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Digital Porous Material Analysis with Multiscale REV

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Digital Porous Media Analysis (DPMA) is the process of using imaging and simulation techniques (e.g., x-ray computed microtomography, Pore-Network Modelling (PNM) and Direct Numerical Simulations (DNS)) to investigate the properties of porous materials. With DPMA, physical processes are investigated in the real structure of a sample and effective porous media properties (e.g., permeability and capillary pressure) are estimated. These properties can then be used for upscaling, provided that the sample investigated is a Representative Elementary Volume (REV) of the full domain of interest. However, most porous materials relevant to the energy transition are multiscale, and thus have pore structures (e.g., microporosity, channels, vugs) spanning several orders of magnitude in size. An REV of such materials cannot be fully characterised by a single image, which would either be too small to be an REV or lack the resolution to accurately resolve the pore/solid interfaces. In this work, we define a multiscale REV of a porous material as an image that can be segmented into resolved and unresolved parts, and for which, for each unresolved voxel, the properties can be associated with a higher resolution image that is an REV of the underlying structure inside that voxel, the combination of which provides an REV of the full domain of interest. Our multi-scale REV workflow is demonstrated on several examples, including microporous carbonate rocks and 3D printed hierarchical foams, and employs multiscale simulation techniques (e.g., Darcy-Brinkman-Stokes models, multiscale PNM) first to confirm a multi-scale REV and then to simulate reactive transport and multiphase flow processes while estimating properties such as permeability, dispersivity and capillary pressure.

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