論文 / 著書情報
Article / Book Information

題目(和文)	X線マイクロトモグラフィーを用いた多孔質内の空隙スケールにおける置換と溶解に関する研究
Title(English)	Pore-scale study of displacement and dissolution in porous media using X-ray microtomography
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Category(English)	Doctoral Thesis
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 機械	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 ）

A better understanding of multiphase flow in porous media is essential for various geophysical processes, such as CO_2 geological sequestration, soil and groundwater remediation, and enhanced oil recovery. Pore-scale imaging provides new insights on the complex dynamics of two-phase flow and reveals the underlying transport mechanism. In this thesis, an X-ray tomography-based experimental and image analysis method was devised for investigating the displacement and dissolution between two immiscible fluids in natural porous media and providing prediction models for engineering applications.

In Chapter 1, the background and motivation of this study were described.

In Chapter 2, the drainage displacement was studied in a three-dimensional porous medium. Three typical drainage displacement patterns were observed, e.g., viscous fingering, capillary fingering, and stable displacement, which are governed by the competition between viscous and capillary forces. Then the pore-scale characteristic of finger structures at breakthrough was quantitatively analyzed, including saturation, finger width, and fractal dimension. According to static features and the dynamic invasion process, a phase diagram for 3D porous media was proposed for the first time. The result will help predict displacement patterns under various fluid properties and flow conditions in natural porous media.

In Chapter 3, a series of imbibition displacements (also known as capillary trapping) were conducted in porous media with various flow rates and particle sizes. Morphological characterizations of trapped bubbles, including residual saturation, bubble size distribution and interfacial area, were determined from reconstructed three-dimensional images. The results show that the critical number of capillary desaturation curves depends on the initial state of the non-wetting phase. A well-connected initial state has a much smaller critical value, which means a lower trapping efficiency. In addition, the capillary has a significant effect on the size distribution of residual phase, and a higher flow rate generate smaller bubbles. The specific interfacial area is proportional to the residual saturation, and the effect of particle size can be normalized by multiplying the median particle diameter.

In Chapter 4, we experimentally elucidated the pore-scale dissolution process and the macroscopic interphase mass transfer coefficient inside a 2D micromodel and a 3D packing. The dissolution process of nonaqueous phase liquid (NAPL) was directly observed inside porous media using the state-of-the-art visualization technology. Results indicated that not all blobs are equally exposed to flowing water and the dead-end pores considerably decreased the dissolution rate. According to the linear driving force model, the NAPL concentration in mobile water was calculated from the changes in residual saturation. Then, the local and overall mass transfer coefficients corrected with concentration and interfacial area were estimated. The overall mass transfer coefficient was higher in the 3D packing under Darcy flow conditions. The major differences between the 3D packing and 2D micromodel can be attributed to the heterogeneity of pore geometry and the differences in pore connectivity.

In Chapter 5, the impact of wettability of pore surfaces on the residual NAPL dissolution was investigated in natural porous media. Three-dimensional pore-scale characteristics of NAPL blobs were determined in water-wet and neutral-wet media. Time-resolved images enable to estimate the temporal changes in the residual saturation and interfacial area, then to calculate the mass transfer coefficient. The results showed that the wettability has a significant impact on the morphology of residual NAPL; thus, affecting the dissolution behavior in natural porous media. The NAPL dissolution rate in the neutral-wet media is faster due to the higher specific interfacial area and more uniform spatial distribution. However, the wettability has a slight effect on the mass transfer coefficient. In the end, several mass transfer empirical correlations were formulated for dissolution in water-wet and neutral-wet porous media.

In Chapter 6, the conclusions of this study and some suggestions for future work were given.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).