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Article / Book Information

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THESIS OUTLINE

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This study examines pore-scale drying and drainage processes in porous media using distinct approaches. The drying process is investigated through experimental study using X-ray micro-tomography (CT), whereas the drainage process is studied through simulation using a weakly compressible scheme. The objectives of this study are:

Drying process of porous media:

1) To understand the 3D pore-scale drying process.
2) To characterize drying regions, in particular the liquid film region and the invasion front.
3) To investigate wettability effects on the drying process of 3D porous medium from a pore-scale perspective.

Drainage process in porous media:

4) To analyze pore-scale saturation and relative permeability of CO_2 under wide-ranging injection velocity and wettability.

This thesis is divided into five chapters. In Chapter 1, we introduce the two different multi-phase transport processes in porous media, which are drying and drainage. Chapters 2 and 3 are dedicated to discussing the details of the findings related to the pore-scale drying process in porous media, whereas Chapter 4 contains the findings related to the drainage process in porous media. Finally, Chapter 5 concludes all the findings and elaborates on possible future work. Details of the contents of each chapter are described below.

Chapter 1 introduces two multi-phase transport processes in porous media: drying and drainage. This chapter outlines the differences and similarities between these processes, reviews previous studies, identifies gaps in current research, and states the objectives and outline of the thesis to guide readers.

Chapter 2 presents an experimental study on the drying of 3D porous media using micro-CT imaging. This chapter provides a comprehensive understanding of the pore-scale drying process, characterizing the liquid film region and the invasion front. Key findings include the visualization of the gas invasion process, quantification of the liquid desaturation profile relative to pore size, and examination of the relationship between the gas-liquid interfacial area and saturation. Finally, the extent of the liquid film was compared with an analytical estimation. In this chapter, we found that capillary rearrangement supports the drying process, significantly affecting liquid phase distribution and liquid cluster formation. Despite the valuable insights provided on capillary rearrangement, further analysis of the parameters influencing capillary rearrangement during the drying process in porous media is required. Wettability is a key parameter that determines capillary rearrangement within the porous medium. However, direct 3D pore-scale experiments exploring the effects of wettability on liquid phase distribution and liquid cluster formation are limited. To address this gap, we focus on these aspects in the next chapter.

Chapter 3 investigates the effects of wettability on the drying process in 3D porous media from a pore-scale perspective, utilizing micro-CT imaging. Two types of porous media with different wettability, water-wet, and neutral-wet, characterized by contact angles of 19° and 90°, respectively, were studied. This chapter discusses differences in drying rates, phase distribution, and saturation between the two conditions. The chapter also analyzes pore-scale capillary rearrangement and liquid cluster morphology, and examines invasion front propagation.

This chapter concludes the discussion on the drying process in porous media.

Chapter 4 shifts focus to the drainage process in porous media, presenting 2D pore-scale simulations of primary CO_2 injection using a weakly compressible numerical scheme. The chapter explores pore-scale saturation and relative permeability of CO_2 under wide-ranging injection velocity and wettability. This chapter provides the color mapping of CO_2 saturation and relative permeability to describe the tendency on how CO_2 saturation and relative permeability varies across injection velocity and wettability. The chapter also provides insight of CO_2 relative permeability at pore-scale domain, which explained the fluid displacement mechanism during drainage process. The results help to bridge understanding of finger-tip and displacement-front advancement at the pore-network scale with relative permeability.

Chapter 5 summarizes the key conclusions from each chapter and offers suggestions for future research directions.