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The Impact of Pore-Scale Heterogeneity on Drying Porous Media

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Isothermal drying of porous materials is driven by evaporation of liquid at the liquid-air interface, causing capillary invasion of air into the medium. The drying rate falls with time due to the advancement of the liquid-air interface deeper into the medium, increasing the distance required for vapor transport out of the medium and decreasing the connectivity of liquid to the open surface. Fundamental understanding and predictive modeling of drying patterns and rates in heterogeneous porous media are still lacking. In this work we study isothermal drying of a heterogeneous 2-D porous media, through pore network model (PNM) simulations and micro-fluidic experiments. We seek understanding of how the macroscopic drying behavior—drying rates and patterns—emerges from the pore-scale physics. In particular, we are interested in the impact of pore-scale heterogeneity, namely pore size distribution and connectivity, on liquid transport mechanisms and pore invasion sequence.

Our model porous media is made using micro-fluidic techniques, where we have designed, and know the location of, every pore and every throat. The experimental cells consist of an array of cylindrical solid pillars of various sizes, closed at all sides but one, which is open to the atmosphere. We use PNM to simulate evaporation at the air-liquid interface and the consequent capillary invasion of air into the medium, using the exact same pore-scale geometry as the experimental micro-fluidic cells. Our simulations suggest that the connectivity of small pores as well as that of large pores has a larger effect on drying patterns and rates than the absolute variation in pore sizes.