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Spontaneous and electrocapillary imbibition dynamics in nanoporous media

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Imbibition is important physics in nanoporous media, related to many energy and technology areas, e.g., fuel cells, water desalinization, bio-sensor, hydrology, hydrocarbon recovery, CO2 geo-storage, underground hydrogen storage, etc. The classic theory to describe the spontaneous imbibition dynamics is the Lucas-Washburn (L-W) equation, while the classic theory to describe the electrocapillary imbibition is the Lippmann equation and the Young –Lippmann (Y-L) equation. However, whether these classic theories are still valid at nanoscale have not been rigorously examined yet.
Therefore herein, we experimentally investigate the dynamics of spontaneous and electrocapillary imbibition in nanoporous media. For spontaneous imbibition in hydrophilic nanoporous media in the absence of evaporation, spontaneous imbibition height is linear with square root of time and a larger pore size causes a faster imbibition, which are consistent with the L-W equation; in contrast, for spontaneous imbibition in hydrophilic nanoporous media in the presence of evaporation, this linear relationship is deviated from linearity at early stages and a modified L-W theoretical model is derived to incorporate the evaporation effect. For electrocapillary imbibition in hydrophobic nanoporous media, counterintuitive voltage polarity dependence and electro-dewetting phenomena are observed, indicating that the Lippmann and the Y-L theory are invalid to describe the fundamentals of electrocapillary imbibition at nanoscale. Hence, the underlying mechanisms responsible for these two novel physics are explained by electrical double layer charging, Faradaic reactions and others.
These insights will provide significant guidance on various applications relevant to energy transition, such as energy storage and conversion devices, water desalination, batteries and fuel cells.

Participation

In-Person

References

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