. [Link](#)
- 17) Boyce, C. M.; Ozel, A.; Kolehmainen, J.; Sundaresan, S. Analysis of the Effect of Small Amounts of Liquid on Gas–Solid Fluidization Using CFD-DEM Simulations. *AIChE J.* **2017**, *63* (12), 5290–5302. [Link](#)
- 16) Boyce, C. M.; Ozel, A.; Rice, N. P.; Rubinstein, G. J.; Holland, D. J.; Sundaresan, S. Effective Particle Diameters for Simulating Fluidization of Non-Spherical Particles: CFD-DEM Models vs. MRI Measurements. *AIChE J.* **2017**, *63* (7), 2555–2568. [Link](#)
- 15) Kolehmainen, J.; Ozel, A.; Boyce, C. M.; Sundaresan, S. Triboelectric Charging of Monodisperse Particles in Fluidized Beds. *AIChE J.* **2017**, *63* (6), 1872–1891. [Link](#)
- 14) Boyce, C. M.; Rice, N. P.; Ozel, A.; Davidson, J. F.; Sederman, A. J.; Gladden, L. F.; Sundaresan, S.; Dennis, J. S.; Holland, D. J. Magnetic Resonance Characterization of Coupled Gas and Particle Dynamics in a Bubbling Fluidized Bed. *Phys. Rev. Fluids* **2016**, *1* (7), 74201. [Link](#)
- 13) Boyce, C. M.; Ozel, A.; Sundaresan, S. Intrusion of a Liquid Droplet into a Powder under Gravity. *Langmuir* **2016**, *32* (34), 8631. [Link](#)
- 12) Kolehmainen, J.; Ozel, A.; Boyce, C. M.; Sundaresan, S. A Hybrid Approach to Computing Electrostatic Forces in Fluidized Beds of Charged Particles. *AIChE J.* **2016**, *62* (7), 2282. [Link](#)
- 11) Boyce, C. M.; Rice, N. P.; Davidson, J. F.; Sederman, A. J.; Dennis, J. S.; Holland, D. J. Magnetic Resonance Imaging of Gas Dynamics in the Freeboard of Fixed Beds and Bubbling Fluidized Beds. *Chem. Eng. Sci.* **2016**, *147*, 13. [Link](#)
- 10) Boyce, C. M.; Rice, N. P.; Sederman, A. J.; Dennis, J. S.; Holland, D. J. 11-Interval PFG Pulse Sequence for Improved Measurement of Fast Velocities of Fluids with High Diffusivity in Systems with Short T2\*. *J. Magn. Reson.* **2016**, *265*, 67. [Link](#)
- 9) Lu, X.; Boyce, C. M.; Scott, S. A.; Dennis, J. S.; Holland, D. J. Investigation of Two-Fluid Models of Fluidisation Using Magnetic Resonance and Discrete Element Simulations. *Procedia Eng.* **2015**, *102*, 1436. [Link](#)
- 8) Boyce, C. M.; Holland, D. J.; Scott, S. A.; Dennis, J. S. Limitations on Fluid Grid Sizing for Using Volume-Averaged Fluid Equations in Discrete Element Models of Fluidized Beds. *Ind. Eng. Chem. Res.* **2015**, *54* (43), 10684. [Link](#)
- 7) Pore, M.; Ong, G. H.; Boyce, C. M.; Materazzi, M.; Gargiuli, J.; Leadbeater, T.; Sederman, A. J.; Dennis, J. S.; Holland, D. J.; Ingram, A.; et al. A Comparison of Magnetic Resonance, X-Ray and Positron Emission Particle Tracking Measurements of a Single Jet of Gas Entering a Bed of Particles. *Chem. Eng. Sci.* **2015**, *122*, 210. [Link](#)
- 6) Boyce, C. M.; Davidson, J. F.; Holland, D. J.; Scott, S. A.; Dennis, J. S. The Origin of Pressure Oscillations in Slugging Fluidized Beds: Comparison of Experimental Results from Magnetic Resonance Imaging with a Discrete Element Model. *Chem. Eng. Sci.* **2014**, *116*, 611. [Link](#)



- 5) Boyce, C. M.; Holland, D. J.; Scott, S. A.; Dennis, J. S. Novel Fluid Grid and Voidage Calculation Techniques for a Discrete Element Model of a 3D Cylindrical Fluidized Bed. *Comput. Chem. Eng.* **2014**, *65*, 18. [Link](#)
- 4) Harper, R. N.; Boyce, C. M.; Scott, S. A. Oxygen Carrier Dispersion in Inert Packed Beds to Improve Performance in Chemical Looping Combustion. *Chem. Eng. J.* **2013**, *234*, 464. [Link](#)
- 3) Boyce, C. M.; Holland, D. J.; Scott, S. A.; Dennis, J. S. Adapting Data Processing To Compare Model and Experiment Accurately: A Discrete Element Model and Magnetic Resonance Measurements of a 3D Cylindrical Fluidized Bed. *Ind. Eng. Chem. Res.* **2013**, *52* (50), 18085. [Link](#)
- 2) Taylor, R. E.; Boyce, C. M.; Boyce, M. C.; Pruitt, B. L. Planar Patterned Stretchable Electrode Arrays Based on Flexible Printed Circuits. *J. Micromechanics Microengineering* **2013**, *23* (10), 105004. [Link](#)
- 1) Barr, M. C.; Rowehl, J. A.; Lunt, R. R.; Xu, J.; Wang, A.; Boyce, C. M.; Im, S. G.; Bulović, V.; Gleason, K. K. Direct Monolithic Integration of Organic Photovoltaic Circuits on Unmodified Paper. *Adv. Mater.* **2011**, *23* (31), 3500. [Link](#)

## **ENTREPRENEURIAL EXPERIENCE**

### **Infinite Corridor Technology, LLC**

Co-Founder and Stretchable Design Engineer, June 2007 – Present

- Invented and prototyped novel substrate designs and first-of-its-kind functioning multi-layered stretchable and flexible electronic circuit boards
- Awarded Defense Advanced Research Projects Agency (DARPA) Small Business Innovation Research (SBIR) contract
- Designed stretchable circuit boards for a wide variety of applications to pursue and/or fulfill contracts for collaborators and for customers in the biomedical, military and consumer electronics industries

## **PATENTS**

- 2) Taylor, R.E., Pruitt, B.L., Boyce, M.C., **Boyce, C.M.**, “In-plane-strain-actuated out-of-plane actuator”, U.S. Utility Patent 10150665 (Application 2014, Granted 2018).
- 1) Boyce, M.C., Socrate, S., **Boyce, C.M.** and Greviskes, B., “Structured material substrates for flexible, stretchable electronics”, U.S. Utility Patent 8,883,287 (Application 2010, Granted 2014).

## **INVITED PRESENTATIONS**

- 16) **Boyce, C.M.** (2021) “Characterizing and Structuring Multiphase Granular Flows” *Invited Seminar at the University of Cambridge.*
- 15) **Boyce, C.M.** (2021) “Characterizing and Structuring Multiphase Granular Flows” *Invited Seminar at The Ohio State University.*
- 14) **Boyce, C.M.** (2021) “Characterizing and Structuring Multiphase Granular Flows” *Invited Seminar at New York University.*

- 13) **Boyce, C.M.** (2021) “Characterizing and Structuring Multiphase Granular Flows” *Invited Seminar at UC Davis.*
- 12) **Boyce, C.M.** (2020) “Characterizing and Structuring Multiphase Granular Flows” *Invited Seminar at Stevens Institute of Technology.*
- 11) **Boyce, C.M.** (2020) “Characterizing and Structuring Multiphase Granular Flows” *Invited Seminar at Columbia University.*
- 10) **Boyce, C.M.** (2020) “Magnetic Resonance Imaging and Optical Imaging of Multiphase Granular Flows” *Invited Seminar at Lamont-Doherty Earth Observatory.*
- 9) **Boyce, C.M.** (2020) “Gaseous Bubbles and Granular Bubbles in Fluidized Granular Particles” *Invited Seminar at Stony Brook University.*
- 8) **Boyce, C.M.** (2020) “Phenomena in Fluidized Granular Flows” *Invited Plenary Lecture at the 12<sup>th</sup> Northeast Complex Fluids and Soft Matter Conference.*
- 7) **Boyce, C.M.** (2019) “MRI, Optical Imaging and Computational Modeling of Fluidization Phenomena” *Invited Sabic Young Professional Award Lecture at the AIChE Annual Meeting.*
- 6) **Boyce, C.M.** (2019) “MRI and Computational Modeling of Multiphase Granular Flows” *Invited Seminar at the City College of New York.*
- 5) **Boyce, C.M.** (2019) “MRI and Computational Modeling of Multiphase Granular Flows” *Invited Seminar at the U.S. Naval Undersea Warfare Center.*
- 4) **Boyce, C.M.** (2019) “Magnetic Resonance Imaging of Multiphase Granular Flows” *Invited Seminar at TU Hamburg.*
- 3) **Boyce, C.M.** (2019) “Structures and Instabilities in Multiphase Granular Flows” *Invited Seminar at the Chinese Academy of Sciences.*
- 2) **Boyce, C.M.** (2018) “MRI and Computational Modeling of Multiphase Chemical Reactors” *Invited Seminar at ExxonMobil Chemical.*
- 1) **Boyce, C.M.** (2018) “MRI and Computational Modeling of Multiphase Flows” *Invited Seminar at Pall Corporation.*

## **PRESENTATIONS**

- 24) Guo, Q., Zhang, Y., Xi, K., Padash, A., Kovar, T.M., Bordbar, A., Chen, B., Zia, W., Boyce, C.M. (2021) “Modeling Structured Bubbling in Vibrated Gas-Fluidized Beds” *Presentation at the NETL Workshop on Multiphase Flow Science, Held Virtually.*
- 23) Guo, Q., Vazquez, C., Xi, K., **Boyce, C.M.** (2020) “Diffusion and Granular Droplet Splitting in Bubble-Free, Vibrated Fluidized Beds” *Presentation at the AIChE Annual Meeting, Held Virtually.*
- 22) Padash, A., Chen, B., **Boyce, C.M.** (2020) “Alternating Bubble Pattern in Liquid-Gas Systems Due to Jet Interaction” *Presentation at the AIChE Annual Meeting, Held Virtually.*
- 21) McLaren, C.P., Kovar, T.M., Penn, A., Müller, C.R., **Boyce, C.M.** (2019) “Gravitational Instabilities in Binary Granular Flows” *Presentation at the AIChE Annual Meeting, Orlando, FL.*

- 20) Rice, N.P., **Boyce, C.M.**, Sederman, A.J., Gladden, L.F., Holland, D.J. (2019) *Presentation at the International Conference on Magnetic Resonance Microscopy, Paris, France.*
- 19) **Boyce, C.M.** “Rapid MRI and Optical Imaging of Fluidization Dynamics” (2019) *Poster Presentation at the International Fine Particle Research Institute Annual General Meeting, Burlington, VT.*
- 18) McLaren, C.P., Kovar, T.M., Penn, A., Müller, C.R., **Boyce, C.M.** (2019) “Gravitational Instabilities in Binary Granular Flows” *Presentation at the Fluidization XVI Conference, Guilin, China.*
- 17) **Boyce, C.M.**, Penn, A., Lehnert, M., Pruessmann, K.P., Müller, C.R. (2019) “Magnetic Resonance Imaging of the Interaction of Jets and Bubbles Injected into Fluidized Beds” *Presentation at the APS March Meeting, Boston, MA.*
- 16) **Boyce, C.M.**, Penn, A., Lehnert, M., Pruessmann, K.P., Müller, C.R. (2018) “Magnetic Resonance Imaging of Injected Bubble and Jet Dynamics in Fluidized Beds” *Presentation at the AIChE Annual Meeting, Pittsburgh, PA.*
- 15) **Boyce, C.M.**, Penn, A., Lehnert, M., Pruessmann, K.P., Müller, C.R. (2018) “MRI of Bubble and Jet Injection into Fluidized Beds”, *Presentation at NETL Workshop on Multiphase Flow Science, Houston, TX.*
- 14) **Boyce, C.M.**, Penn, A., Lehnert, M., Pruessmann, K.P., Müller, C.R. (2018) “MRI of Anomalous Flow upon Gas Injection into Fluidized Beds” *Poster Presentation at the Granular Matter Gordon Research Conference, North Easton, MA.*
- 13) **Boyce, C.M.**, Penn, A., Pruessmann, K.P., Müller, C.R. (2018) “Magnetic Resonance Imaging and Modeling of Liquid-Solid Fluidization” *Presentation at the 8<sup>th</sup> World Congress on Particle Technology, Orlando, FL.*
- 12) **Boyce, C.M.**, Penn, A., Pruessmann, K.P., Müller, C.R. (2017) “Magnetic Resonance Imaging of Wet Fluidization” *Presentation at the AIChE Annual Meeting, Minneapolis, MN.*
- 11) **Boyce, C.M.**, Penn, A., Pruessmann, K.P., Müller, C.R. (2017) “Magnetic Resonance Imaging of Gas-Solid Fluidization with Liquid Bridging” *Poster presented at Powders and Grains, Montpellier, France.*
- 10) **Boyce, C.M.**, Ozel, A., Kolehmainen, J., Sundaresan, S. (2016) “CFD-DEM Simulation of Hydrodynamics in Wet Gas-Solid Fluidized Beds” *Presentation at the AIChE Annual Meeting, San Francisco, CA.*
- 9) **Boyce, C.M.**, Ozel, A., Sundaresan, S. (2015) “MRI Measurements and Simulation Predictions of Gas Dynamics in a Fluidized Bed” *Presentation at the AIChE Annual Meeting, Salt Lake City, UT.*
- 8) **Boyce, C.M.**, Ozel, A., Sundaresan, S. (2015) “Agglomerate Growth and Breakup in Wet Fluidized Beds” *Presentation at the AIChE Annual Meeting, Salt Lake City, UT.*
- 7) **Boyce, C.M.**, Rice, N.P., Dennis, J.S., Holland, D.J. (2014) “Magnetic resonance imaging of gas dynamics in a fluidized bed” *Presentation at the AIChE Annual Meeting, Atlanta, GA.*

- 6) **Boyce, C. M.**; Davidson, J. F.; Holland, D. J.; Scott, S. A.; Dennis, J. S. The Origin of Pressure Oscillations in Slugging Fluidized Beds: Comparison of Experimental Results from Magnetic Resonance Imaging with a Discrete Element Model. *Chem. Eng. Sci.* **2014**, *116*, 611.
- 5) **Boyce, C.M.**, Scott, S.A., Holland, D.J, Dennis, J.S. (2014) “Practical limitations of fluid grid sizing in a 3D cylindrical DEM-CFD model” *Presentation at the AIChE Annual Meeting, Atlanta, GA.*
- 4) **Boyce, C.M.**, Holland, D.J., Scott, S.A., Dennis, J.S. (2013) “Understanding the origin of pressure oscillations in slugging fluidized beds using a discrete element model and magnetic resonance measurements.” *Presentation at the AIChE Annual Meeting, San Francisco, CA.*
- 3) **Boyce, C.M.**, Holland, D.J., Scott, S.A., Dennis, J.S. (2013) “Adapting data processing to compare model and experiment accurately: a discrete element model and magnetic resonance measurements of a 3D cylindrical fluidized bed” *Presentation at AIChE Annual Meeting, San Francisco, CA.*
- 2) **Boyce, C.M.**, Holland, D.J., Scott, S.A., Dennis, J.S. (2013) “Novel fluid grid and voidage calculation techniques for a discrete element model of a 3D cylindrical fluidized bed.” *Presentation at the AIChE Annual Meeting, San Francisco, CA.*
- 1) **Boyce, C.M.**, Holland, D.J., Scott, S.A., Dennis, J.S. (2013) “Computational modelling of fluidized beds: A 3-D cylindrical DEM-CFD model.” *Poster presented at The 14<sup>th</sup> International Conference on Fluidization, Noordwijkerhout, The Netherlands*