論文 / 著書情報
Article / Book Information

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Title(English)	Effect of gas generation by chemical reactions on two-phase displacement in porous media
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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨
THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 エネルギー　系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

The main objective of this work is to investigate the effects of in-situ generation of gases through chemical reactions on fluid flow in porous media, such as the promotion of EOR and the remediation of soil and groundwater. Over the past few decades, numerous studies and industrial applications have been conducted. While many industrial applications have demonstrated the benefits of gas generation for production, the precise underlying causes and influencing factors remain unclear. These existential questions guide our investigation into the complex interplay between chemical reactions, bubble formation, and fluid flow dynamics in porous media with a strong emphasis on characteristic times. This thesis is organized as follows:

In Chapter 1, we emphasized the prevalence of gas generation phenomena within porous media, highlighting their frequent utilization across a wide range of industrial processes. Moreover, it underscored the critical importance of delving into the intricacies of in situ gas generation within porous media. This exploration is particularly significant in the context of Enhanced Oil Recovery (EOR) and groundwater remediation, where a deeper understanding can lead to more effective optimization of processes and improved outcomes.

In Chapter 2, we explore the influence of gas bubble generation resulting from a chemical reaction on viscous fingering (VF) in a Hele-Shaw cell with miscible two-phase liquids. The displacing and displaced fluids are sodium bicarbonate ($NaHCO_3$) and citric acid ($C_6H_8O_7$) solutions, respectively. Our investigation focuses on four critical time scales: displacement, chemical reaction, bubble nucleation, and bubble coalescence, as well as the viscosity ratio. We aim to understand their role in shaping displacement patterns in the presence of gas bubbles. When the displacement time is shorter than the nucleation time, VF patterns initially form, followed by the emergence of small gas bubbles within the fingers. Conversely, when the nucleation time is shorter than the displacement time, rapid bubble coalescence induces outward gas nucleation, impeding fluid mixing. Furthermore, we discuss the impact of $C_6H_8O_7$ concentration and viscosity ratio within the context of these critical time scales.

In Chapter 3, we examine the impact of foam generation through a chemical reaction on viscous fingering (VF) using Hele-Shaw cell and micro-channel experiments. Our findings reveal that the surfactant significantly influences coalescence, nucleation, and displacement times, which, in turn, affect VF patterns as injection rates vary. When the displacement time greatly exceeds the coalescence time, initial small bubbles merge into larger ones, exacerbate the instability of the interface and affect the mixing of the two fluids. Conversely, when displacement time approaches nucleation time and is considerably less than coalescence time, a substantial number of small bubbles form but don't coalesce, widening the finger and inhibiting fluid flow. Additionally, we discuss the effects of surfactant and citric acid concentration concerning characteristic times in the Hele-Shaw cell. In the micro-channel, we observed that previously generated foam not only hinders preferential flow channels but also enhances micro-displacement efficiency while impeding oil film formation.

In Chapter 4, we discuss the effect of in-situ gas generation on trapped oil through chemical reactions using CT scanning. We found that the generated gas can effectively induce the redistribution of the trapped oil. The higher the concentration of reactants, the more pronounced the effect. Meanwhile, the surfactant has a significant effect on the transportation of the trapped oil, which can break up

the oil clusters into smaller droplets that are easier to move and at the same time form foam structures in the porous medium. At the same time, the surfactant will also help the generated gas to form a foam structure within the porous medium. With the multiple effects of surfactants, the recovery of oil in porous media increases from 86% to 94%. Besides, gravity also affects the distribution of fluids in 3D porous media.

In Chapter 5, we discuss, in conjunction with pore-scale images, how the redistribution of trapped contaminants evolves over time as the contaminant (NAPL) decomposes and gas is generated. This investigation elucidates that hydrogen peroxide exerts efficient contaminant removal by not only facilitating degradation but also by instigating a range of micro dynamic phenomena, driven by the evolving gas phase, thereby remobilizing the entrapped NAPL at the pore scale. This research visualizes the intricate interplay among the gas phase, aqueous phase, and NAPL, also delineates the influence of hydrogen peroxide concentration on this multifaceted process. By addressing this microscale knowledge gap, the present study offers valuable insights for the design of well-informed groundwater remediation strategies.

In summary, our study has revealed the complex interactions between gas generation and fluid distribution and flow in porous media. These findings provide important guiding principles for improving and optimizing applications such as underground pollutant remediation and oil and gas extraction. They also underscore the significance of considering gas generation in the design and implementation of these processes. Future research will delve deeper into these mechanisms to better understand and leverage the impact of gas on fluid flow in porous media.