Announces the Ph.D. Dissertation Defense of

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

“Microfluidics for Carbon Capture and Sequestration”

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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 (CO₂) 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 CO₂. The first is the slow reaction of carbonic acid (H₂CO₃) formation from the reaction between injected CO₂ and brine. Another technical challenge to the realization of industrial-scale carbon sequestration is the drying-out of brine induced by CO₂ advection. The resident brine near a wellbore area is rapidly evaporated while precipitating significant amounts of salt at pores when gaseous CO₂ 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 CO₂ hydration in deep saline aquifers. First of all, to achieve acceleration of CO₂ dissolution under reservoir-specific conditions, the catalytic effect of Ni NPs was investigated by monitoring change in CO₂ 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 CO₂. This sequential injection strategy showed great potential for preventing aquifer formation damage by decreasing brine drying-out and enhancing CO₂ dissolution significantly. Lastly, I evaluated the CO₂ capturing performance of Ni NPs as a possible additive in an MEA solvent to meet CO₂ reduction and environmental protection demands. The results were promising: the catalytic potential of Ni NPs accelerates the average CO₂ 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
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CONCERNING PERIOD OF PREPARATION & QUALIFYING EXAMINATION
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Published Papers:
10) S. Seo, M. Kim, “Nickel Nanoparticles for Carbon Capture via Micro CO₂ 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.
17) S. Seo, M. Mastiani, K. Garcia, M. Kim, “Dynamics of Water Evaporation and Salt Precipitation during CO₂ Injection to Microfluidic Chips”, 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.
