COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
FLORIDA ATLANTIC UNIVERSITY

Announces the Ph.D. Dissertation Defense of

Seokju Seo

for the degree of Doctor of Philosophy (Ph.D.)

"Microfluidics for Carbon Capture and Sequestration"

September 13, 2019, 1:00 P.M.
Engineering West, Room 187
777 Glades Road
Boca Raton, FL

DEPARTMENT:
Ocean and Mechanical Engineering

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ABSTRACT OF DISSERTATION
Carbon capture and sequestration (CCS) has been considered a promising technology for mitigating heavy atmospheric carbon dioxide (CO_2) concentration as an immediate response to global climate change and ocean acidification. Despite various previous studies on CCS, there has been a paucity of research for overcoming many challenges. In geological carbon sequestration, there are two major issues in achieving a feasible means of storing CO_2. The first is the slow reaction of carbonic acid (H_2CO_3) formation from the reaction between injected CO_2 and brine. Another technical challenge to the realization of industrial-scale carbon sequestration is the drying-out of brine induced by CO_2 advection. The resident brine near a wellbore area is rapidly evaporated while precipitating significant amounts of salt at pores when gaseous CO_2 is continuously injected into these aquifers. On the other hand, in industrial post-carbon capture processes, monoethanolamine (MEA) has been dominantly used as an absorption solvent. However, it generates significant amounts of toxic wastewater containing a heavy chemical difficult to treat. The objectives of this thesis are to address these challenges in CCS, making the CCS technology feasible and competitive. I developed and evaluated an innovative method for geologic

carbon sequestration, namely nickel nanoparticles (Ni NPs) addition to the injection fluid, to address issues of the slow reaction in deep saline aquifers. The catalytic activity of Ni NPs was evaluated using the microfluidic technique to confirm their possibility of additive for enhancing CO_2 hydration in deep saline aquifers. First of all, to achieve acceleration of CO_2 dissolution under reservoir-specific conditions, the catalytic effect of Ni NPs was investigated by monitoring change in CO_2 bubble size at various Ni NPs concentration, pH, and different levels of salinity. Then, steric stabilization of Ni NPs by adsorbing polymers has been studied to further enhance Ni NPs' catalytic activity. Second, to overcome the brine drying-out challenge, I proposed a new strategy of sequential water injection with CO_2. This sequential injection strategy showed great potential for preventing aquifer formation damage by decreasing brine drying-out and enhancing CO_2 dissolution significantly. Lastly, I evaluated the CO_2 capturing performance of Ni NPs as a possible additive in an MEA solvent to meet CO_2 reduction and environmental protection demands. The results were promising: the catalytic potential of Ni NPs accelerates the average CO_2 absorption rate by 34% and 54% in the limited mixing and the high mixing conditions, respectively. The results presented in this dissertation could help alleviate global concerns raised by CCS technology and would offer strategies for stable CCS technology with improved efficiency.

BIOGRAPHICAL SKETCH
Born in Seoul, South Korea
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CONCERNING PERIOD OF PREPARATION
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Time in Preparation: 2016 - 2019

Qualifying Examination Passed: Spring 2017

Published Papers:

1) S. Seo, B. Lages, M. Kim, "Catalytic CO_2 Absorption in an Amine Solvent using Nickel Nanoparticles for Post-Combustion Carbon Capture", Journal of CO_2 Utilization, (Under review).

2) M. Mastiani, N. Firoozi, N. Petrozzi, S. Seo, M. Kim, "Polymer-Salt Aqueous Two-Phase System (ATPS) Micro-Droplets for Cell Encapsulation", Scientific Reports, (Under review).

3) S. Seo, M. Mastiani, M. Hafez, G. Kunkel, C.G. Asfour, K.I. Garcia-Ocampo, N. Linares, C. Saldana, K. Yang, M. Kim, "In-situ Injection of CO_2 Microbubbles into Deep Saline Aquifers for Carbon Sequestration", International Journal of Greenhouse Gas Control, (2019) 83, 256-264.

4) M. Mastiani, S. Seo, B. Riou, M. Kim, "High Inertial Microfluidics for Droplet Generation in a Flow-Focusing Geometry", Biomedical Microdevices, (2019) 21(3) 50.

5) S. Seo, M. Mastiani, B. Mosavati, D.M. Peters, P. Mandin, M. Kim, "Performance Evaluation of Environmentally Benign Nonionic Biosurfactant for Enhanced Oil Recovery", Fuel, (2018) 234 48-55.

6) M. Mastiani, S. Seo, B. Mosavati, M. Kim, "High-Throughput Aqueous Two-Phase System Droplet Generation by Oil-Free Passive Microfluidics", ACS Omega, (2018) 3(8) 9296-9302.

7) S. Seo, G.A. Perez, K. Tewari, X. Comas, M. Kim, "Catalytic Activity of Nickel Nanoparticles Stabilized by Adsorbing Polymers for Enhanced Carbon Sequestration", Scientific Reports, (2018) 8 11786.

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9) S. Seo, M. Nguyen, M. Mastiani, G. Navarrete, M. Kim, "Microbubbles Loaded with Nickel Nanoparticles: A Perspective for Carbon Sequestration", Analytical Chemistry, (2017) 89(20) 10827–10833.

10) S. Seo, M. Kim, "Nickel Nanoparticles for Carbon Capture via Micro CO_2 Bubbles", 71st Annual Meeting of the APS Division of Fluid Dynamics, Nov. 18–20, 2018, Atlanta, Georgia, USA.

11) M. Mastiani, S. Seo, B. Mosavati, M. Kim, "Oil-Free Passive Generation of Aqueous Two-Phase System Micro Droplets", 71st Annual Meeting of the APS Division of Fluid Dynamics, Nov. 18–20, 2018, Atlanta, Georgia, USA.

12) S. Seo, M. Mastiani, C. Saldana, M. Kim, "Porous Photobioreactor for Improved Biofuel Production by Microalgae", ASME International Mechanical Engineering Congress & Exposition (IMECE), Nov. 3–9, 2017, Tampa, Florida, USA.

13) M. Mastiani, S. Seo, S. Jimenez, N. Petrozzi, M. Kim, "Understanding Fundamental Physics of Aqueous Droplet Generation Mechanisms in the Aqueous Environment", ASME International Mechanical Engineering Congress & Exposition (IMECE), Nov. 3–9, 2017, Tampa, Florida, USA.

14) M. Mastiani, S. Seo, M. Kim, "Aqueous Droplet Generation in High Inertial Air Flow", ASME International Mechanical Engineering Congress & Exposition (IMECE), Nov. 3–9, 2017, Tampa, Florida, USA.

15) S. Seo, M. Mastiani, G.A. Perez, M. Kim, "Enhanced Catalytic Potential of Nickel Nanoparticles for Carbon Sequestration", 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.

16) S. Seo, M. Mastiani, D. Peters, M. Kim, "Microfluidics for Enhanced Oil Recovery from Underground Reservoirs using Nonionic Surfactant", 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.

17) S. Seo, M. Mastiani, K. Garcia, M. Kim, "Dynamics of Water Evaporation and Salt Precipitation during CO_2 Injection to Microfluidic Chips", 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.

18) M. Mastiani, S. Seo, M. Kim, "Water-in-Water Droplet Generation using Pressure Driven Flow", 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.

19) M. Mastiani, S. Seo, M. Kim, “Water-in-Air Droplet Generation in a T-Junction Geometry”, 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.

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21) S. Seo, M. Mastiani, C. Asfour, K. Garcia, D. Peters, M. Kim, “Geological Lab-on-a-Chip for Salt Precipitation During CO_2 Sequestration in Deep Saline Aquifers”, Challenges in Environmental Science & Engineering, Nov. 11–15, 2017, Kunming, China.