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Imbibition on the single-pore level: what happens in the absence of cooperative phenomena?

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Commonly, studies on imbibition focus on porous matrices with bicontinuous morphology that contain spongy pore systems with neck-node morphologies. In this context, much attention has been paid to cooperative imbibition phenomena such as imbibition front broadening, viscous fingering, or avalanche-like relaxations of the imbibition fronts, which occur in systems of hydraulically coupled pores. Non-cooperative imbibition phenomena confined to the single-pore level have attracted less attention. However, even the invasion of a separate cylindrical pore by a wetting liquid is accompanied by wealth of complex physical phenomena. Even though effects related to local variations in the Laplace pressure across the menisci at the imbibition front are absent, the transition from an empty cylindrical pore to a filled cylindrical pore is characterized by complex kinetics and the possible occurrence of long-lived metastable or transient imbibition morphologies. Theoretical treatment of single-pore imbibition has remained demanding, and predictive understanding of single-pore infiltration is premature. However, model systems allow experimentally capturing insights into single-pore imbibition. The infiltration of polymeric melts into self-ordered nanoporous anodic aluminum oxide (AAO) is an example for a revealing model scenario. AAO contains arrays of straight, separated cylindrical nanopores with narrow pore size distribution. The pore diameters range from 20 nm to 400 nm, the pore depths may amount up to 100 microns. Infiltration takes place on time scales convenient for laboratory experiments. If polymers with high glass transition temperature are infiltrated, transient infiltration stages can easily be frozen by vitrification of the polymer. Limiting cases are infiltration via intermediate precursor films on the pore walls and classical capillary infiltration by propagation of a thread of the invading liquid. Neither the transition between precursor film wetting and capillary wetting, nor the transition from a precursor film scenario to complete pore filling is satisfactorily understood. In this talk, the current state of knowledge concerning infiltration of AAO with polymers will be summarized with a special focus on known transient infiltration states, such as precursor film thickening and precursor film instabilities.

References

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